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ORIGINAL RESEARCH

Self-awareness for financial decision making abilities is linked to right temporal cortical thickness in older adults

Preeti Sunderaraman[1,2,3] · Seonjoo Lee[4] · Eleanna Varangis[1,2,3,4] · Christian Habeck[1,2,3] · Silvia Chapman[1,2,3] · Jillian L. Joyce[1,2] · Whitney Hartstone[1,2] · Adam M. Brickman[1,2,3] · Yaakov Stern[1,2,3] · Stephanie Cosentino[1,2,3]

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Abstract

Everyday financial decision making and the awareness of the integrity of one's financial decision making abilities (or financial awareness) are both critical to study in older adults as they can help identify those at risk for making suboptimal financial decisions and prevent financial loss. In the current study, we examined the cognitive and cortical thickness correlates of financial decision making and financial awareness in 59 community-dwelling participants co-enrolled in a larger study (mean age=68.35 years (SD=5.5), mean education=15.91 (SD=2.36), 61% = women, 67% = White, 30% = Black participants). Data from standardized measures of financial decision making and cognition was investigated along with FreeSurfer (v. 5.3) derived thickness regions. Based on metacognitive frameworks, financial awareness was measured along with a well-validated measure of memory awareness. Results revealed that numeracy, executive functioning and vocabulary were associated with financial decision making, whereas in analysis adjusted for financial decision making, memory awareness relative to cognition was most strongly linked to financial awareness. No significant associations between thickness and financial decision making were found. However, both financial and memory awareness were associated with the same right-hemisphere temporal thickness regions underscoring the idea of a common substrate of awareness. Interestingly, our findings converge with the emerging work on financial exploitation in which the right sided temporal regions have been found to play a prominent role. Incorporating the contributing role of self-awareness in various models of financial exploitation will be an important consideration for future studies.

Keywords financial decision making · self-awareness · cortical thickness · medial temporal region · cognition

Introduction

Financial decision making (FDM) refers to the ability to conduct financial tasks autonomously to manage one's finances without error or preventable financial loss (Lichtenberg et al., 2015; Marson, 2016; National Academies of Sciences & Medicine, 2016). Several studies highlight that older adults (OAs), an especially vulnerable but wealthy segment of the population, experience financial loss ranging from $2.9 to $36.5 billion annually (Lichtenberg et al., 2015; Teaster et al., 2012). Both cognitively healthy older adults and those with cognitive compromise are prone to suboptimal decision making and experience various adverse consequences. For instance, age-related cognitive decline and factors associated with aging increase susceptibility to poor decision making including making poor investments, being delinquent on credit card payments, and being at increased risk for financial exploitation (Agarwal et al., 2009; Fenge, 2017; Nicholas, Langa, Bynum, & Hsu, 2021; Tymula et al., 2013; Yu et al., 2021). Therefore, identifying the cognitive abilities and brain regions that contribute to FDM among cognitively healthy OAs can help to identify individuals at risk for poor FDM at a time when they are likely to be

✉ Preeti Sunderaraman
psun@bu.edu

1 Cognitive Neuroscience Division of the Taub Institute for Research on Alzheimer's Disease and the Aging Brain, Columbia University Irving Medical Center, New York, NY, USA

2 Gertrude. H. Sergievsky Center, Columbia University Irving Medical Center, New York, NY, USA

3 Department of Neurology, Columbia University Irving Medical Center, New York, NY, USA

4 Department of Psychiatry, Columbia University Irving Medical Center, New York, NY, USA

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responsible for managing the assets they have accumulated over their lifetimes.

In those with mild cognitive impairment (MCI) and Alzheimer's disease (AD), impairments in cognitive abilities including numeracy, executive functioning, memory, and visuomotor sequencing are associated with reduced FDM (Sherod et al., 2009). However, the role of specific cognitive abilities in supporting FDM among healthy OAs is unclear. Some studies find no association between specific cognitive abilities and FDM, while others report links between FDM and numeracy, attention, executive abilities, memory, visuomotor construction and processing speed (Pachana et al., 2014; Sherod et al., 2009; Shivapour, Nguyen, Cole, & Denburg, 2012).

Examining specific cognitive abilities along with regional brain structure among cognitively healthy OAs will allow stronger inferences regarding the aspects of cognition and brain integrity that may be critical for maintaining intact FDM. Few studies have investigated these links in healthy OAs, with most studies focusing on neurological populations (i.e., MCI, AD). Across these volumetric studies, cortical and subcortical regions including the angular gyrus, precuneus, medial and dorsolateral prefrontal cortex, inferior temporal and middle temporal cortex, cingulate cortex, nucleus accumbens, left medial and lateral amygdala and anterior thalamic radiation have been implicated in FDM (Benavides-Varela et al., 2020; Griffith et al., 2010; Han et al., 2016; Stoeckel et al., 2013). However, the relationship between cortical thickness measures and FDM has not yet been examined. While volume and thickness are both measures of structural neuroimaging techniques, volume and thickness have been known to reveal differential associations with cognition (Gautam, Anstey, Wen, Sachdev, & Cherbuin, 2015), and the association of these two structural measures with other brain measures such as surface area and cortical gyrification varies (Gautam et al., 2015; Winkler et al., 2010). Additionally, since current statistical techniques to correct for head size in volumetric assessment inadequately address this inherent limitation of this metric, cortical thickness can be seen as a less biased metric similarly reflecting the degree of neuronal loss in the context of healthy and pathological patterns of aging (Schwarz et al., 2016).Therefore, understanding the links between cortical thickness and FDM will help us to develop a more comprehensive picture of the brain and behavior.

It is equally important to concurrently understand the substrates of financial awareness, i.e., the awareness of one's own FDM abilities. There is evidence that financial awareness is a reliable construct, independent from FDM itself, and associated with memory awareness (i.e., metamemory, or the knowledge of one's memory abilities), a well-established aspect of self-awareness (Sunderaraman, Chapman, et al., 2020b). Of the various metacognitive metrics that were used to calculate financial awareness, a calibration score reflecting the average degree of confidence was found to be the most meaningful method. It is arguable that with reduced financial awareness, individuals may jeopardize their own financial well-being, be vulnerable to financial exploitation, and potentially incur heavy financial losses. Empirical evidence from memory awareness studies in individuals with MCI and AD has found that, those with impaired memory awareness are less likely to modify their approach to cognitively demanding tasks (e.g., using a pillbox to manage medications) (Cosentino, Metcalfe, Cary, et al., 2011a; Shaked et al., 2019) and may engage in more dangerous behaviors (e.g., driving) (Starkstein et al., 2007).

Little is known about the neurocognitive substrates of financial awareness. Historically, elements of self-awareness more broadly, particularly metamemory, have been linked to executive abilities and the structural integrity of the prefrontal cortex (Cosentino et al., 2011a; Fleming & Dolan, 2012). Increasingly, however, evidence points to a prominent role for midline and cortical structures, including the insula and cingulate, in supporting metamemory and self-evaluative processing more broadly (Bertrand et al., 2018; Buchy & Lepage, 2015; Klein et al., 2013; van der Meer et al., 2010). Finally, regarding laterality, there is evidence that regions in the right hemisphere may differentially contribute to elements of self-awareness (Cosentino, Brickman, Adam, et al., 2015b; Harwood et al., 2005; Klein et al., 2013). Whether or not similar regions are associated with financial awareness remain to be seen. In those with neurodegenerative conditions such as AD and fronto-temporal dementia, the right-hemisphere medial temporal regions have been associated with self-awareness. There is also evidence that right-hemisphere regions involving the insula, cingulate cortex, and medial frontal regions are associated with financial exploitation in older adults (Han et al., 2016; Lamar et al., 2020; Spreng et al., 2017; Weissberger et al., 2020). Therefore, in the current study, we sought to specifically investigate whether thickness in the right-sided insula, anterior cingulate cortex, and prefrontal region was associated with financial awareness.

The current study examined the cognitive and structural correlates of FDM and financial awareness in healthy OAs. We first examined the associations between FDM, financial awareness and apriori selected regions of interest (ROIs). On an exploratory basis, a whole brain analysis was also run by selecting all 34 bilateral ROIs and examining their associations with FDM. We also ran exploratory analysis between financial awareness and 7 cortical ROIs (per hemisphere) based on evidence from previous literature (Bertrand et al., 2018; Cosentino, Brickman, Adam, et al., 2015b). We have previously shown that memory awareness is moderately associated with financial awareness using established metacognition frameworks.

Therefore, these two types of awareness may theoretically map onto a broader aspect of self-awareness. There is also evidence that two different domains of awareness (motor and memory) are associated with each other (Chapman et al., 2018). Therefore, to check for convergent validity in the current study, we explored the associations between a well-validated memory awareness measure (metamemory; Cosentino et al., 2007) and cortical thickness in the same pre-specified 7 ROIs. In addition, we also checked for associations between financial awareness and, memory awareness and cognition to examine the nature of the associations.

Based on our previous work, we operationalized financial awareness along a spectrum from under- to overconfidence in FDM. We hypothesized the following: (1) FDM and cognition: Numeracy, executive functioning, and vocabulary will show stronger associations with FDM compared to processing speed or memory. (2) FDM and cortical thickness: FDM will be more strongly associated with thickness of bilateral dorsolateral prefrontal and bilateral inferior parietal regions than that of other brain regions. (3) Financial Awareness and, Memory awareness and Cognition: Financial awareness will be more strongly associated with memory awareness than primary cognitive domains (i.e., memory, executive functioning, processing speed, and vocabulary). (4) Financial Awareness and Thickness: Financial awareness will show stronger associations with thickness in the right-sided insula, anterior cingulate cortex, and prefrontal region.

MATERIALS AND METHODS

Participants

Community-dwelling participants were recruited for the Reference Ability Neural Network Study (RANN; Stern et al., 2014) wherein extensive cognitive and neuroimaging data were collected. Data for the current study were then prospectively collected from 60 cognitively healthy OAs in a single session examining FDM, financial awareness and numeracy (average months between RANN participation and current study = 7.8 months). Participants were required to be native English speakers, strongly right-handed (determined via a set of items administered during the telephone screen), and have a minimum of fourth-grade reading level (Stern et al., 2014). They were screened for dementia or MCI using the Dementia Rating Scale with a minimum cutoff score of 130 (Mattis, 1988), hearing and/or visual impairment, and MRI contraindications. Written informed consent was obtained from all participants and compensation was provided at the end of the study. The Columbia University Medical Center Internal Review Board approved this study.

Cognitive Measures

Four cognitive domains based on composite scores – executive function, memory, language, and processing speed – were measured using paper-and-pencil tests in the RANN study (Stern et al., 2014). Numeracy was assessed as part of the current study (Sunderaraman, Barker, et al., 2020). For further information about the exact measures, please see the Supplementary section.

FDM

Twenty objective items from the Financial Competence Assessment Inventory were used in the current study (Kershaw & Webber, 2008; Sunderaraman et al., 2018; Sunderaraman, Chapman, et al., 2020b). Items were either performance-based and observable (e.g., writing a check) or were conceptual knowledge questions that could be scored objectively with an external criterion (e.g., what is the meaning of assets?). Accuracy was originally scored on a scale from 1 to 5, but was collapsed into 1 to 3 because of the distribution of the data (Sunderaraman, Chapman, et al., 2020b). The total accuracy ranged from 20 to 60.

Financial Awareness

Before and after each FCAI item, participants made prospective and retrospective judgments about their performance (How confident are you that you answered that question correctly?) on the specified item on a scale from 1 (unsure) to 4 (very confident). Because of the high correlation between the judgments (Sunderaraman, Chapman, et al., 2020b), only prospective judgments were used in this study. The 4-point scale was collapsed into a 3-point scale ranging from 1 to 3 to bring it numerically on the same scale as the FCAI accuracy ranges. This matching enabled calculation of the awareness score; details regarding the development of the confidence rating scale can be found in Sunderaraman, Chapman, et al. (2020). Based on established metacognitive frameworks (Cosentino et al., 2007; Dunlosky & Tauber, 2016), calibration was calculated by subtracting average accuracy from the average confidence rating to determine the extent to which individuals were over- or underconfident. A score of zero indicated perfect calibration, positive scores indicated overconfidence, and negative scores indicated under confidence in one's financial abilities (total score range: -2 to 2).

Memory Awareness

Details about this task have been described previously (Bertrand et al., 2018; Cosentino, Brickman, Griffith, et al., 2015a; Cosentino et al., 2011a). Briefly, this task consisted of 20 items wherein participants have to learn trivia

information. Participants were asked to predict if they would recognize the correct answer (Yes, Maybe, No) and recognition accuracy was scored dichotomously (correct or incorrect). Similar to financial awareness, calibration scores were derived where zero indicated perfect calibration, positive scores indicated overconfidence, and negative scores indicated underconfidence in one's memory abilities (total score range: -1 to 1).

Structural Neuroimaging

Cortical thickness

A 3.0 T Philips Achieva Magnet using a standard quadrature head coil was used for image acquisition. T1-weighted images of the whole brain were acquired for each subject using a Magnetization Prepared Rapid Gradient Echo (MPRAGE) sequence with the following parameters: TE/TR: 3/6.5 ms; Field of view: 256 mm; Flip angle: 8°; In-plane resolution: 256 × 256 voxels; Slice thickness/gap: 1/0 mm; Slices: 180. All T1 image segmentation was performed using FreeSurfer (v. 5.3; (Dale et al., 1999; Fischl et al., 2002; Fischl et al., 2004a, b)), and inspetced visually for any possible inaccuracies. Segmentation inaccuracies were manually corrected. For each region, the average distance between the gray/white matter boundary and the pial surface is calculated to reflect the cortical thickness of that region.

Regions of Interest (ROIs) for cortical thickness analysis were defined based on the standard FreeSurfer cortical parcellation, which utilizes the Desikan-Killiany Atlas (Desikan et al., 2006; Fischl et al., 2004a, b). This parcellation scheme divides the cortex into 34 gyral-based neuroanatomical ROIs per hemisphere. Based on previous literature cortical thickness data corresponding to the following 7 bilateral ROIs (14 ROIs in total) were as follows: (i) Dorsolateral prefrontal: superior frontal gyrus, rostral middle frontal gyrus, and caudal middle frontal gyrus; (ii) Medial prefrontal: medial orbital and frontal pole; (iii) Temporal: entorhinal, parahippocampal, and temporal pole; (iv) Anterior cingulate cortex (ACC): caudal and rostral; (v) Posterior cingulate cortex (PCC); (vi) Parietal: superior parietal and precuneus; and (vii) Insula.

Data Analysis

Data were analyzed using R and IBM SPSS v.25. The data were checked for skewness and negatively skewed data were square root transformed. All the associations were examined with Pearson correlations. Any given demographic variable was used as a covariate only if it was associated with both the primary variables of interest. Both, FDM and four aspects of cognition (executive function, vocabulary, speed, and numeracy), except memory, were associated with education. Therefore, the association between FDM and cognition, except memory, was adjusted for education. As metamemory was not associated with education, the analyses between FDM and metamemory were unadjusted for education. To keep the analysis across FDM, cognition and metamemory comparable, we also ran the analysis adjusting and unadjusting for education across all correlations (results were largely similar; see Supplementary Table 1). While examining the relationship between financial awareness and cognition, we first calculated unadjusted correlations, and then calculated partial correlations adjusting for FDM. Given the hypothesis-driven nature of the correlations, the association between FDM, financial awareness, cognition and thickness were not adjusted for multiple comparisons. Moreover, given that this is the first study to investigate these associations, all the findings have been reported for future replicability and reproducibility of the findings. Medium to large effect sizes were considered for interpreting the findings.

Results

See Table 1 for the demographic details. Scatterplots depicting the associations between i) FDM and financial awareness, ii) financial and memory awareness, and iii) financial awareness and the right temporal thickness are presented as supplementary figures 1-3.

FDM, FA, Cognition and Metamemory

FDM and financial awareness were associated with numeracy, executive functioning, and vocabulary (see Table 2). FDM was negatively associated with financial awareness (r = -.547, p <.001). After adjusting for FDM, there were no significant associations between financial awareness and

Table 1 Demographics characteristics of the sample

		Mean (SD; range)
Age		68.35 (5.5; 57-84)
Education (yrs)		15.91 (2.36; 12-22)
Women; n (%)		35 (61)
Race; n (%)		
	White	38 (67)
	Black	17 (30)
	Asian	1 (2)
	Native Hawaiian/ Pacific Islander	1 (2)
Ethnicity; n (%)		
	Non-Hispanic	54 (95)

Table 2 FDM, Financial Awareness (FA), cognition, and memory awareness

	FDM	FA (Unadjusted)	FA (Adjusted for FDM)
	r (p)		
FDM	NA	**-0.547 (0.000)**	NA
Numeracy	**0.387 (0.004)**	**-0.422 (0.002)**	-0.153 (0.288)
Executive Function	**0.371 (0.005)**	**-0.410 (0.003)**	-0.215 (0.134)
Memory	-0.005 (0.969)	-0.128 (0.366)	-0.159 (0.271)
Vocabulary	**0.326 (0.014)**	**-0.352 (0.011)**	-0.145 (0.316)
Speed	0.137 (0.313)	-0.117 (0.408)	0.061 (0.671)
Metamemory	-0.192 (0.153)	**0.414 (0.002)**	**0.372 (0.007)**

The sample consisted of 57 individuals. Due to missing data, n was 49 for the financial awareness data

Bold font indicates $p < .05$

Table 3 Correlations between financial awareness, memory awareness, and thickness ROIs

Thickness ROIs	Financial Awareness		Memory Awareness	
	r	*p*	*r*	*P*
Right Prefrontal	0.158	0.279	-0.015	0.913
Left Prefrontal	0.131	0.371	-0.088	0.525
Right Medial Prefrontal	-0.119	0.417	-0.003	0.981
Left Medial Prefrontal	0.152	0.297	0.056	0.686
Right Anterior Cingulate	-0.099	0.499	-0.046	0.742
Left Anterior Cingulate	-0.118	0.418	0.104	0.456
Right Posterior Cingulate	-0.027	0.854	0.141	0.309
Left Posterior Cingulate	0.090	0.540	0.081	0.559
Right Temporal	**-0.286**	**0.047**	**-0.287**	**0.035**
Left Temporal	-0.145	0.321	-0.128	0.358
Right Medial Parietal	-0.011	0.939	-0.008	0.955
Left Medial Parietal	0.063	0.667	0.043	0.756
Right Insula	-0.189	0.193	-0.192	0.165
Left Insula	-0.219	0.131	-0.164	0.235

Bold font indicates $p < .05$

cognition; only the significant association between financial awareness and metamemory remained.

FDM, Financial Awareness, Metamemory and Cortical Thickness

Both financial awareness and metamemory were associated most strongly with the right-hemisphere temporal ROIs (see Table 3; Figure 1). Significant associations were not observed between FDM and any areas of cortical thickness (see Supplementary Table 2).

Discussion

To our knowledge, this is the first study to examine associations between FDM, financial awareness, cognition and cortical thickness in cognitively healthy older adults. We also explored how memory awareness was associated with cortical thickness, and whether commonalities existed between the structural substrates of memory awareness and financial awareness. The results showed that various aspects of cognition, especially numeracy, executive functioning and vocabulary were associated with FDM whereas the primary correlate of financial awareness was metamemory. This finding supports the notion that, at least in older adults, financial awareness has a metacognitive component that does not map onto other aspects of cognition. Regarding cortical thickness, no significant associations were found with FDM. However, financial awareness was associated with right-hemisphere temporal thickness suggesting that financial awareness may be more sensitive to structural brain features than FDM in cognitively healthy individuals. Moreover, memory awareness was also strongly related to the same region, underscoring the idea that there may be a common substrate for elements of self-awareness.

FDM and Cognition Numeracy showed the strongest association between FDM and cognition, followed by executive functioning and then vocabulary. Given the hypothesis-driven nature of the correlations, we did not adjust for multiple comparisons. However, even if Bonferroni corrections were to be applied, the results remained largely unchanged with numeracy and executive functioning withstanding correction. The current findings, in line with Sherod et al.'s (2009) study, reinforce the role of numeracy as being integral to FDM. In the current study, numeracy involves aspects of mental arithmetic, written math, and numerical reasoning involving probability estimations (Sunderaraman et al., 2020a). Proficiency with numerical information is required in several financial decisions involving buying, selling, saving and investing. A role for executive functioning is also undeniable, e.g., for decisions related to budgeting and choosing health care plans. In this study, executive functioning involved performance on reasoning and sequencing abilities, both of which are essential for healthy financial planning. A third ability, vocabulary, involved aspects of crystallized abilities in the form of word reading and conceptual knowledge. The ability to understand financial terminology (e.g., deductibles, interest fees, etc.) is required to effectively conduct financial tasks. The remaining

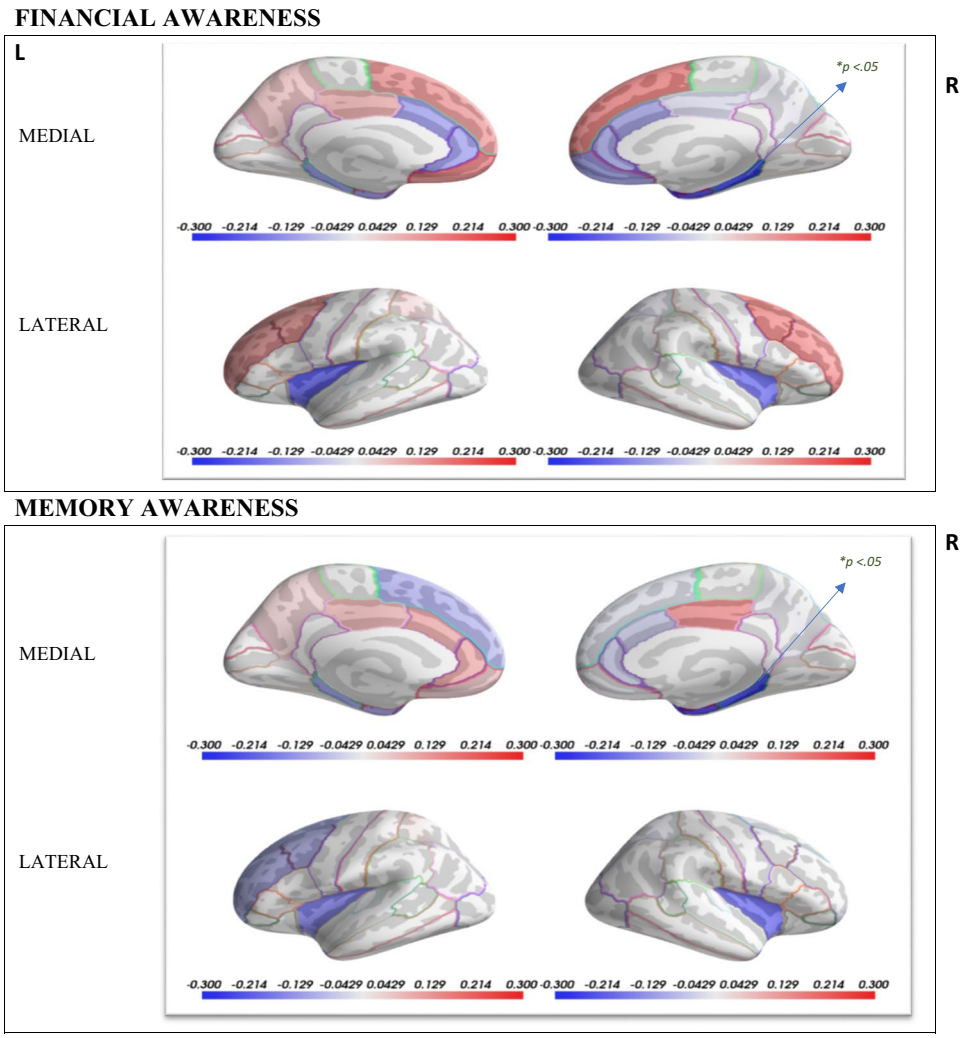

Fig. 1 3-dimensional representation of the brain's grey matter derived in FreeSurfer with ROIs used in the study superimposed. Colors reflect the strength of the association between financial awareness and ROI thickness with cool colors (blues) indicating negative associations and warm colors (red) indicating positive associations. Color scale indicates r values. Significant correlations are marked with an asterisk

cognitive abilities (memory, processing speed) are involved to a relatively lower extent probably because of the nature of the financial tasks examined in this study. It is safe to assume that task-specific demands (e.g., recalling a bank account PIN versus budgeting) places differential demands on memory, for example. Differences in FDM tasks may explain the contrasting results in the literature pertaining to the involvement of various cognitive abilities (Sherod et al., 2009; Shivapour et al., 2012).

Financial Awareness and Cognition When FDM was partialled out of the analysis, the association of the cognitive abilities and financial awareness diminished. Only the association between financial awareness and memory awareness remained significant, suggesting that financial awareness maps onto other aspects of awareness more so than primary aspects of cognition. This finding resonates with work demonstrating selective associations between metamemory and other forms of self-evaluation in healthy OAs and individuals with AD (Chapman et al., 2018; Cosentino et al., 2007).

FDM and Cortical Thickness Significant associations between cortical thickness and FDM were not found. One reason for this finding may be related to the task used in this study. FDM includes an array of tasks including the ability to read bills, write a check, and define financial concepts. In functionally intact older adults FDM may depend on the integrity of large-scale cortical/subcortical regions and therefore no specific region may be clearly associated with FDM. However, with increasing brain pathology, the relevance of specific cortical regions may become more evident. It is also possible that the thickness metrics used in this study are not sensitive enough to detect functional correlates in a fine-grained manner due to the nature of the measurement instruments used to examine FDM and/or thickness metrics.

Financial Awareness, Memory awareness, and Cortical Thickness Right temporal thickness in the temporal pole, entorhinal and parahippocampal regions was associated with financial awareness such that thinner cortex in these regions was associated with higher calibration scores, reflecting

over confidence. These regions were not hypothesized to be the primary correlates of financial awareness; rather, we expected a more prominent role for other right sided midline and cortical structures including the insula and cingulate, as well as the medial PFC. Although the significant correlations do not withstand Bonferroni correction, we nevertheless report the findings given the effect size and the overlap in the ROIs involved in financial awareness and memory awareness. Moreover, current results are consistent with a number of previous studies pointing to a role for various right temporal regions in supporting aspects of self-awareness. For example, in MCI, AD, and behavioral variant FTD, right medial temporal regions along with the hippocampus, were associated with self-awareness (Chavoix & Insausti, 2017). Other studies have linked decreased volume in the right temporal regions to overestimation of abilities (Shany-Ur et al., 2014), and higher senile plaque density of the right hippocampus to poor memory awareness in AD (Marshall et al., 2004). Together with these studies, our findings suggest that the right temporal ROI may have special significance to self-awareness.

Reduced financial awareness may predispose an individual to financial exploitation. Interestingly, studies on financial exploitation find the right temporal cortex to be associated with increased scam susceptibility. A recent study found that in non-demented adults, 3 clusters including the right-sided parahippocampal/hippocampal/fusiform, hipoocampal, and middle temporal regions were inversely associated with scam susceptibility (Han et al., 2016). Reduced right hemisphere white matter integrity in temporal pathways connecting the parietal and occipital cortex was also associated with higher scam susceptibility in these OAs (Lamar et al., 2020). Yet another study found that financially exploited individuals had thinner cortex in the right anterior insula and right posterior superior temporal cortices (Spreng et al., 2017). Finally, a functional connectivity study also found that older adults who reported being financially exploited, showed less connectivity between the insula and cingulate cortex, and between the right insula and left temporal regions and dorsolateral prefrontal cortex (Weissberger et al., 2020). Based on these findings, one can speculate that compromises to self-awareness, and financial awareness in particular, may be an important mechanism by which vulnerability to exploitation arises (Lichtenberg et al., 2020; Shao et al., 2019; Spreng, Karlawish, & Marson, 2016). The Social Cognitive Neuroscience model offers a novel framework to understand the factors that feed an individual's risk of financial exploitation (Spreng et al., 2016) including both cognitive and social capacities. .It is conceivable that self-awareness may contribute to this framework primarily as a moderating variable and can affect the relationship between both or either pathway (social and/or cognitive) and exploitation risk (see Figure 2). Specifically, the moderating effect of

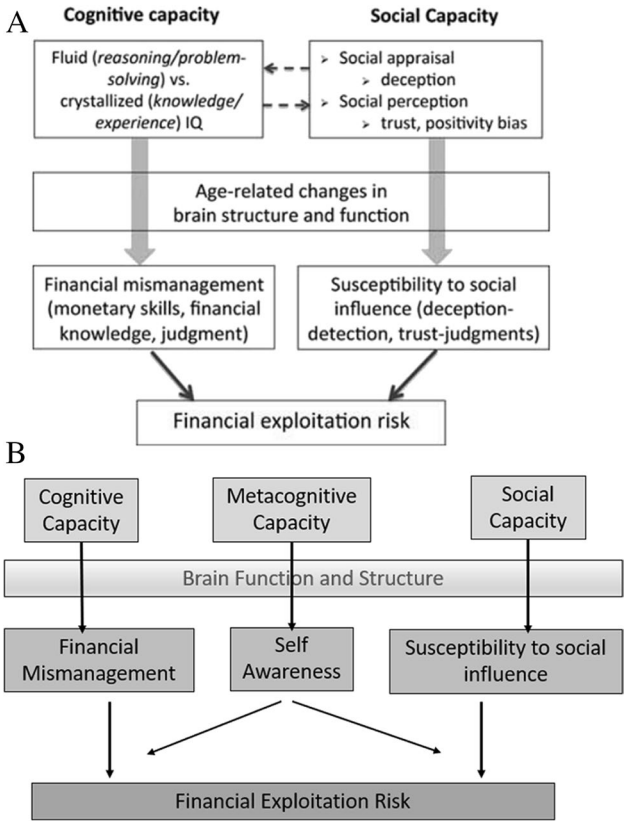

Fig. 2 The Social Cognitive Neuroscience model of financial exploitation risk (Spreng, Karlawish & Marson, 2016; reproduced with permission). Panel A depicts the original proposed model, whereas panel B shows one possible mechanism by which self-awareness may contribute to the model. In this figure, awareness may moderate the pathways associated with financial exploitation risk while the brain function and structure may mediate the associations among the pathways and financial exploitation risk

self-awareness would be that higher self-awareness would reduce the effect of cognitive or social impairment on financial exploitation risk. This is just a preliminary mechanism proposed, and there could be other ways in which awareness could play a role in this framework. Future work with carefully designed longitudinal studies can directly elucidate these possibilities."

The current study has some limitations. i) It consisted of highly educated OAs which may have resulted in a homogenous sample. The resulting restricted range of values could have limited our ability to find significant associations, particularly for FDM. ii) Advanced analysis which have been proposed to be powerful to detect associations among highly correlated variables could not be conducted given the small sample size. Multivariate approaches using larger and more heterogeneous samples offer a promising avenue of future research. iii) Domains such as visuospatial functioning were not included and should be examined in future studies. Despite these limitations, this is the first study

to directly examine financial awareness in relation to cortical thickness, revealing a seemingly important role for right temporal temporal regions. Moreover, the constitution of the sample consisting of 30% Black participants is an added strength of the study. The consistency of findings across both financial awareness and memory awareness implicates a common cortical substrate for awareness and may inform models of financial exploitation moving forward. A caveat to the study is that the non-inclusion of younger adults and the cross-sectional nature of the study design limits the generalizability of the study across the life-span. However, the findings have important implications for older adults. Longitudinally designed studies will be required to understand how aging influences the association between thickness and financial awareness.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s11682-021-00590-w.

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Author contributions Author contributions included conception and study design (PS and SC), data collection or acquisition (PS, SC, YS), statistical analysis (PS, SL, AB, CH and SC), interpretation of results (AMB, EV, CH, PS, SC, YS), drafting the manuscript work or revising it critically for important intellectual content (AMB, PS, SC, SC, and YS) and approval of final version to be published and agreement to be accountable for the integrity and accuracy of all aspects of the work (All authors).

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Data availability The data will be shared upon request from the corresponding author.

Declarations

Compliance with ethical standards The Columbia University Medical Center's Institutional Review Committee has reviewed and approved the study protocol described in the manuscript. All study participants have provided written informed consent.

Conflict of interest None of the authors have a conflict of interest to disclose.

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