Received: 14 June 2021 | Revised: 28 October 2021 | Accepted: 14 November 2021
DOI: 10.1002/hbm.25747

RESEARCH ARTICLE

WILEY

Financial decision-making and self-awareness for financial decision-making is associated with white matter integrity in older adults

Preeti Sunderaraman[1,2,3] | Yunglin Gazes[1,2,3] | Gema Ortiz[1,2] | Christopher Langfield[1,2] | Ashley Mensing[1,2] | Silvia Chapman[1,2] | Jillian L. Joyce[1,2] | Adam M. Brickman[1,2,3] | Yaakov Stern[1,2,3] | Stephanie Cosentino[1,2,3]

[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, New York, USA

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

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

Correspondence
Preeti Sunderaraman, Department of Neurology, Boston University School of Medicine, Medical Campus, 72 East Concord Street, Massachusetts 02118, The Framingham Heart Study - Brain Aging Program, 73 Mount Wayte Avenue, Framingham, MA 01702, USA.
Email: psun@bu.edu

Funding information
National Institutes of Health/Ruth L. Kirschstein Predoctoral Individual National Research Service, Grant/Award Number: F32AG053035; National Academy of Neuropsychology; National Center for Advancing Translational Sciences, Grant/Award Number: UL1TR001873; National Institutes of Health/National Institute Of Aging, Grant/Award Number: R01 AG026158 & RF1AG038465

Abstract

Financial decision-making (FDM) and awareness of the integrity of one's FDM abilities (or financial awareness) are both critical for preventing financial mistakes. We examined the white matter correlates of these constructs and hypothesized that the tracts connecting the temporal–frontal regions would be most strongly correlated with both FDM and financial awareness. Overall, 49 healthy older adults were included in the FDM analysis and 44 in the financial awareness analyses. The Objective Financial Competency Assessment Inventory was used to measure FDM. Financial awareness was measured by integrating metacognitive ratings into this inventory and was calculated as the degree of overconfidence or underconfidence. Diffusion tensor imaging data were processed with Tracts Constrained by Underlying Anatomy distributed as part of the FreeSurfer analytic suite, which produced average measures of fractional anisotropy and mean diffusivity in 18 white matter tracts along with the overall tract average. As expected, FDM showed the strongest negative associations with average mean diffusivity measure of the superior longitudinal fasciculus -temporal (SLFT; $r = -.360$, $p = .011$) and -parietal ($r = -.351$, $p = .014$) tracts. After adjusting for FDM, only the association between financial awareness and average mean diffusivity measure of the right SLFT ($r = .310$, $p = .046$) was significant. Overlapping white matter tracts were involved in both FDM and financial awareness. More importantly, these preliminary findings reinforce emerging literature on a unique role of right hemisphere temporal connections in supporting financial awareness.

KEYWORDS
aging, diffusion tensor imaging, financial decision-making, numeracy, self-awareness, white matter integrity

1 | INTRODUCTION

Older adults are at elevated risk for being diagnosed with neurodegenerative conditions such as Alzheimer's disease (AD), and some studies suggest brain changes may occur at least 20 years prior to the onset of the clinical symptoms (Alzheimer's Disease Facts and Figures, 2020). Data projections indicate a 22% increase in the number of AD cases from about 5.8 million in 2020 to about 7.1 million in 2025 (Alzheimer's Disease Facts and Figures, 2020). Older adults, who hold about 70% of all disposable income, are vulnerable to making suboptimal financial decisions such as choosing poor investments (Gamble, Boyle, Yu, & Bennett, 2015; Korniotis & Kumar, 2011). A recent large-scale population-based study found that delinquent credit card payments and subprime credit scores were present in Medicare beneficiaries about 6 and 2.5 years prior to a dementia diagnosis, respectively (Nicholas, Langa, Bynum, & Hsu, 2021). Older adults are also highly prone to financial exploitation, with data suggesting a related net loss of $2.9 billion to $36.5 billion (Consumer Financial Protection Bureau, 2017). These observations necessitate a thorough investigation of financial decision-making (FDM) and its constituent elements in the context of various brain-related indices in healthy older adults.

FDM is a multidimensional construct, and is generally defined as the ability to autonomously conduct financial tasks in order to manage one's finances without error or preventable financial loss (Lichtenberg, Ficker, & Rahman-Filipiak, 2016; D. C. Marson et al., 2000). There are important differences in the concepts of financial ability, capability, competency, or capacity. For example, the term financial competency is used in forensic settings, while the term financial capacity is used in the context of medical/clinical evaluations. However, these terms are sometimes used interchangeably, even though they are not synonymous (Lichtenberg, Stoltman, Ficker, Iris, & Mast, 2015; D. Marson, 2016; National Academies of Sciences, Engineering, & Medicine, 2016). Older adults are vulnerable to making suboptimal financial decisions such as displaying substandard credit card behaviors, and annual financial losses are estimated to range from $2.9 billion to $36.5 billion (Acierno et al., 2010; Agarwal, Driscoll, Gabaix, & Laibson, 2009; Conrad, Iris, Ridings, Langley, & Wilber, 2010; Consumer Financial Protection Bureau, 2017).

Financial awareness is a critical, but often overlooked, aspect of FDM that is distinct from FDM itself. For example, while everyday FDM typically involves activities such as paying bills, purchasing goods, and saving money, financial awareness is the extent to which an individual accurately perceives his or her own FDM skills. Financial awareness, analogous to FDM, can be construed as a multifaceted construct. One facet, "offline" (e.g., global, day to day) awareness of one's current, personal financial circumstances, can be challenging to assess without direct knowledge of the individual's actual circumstances (e.g., credit score, history of vulnerability to scam, etc.), and informants are not always accurate in their impressions of an individual's circumstances or abilities (Martyr & Clare, 2018; Sunderaraman, Cosentino, Lindgren, James, & Schultheis, 2018). Another facet of financial awareness relates to "online," or in the moment, awareness of performance on a financial task (Sunderaraman, Chapman, Barker, & Cosentino, 2020). Several studies have shown that metacognitive tasks which measure online awareness of abilities such as memory and executive function relate to more global levels of awareness for these abilities in day-to-day life (Cosentino, Metcalfe, Butterfield, & Stern, 2007; Cosentino, Metcalfe, Cary, De Leon, & Karlawish, 2011; Koren et al., 2004).

Relative to studying structural brain regions via volume and cortical thickness in older adults, examining white matter integrity offers another perspective on how the aging brain may be linked to FDM. White matter, consisting of myelinated axons and glia, is responsible for communication among different brain regions. White matter integrity as measured by diffusion tensor imaging (DTI) examines the cohesion of axonal tracts by detecting the diffusion of water molecules. In intact axons relative to damaged ones, the diffusion of water is more anisotropic which reflects as higher fractional anisotropy (FA) and lower diffusivity (Mori & Zhang, 2006). Studies report that compared to measures of structural integrity such as cortical thickness, white matter integrity is more closely associated with cognitive aging (Ziegler et al., 2010). Therefore, it becomes important to examine whether and how white matter is associated with FDM and financial awareness.

In healthy older adults, FDM is strongly associated with numerical and reasoning abilities (Boyle et al., 2013; Demakis, Szczepkowski, & Johnson, 2018; Sunderaraman, Barker, Chapman, & Cosentino, 2020), and studies have linked numerical/arithmetic abilities to specific white matter networks (Grotheer, Zhen, & Grill-Spector, 2019). For example, the superior longitudinal fasciculus (SLF) along with the arcuate fasciculus (AF) are implicated in numerical/mathematical abilities such as adding in some studies, while other studies identified tracts including corticospinal tract (CST), cingulum-cingulate gyrus (CCG), and the inferior longitudinal fasciculus (ILF) (Grotheer et al., 2019; Matejko & Ansari, 2015; Moeller, Willmes, & Klein, 2015). In another study, temporal discounting, the tendency to prefer smaller monetary rewards over a shorter time period compared to larger rewards over a longer time period, was associated with reduced integrity of the bilateral frontal, frontostriatal, and temporal–parietal white matter tracts (Han et al., 2018). Across most studies, the SLF has been recognized consistently as an important tract for numeracy, making it a prime candidate for supporting healthy FDM in older adults (Matejko & Ansari, 2015).

While studies, although quite limited, have examined the links between white matter and FDM, the association of white matter integrity in relation to *awareness* of one's FDM (i.e., financial awareness) has yet to be examined. FDM and financial awareness, both measured using standardized, objective tools, involve different neuroanatomical substrates. Cortical thickness, while not associated with everyday FDM in cognitively healthy older adults, was associated with financial awareness (Sunderaraman et al., 2021). Specifically, thinner right temporal cortex (temporal pole, parahippocampus, and entorhinal regions) was linked to overconfidence in one's financial abilities. Relatedly, other studies found that right temporal compromise is involved in increased risk for scam susceptibility and financial exploitation (Han et al., 2016; Lamar et al., 2020; Spreng et al., 2017). Specifically, lower white matter integrity in the right temporal–parietal and temporal–occipital regions was associated with increased self-reported scam susceptibility in a sample of older adults without dementia (Lamar et al., 2020). Overall, studies of self-awareness have found greater involvement of right versus left neural substrates and connections. We therefore expected the right-lateralized networks to be most strongly related to financial awareness. Borrowing from the broader self-awareness literature, there is also emerging evidence that the SLF tracts are associated with other aspects of self-referential processing involving motor awareness (Pacella et al., 2019). Therefore, we anticipated that the SLF tracts connecting the frontal–temporal–parietal regions would also be implicated in financial awareness, perhaps with a differential role for right-sided tracts.

Different types of white matter metrics can contribute to different task-tract associations. For example, FDM was associated with FA, but not diffusivity, in the cingulo–parietal–frontal and temporo-occipital regions in those with mild cognitive impairment (Gerstenecker, Hoagey, Marson, & Kennedy, 2017). In the same study, mean diffusivity (MD), but not FA, in the anterior cingulate, callosum, and frontal regions, were associated with FDM in those with AD (Gerstenecker et al., 2017). Therefore, in the current study, we examined the association between financial awareness and white matter integrity using FA and MD metrics.

A few different methods are available for processing diffusion images, including voxel-based spatial statistics (TBSS) (Soares, Marques, Alves, & Sousa, 2013) and TRActs Constrained by UnderLying Anatomy (TRACULA). While TRACULA is an automated probabilistic tractography toolbox within Freesurfer (Yendiki et al. (2011a, 2011b)), voxel-based methods require accurate registration algorithms using tensor datasets (Mukherjee, Chung, Berman, Hess, & Henry, 2008). Compared to voxel-based approaches, tract-based approaches, such as TRACULA, may be less able to detect abnormalities in the tracts if these are not universally present throughout the given tract. On the other hand, TRACULA is less fraught by inaccuracies associated with intersubject registration given that quantification automatically occurs within an individual subject's space (Mak et al., 2021; Mamah, Ji, Rutlin, & Shimony, 2019).

To summarize, the current study examined the associations of white matter integrity using TRACULA with FDM and financial awareness. We hypothesized that measures reflecting white matter integrity in the SLF connecting the temporal and frontal regions would be most strongly associated with both FDM and financial awareness. Based on previous studies, we did not expect FDM to be lateralized, and therefore investigated 8 bilateral white matter tracts in addition to forceps minor, forceps major, and the across tract average. In the case of financial awareness, right-sided SLF tracts were hypothesized to be the most salient fibers. An exploratory aim was to examine the association of integrity measures derived in all 18 white matter tracts with FDM and financial awareness.

2 | MATERIALS AND METHODS

2.1 | Participants

Participants were recruited for the Reference Ability Neural Network (RANN) Study (Stern et al., 2014), wherein neuroimaging data were collected. Data for the current study were then prospectively collected from 60 cognitively healthy older adults in a single session examining FDM, financial awareness, and memory awareness (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 Institutional Review Board approved this study.

2.2 | Financial decision-making

Twenty objective items from the Financial Competence Assessment Inventory were used (Kershaw & Webber, 2008; Sunderaraman et al., 2018; Sunderaraman, Chapman, et al., 2020). 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?). Examples of other items include ability to: understand bills, fill out an insurance form, and perform basic arithmetic calculations based on a hypothetical situation. 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., 2020). The total accuracy ranged from 20 to 60.

2.3 | Financial awareness

Before and after each Financial Competence Assessment Inventory 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., 2020), 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), calculation of calibration required that the average accuracy on the FDM task be subtracted from the average prediction score (i.e., individuals' confidence ratings predicting how they would perform) to determine the extent to which individuals were overconfident 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).

2.4 | Procedures

2.4.1 | MRI acquisition

MRI images were acquired in a 3.0 T Philips Achieva scanner using a standard quadrature head coil. A T1-weighted scout image was acquired to determine subject position followed by a T1-weighted MPRAGE scan with a TE/TR of 3/6.5 ms and flip angle of 8°, in-plane resolution of 256 × 256, field of view of 25.4 × 25.4 cm, and 165–180 slices in axial direction with slice-thickness/gap of 1/0 mm. The DTI images were acquired in 55 directions with 1 b-0 volume using these parameters: $b = 800$ s/mm^2; TE = 69 ms; TR = 11,032 ms; flip angle = 90°; in-plane resolution 112 × 112 voxels; acquisition time 12 min 56 s; slice thickness = 2 mm (no gap); and 75 slices.

Any T1-weighted scans with potentially clinically significant findings were reviewed by a neuroradiologist and removed from the sample prior to the current analysis. However, no clinically significant findings were identified or removed.

2.5 | Structural T1 processing

Segmentation of the T1-weighted image was a necessary step in processing the DTI data. Each subject's structural T1-weighted scan was reconstructed using FreeSurfer v5.1 (http://surfer.nmr.mgh.harvard.edu/). Each subject's white and gray matter boundaries as well as gray matter and cerebral spinal fluid boundaries were visually inspected slice by slice, manual control points were added in the case of any visible discrepancy, and reconstruction was repeated until we reached satisfactory results within every subject based on visual inspection. The subcortical structure borders were plotted by FreeView visualization tools and compared against the actual brain regions. In case of discrepancy, they were corrected manually.

2.6 | DTI analysis

DTI data were processed with TRACULA distributed as part of the FreeSurfer v. 5.2 library (Yendiki et al. (2011a, 2011b)). This older version of the software was used to ensure consistency across the entire study cohort. The software produces 18 major white matter tracts, along with the overall tract average, as listed below:

- forceps major, which passes through genu of corpus callosum (FMAJ);
- forceps minor, which passes through splenium of corpus callosum (FMIN);
- bilateral anterior thalamic radiation (ATR);
- bilateral cingulum - angular (infracallosal) bundle (CAB);
- bilateral CCG (supracallosal) bundle;
- bilateral CST;
- bilateral ILF;
- bilateral SLF - parietal bundle (SLFP);
- bilateral SLF - temporal bundle (SLFT);
- bilateral uncinate fasciculus (UNC).

Using DTI analysis, along with the forceps minor, forceps major, and across tract average, we examined FDM using the average of 8 bilateral white matter tracts, while financial awareness was examined using 16 tracts, 8 per hemisphere. These tracts were derived individually for each participant to enable derivation of mean FA and MD within each tract. Specifically, the software performs informed automatic tractography by incorporating anatomical information from a training data set, provided by the software, with the anatomical segmentation of the T1-weighted image of the current data set, thus increasing the accuracy of the white matter tract placement for each participant. Standard DTI processing steps using the FMRIB's Diffusion Toolbox (FMRIB's Software Library v. 4.1.5) including eddy current correction, tensor estimation, and bedpostx were performed prior to tractography. See Yendiki et al. (2011a, 2011b) for detailed steps performed by the TRACULA software. For each participant, the means of FA and MD for each of the 18 tracts were entered into subsequent analyses. Using factor analysis, axial and radial diffusivity metrics were found to be highly correlated to FA and MD, and the four DTI metrics formed two independent factors (unpublished data; also see Gazes et al., 2020). FA ranges from 0 to 1 with higher number representing more intact white matter integrity whereas lower MD values are consistent with more intact white matter integrity.

2.7 | Data analysis

Data were analyzed using IBM SPSS v.25. The data were checked for skewness and negatively skewed data were square root transformed (Field, 2013). Any given demographic variable was used as a covariate only if it was associated with the two variables of interest in Pearson correlations. To understand the association between financial awareness and white matter integrity at any given level of FDM, the latter was included as a covariate if it was related to both variables. Given the hypothesis-driven nature of the correlations, the association between FDM, financial awareness, and white matter metrics 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.

3 | RESULTS

See Table 1 for the demographic details. Overall, one participant was excluded because of new information about a psychiatric diagnosis, one was excluded because data for FDM were not collected, white matter metrics data were unavailable for nine participants, and financial awareness data were not collected for five participants. In total, 49 participants were included in the FDM analysis and 44 in the financial awareness analyses.

3.1 | Selection of covariates

3.1.1 | Demographics

FDM was associated only with education ($r = .528$, $p < .001$). However, none of the white matter tract metrics (FA or MD) was associated with education. Age was associated with white matter tracts (see supplementary table) but not with either FDM or financial awareness. Financial awareness was not associated with any other demographics. Therefore, correlations examining white matter in relation to the financial variables were not demographically adjusted.

3.1.2 | Financial variables

FDM was associated with financial awareness ($r = -.618$, $p < .001$). Therefore, correlations examining white matter metrics in relation to financial awareness were adjusted for FDM only if it was also associated with these metrics (see results below).

3.2 | Financial decision-making and white matter integrity

FDM was associated with both FA and MD (see Table 2; Figure 1). For FA, FDM was positively associated with ATR ($r = .301$, $p = .036$). For MD, FDM showed the strongest negative associations with SLFT ($r = -.360$, $p = .011$) and SLFP ($r = -.351$, $p = .014$), followed by ILF ($r = -.313$, $p = .030$) and ATR ($r = -.305$, $p = .033$). The associations between age and these white matter tracts were nonsignificant (r ranged from .012 to .169).

TABLE 1 Demographics characteristics of the sample

	Mean (*SD*; range)
Age	68.43 (5.14; 57–80)
Education (years)	15.88 (2.41; 12–22)
Women, *n* (%)	29 (59)
Race, *n* (%)	
White	33 (67)
Black	14 (29)
Asian	1 (2)
Native Hawaiian/Pacific Islander	1 (2)
Ethnicity, *n* (%)	
Hispanic	3 (6)

3.3 | Financial awareness and white matter integrity

Table 3 depicts the associations between financial awareness and white matter integrity (see Figure 2 for the tracts with significant associations). For FA, significant association was observed between financial awareness and left SLFT ($r = -.319$, $p = .035$) and it was marginally significant for left ATR ($r = -.288$, $p = .058$). Several associations in the case of the MD metric were identified, with the four strongest associations between financial awareness and right SLFP ($r = .437$, $p = .003$), right SLFT ($r = .433$, $p = .003$), followed by left ATR ($r = .391$, $p = .009$) and left ILF ($r = .383$, $p = .010$). After adjusting for FDM, only the association between financial awareness and right SLFT ($r = .310$, $p = .046$) was significant; while it was marginally significant between financial awareness and right SLFP ($r = .296$, $p = .057$). The associations between age and these white matter tracts were nonsignificant (r ranged from −.03 to .13).

4 | DISCUSSION

To our knowledge, this is the first study to examine the association of white matter integrity with FDM and awareness of one's financial abilities in older adults without dementia. A key, albeit preliminary finding from this study, is that integrity measures of long-range fibers, especially those connecting frontal–temporal regions were most strongly associated with both FDM and financial awareness. The ATR and the ILF fibers were also consistently associated with both FDM and financial awareness. Importantly, the right SLF tracts, connecting temporal–frontal and parietal–frontal regions, were uniquely associated with financial awareness after adjusting for FDM itself.

Interestingly, while both FA and MD measures were associated with FDM and financial awareness, relatively more associations were noted when white matter integrity was measured using the MD metric. This finding resonates with the results from a large epidemiological examination of brain measures across a wide age range demonstrating that MD declines by 2 *SD*s relative to age 45 twenty years earlier than FA (Vinke et al., 2018), supporting MD's greater sensitivity to aging effect than FA. The wide disparity between the two seemingly correlated white matter integrity measures may be due to the two measures being sensitive to different aspects of the white matter structure (Farrell et al., 2010; Molina et al., 2020). For example, an animal study reported associations between histological measures of axonal damage and FA changes in mice with experimentally induced mild traumatic brain injury, but this damage was not found to be associated with MD changes (Molina et al., 2020).

TABLE 2 Associations between financial decision-making and white matter integrity

	Financial decision-making				
	FA*		MD*		
	r	*p*	*r*	*p*	*N*
Across tract average	.241	.095	−**.294**[a]	**.040**	49
Forceps major	−.100	.496	.012	.937	49
Forceps minor	.012	.936	−.077	.599	49
Anterior thalamic radiation	**.301**[a]	**.036**	−**.305**[a]	**.033**	49
Cingulum - angular (infracallosal) bundle	.188	.195	−.057	.699	49
Cingulum - cingulate gyrus (supracallosal) bundle	.103	.482	−.039	.791	49
Corticospinal tract	.232	.108	−.157	.281	49
Inferior longitudinal fasciculus	.223	.129	−**.313**[a]	**.030**	48
Superior longitudinal fasciculus - parietal bundle	.224	.121	−**.351**[a]	**.014**	49
Superior longitudinal fasciculus - temporal bundle	.262	.068	−**.360**[a]	**.011**	49
Uncinate fasciculus	.146	.315	−.168	.249	49

*FA: fractional anisotropy; MD: mean diffusivity.
[a]indicate p < .05

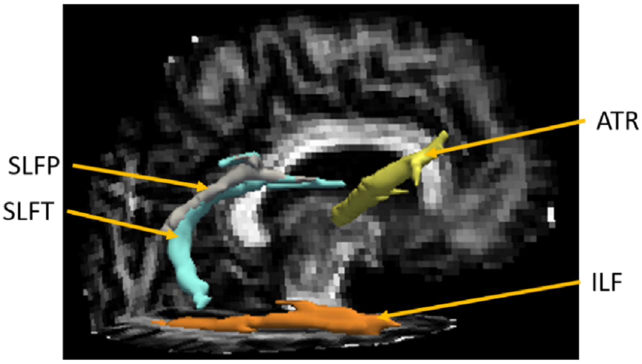

FIGURE 1 White matter tracts associated with financial decision-making. ATR, anterior thalamic radiation; ILF, inferior longitudinal fasciculus; SLFP, superior longitudinal fasciculus - parietal bundle; SLFT, superior longitudinal fasciculus - temporal bundle

4.1 | Financial decision-making

The SLF tracts for the temporal–frontal and parietal–frontal regions showed the strongest associations with FDM. Both the left and right SLF have been implicated in numerical abilities (Matejko & Ansari, 2015; Moeller et al., 2015). Typically, the SLF is recognized as a crucial bundle of association tracts involved in cognitive and social processes including attention, memory, language, reasoning, and emotions and is known to connect the temporal, parietal, and occipital lobes with ipsilateral frontal regions (Petrides & Pandya, 2002; Schmahmann, Smith, Eichler, & Filley, 2008). Some of the well-known SLF endpoints involve regions of the supramarginal gyrus and inferior parietal lobule, heavily implicated in numerical abilities (Amalric & Dehaene, 2016; Arsalidou, Pawliw-Levac, Sadeghi, & Pascual-Leone, 2018; Grotheer et al., 2019; Moeller et al., 2015).

FDM was also associated with the integrity of the ILF tract, previously implicated in numerical abilities (Matejko & Ansari, 2015). The involvement of left ILF more than the right ILF is also notable. Highly acquired numerical skills such as addition or multiplication may rely on phonological information processing, that is, they recruit language- and retrieval-related circuits from the left temporal–parietal–occipital regions (Hu et al., 2011; Matejko & Ansari, 2015).

Finally, the bilateral ATR was consistently associated with FDM using both FA and MD metrics. This white matter fiber bundle, known to play a key role in executive functioning such as planning, connects the dorsomedial thalamic nucleus to the prefrontal cortex (especially the dorsolateral region) via the internal capsule. Our finding supports evidence that the thalamus is vital for numeracy-related tasks (Matejko & Ansari, 2015; Moeller et al., 2015).

It is worth noting that our findings do not converge with Gerstenecker et al. (2017) study in which no significant associations were found between FDM and white matter integrity as measured by TBSS in healthy adults. One reason for the discrepancy could be due to the manner in which white matter integrity was measured in that study. Unlike TRACULA (used in the current study) which eliminates the inaccuracies caused by intersubject registration, it is known that certain preprocessing steps (e.g., warping participants to a common individual prototype, smoothing data, etc.) can affect the reliability of the TBSS metrics (Madhyastha et al., 2014). Another possibility is that the nature of the FDM tasks used may tap into different aspects of financial abilities.

4.2 | Financial awareness

A key finding of this study is that after controlling for FDM, FA was associated with the right SLF. The middle frontal region involved in the default mode network and inferior frontal region are known to play a role in executive function and social cognitive abilities, including motivation and self-monitoring (Fujiwara, Schwartz, Gao, Black, & Levine, 2008; Wood, Heitmiller, Andreasen, & Nopoulos, 2008).

TABLE 3 Associations between financial awareness and white matter integrity

	Financial awareness				
	FA*		MD*		
	r	*p*	*r*	*p*	*N*
Forceps major	.071	.646	−.084	.587	44
Forceps minor	.111	.473	.002	.989	44
Left anterior thalamic radiation	**−.288**	**.058**	**.391**[b]	**.009**	44
Left cingulum - angular (infracallosal) bundle	−.131	.396	.087	.573	44
Left cingulum - cingulate gyrus (supracallosal) bundle	.076	.625	.017	.911	44
Left corticospinal tract	−.109	.480	.201	.190	44
Left inferior longitudinal fasciculus	−.085	.582	**.383**[a]	**.010**	44
Left superior longitudinal fasciculus - parietal bundle	−.186	.227	**.341**[a]	**.024**	44
Left superior longitudinal fasciculus - temporal bundle	**−.319**[a]	**.035**	**.352**[a]	**.019**	44
Left uncinate fasciculus	−.096	.536	.214	.162	44
Right anterior thalamic radiation	−.242	.114	**.362**[a]	**.016**	44
Right cingulum - angular (infracallosal) bundle	−.032	.835	.033	.834	44
Right cingulum - cingulate gyrus (supracallosal) bundle	.103	.508	.222	.147	44
Right corticospinal tract	−.095	.538	**.350**[a]	**.020**	44
Right inferior longitudinal fasciculus	−.126	.420	**.299**	**.051**	43
Right superior longitudinal fasciculus - parietal bundle	−.190	.218	**.437**[b]	**.003**	44
Right superior longitudinal fasciculus - temporal bundle	−.158	.306	**.433**[b]	**.003**	44
Right uncinate fasciculus	−.092	.554	.116	.455	44
Across tract average	−.172	.265	.269	.078	44

*FA: fractional anisotropy; MD: mean diffusivity
[a]indicates $p < .05$
[b]indicates $p < .01$

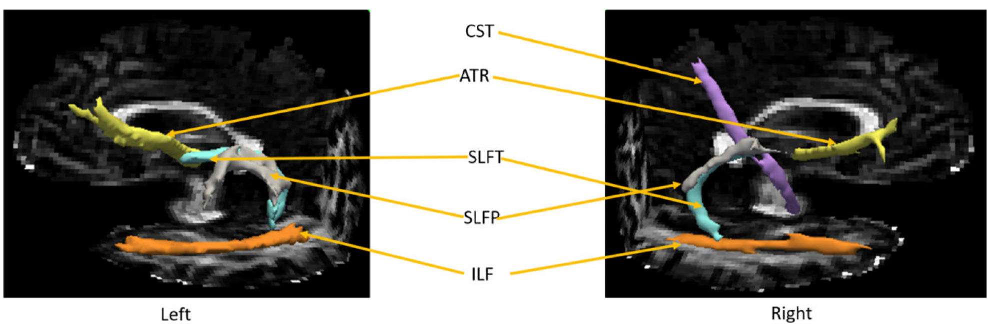

FIGURE 2 White matter tracts associated with financial awareness. ATR, anterior thalamic radiation; CST, corticospinal tract; ILF, inferior longitudinal fasciculus; SLFP, superior longitudinal fasciculus - parietal bundle; SLFT, superior longitudinal fasciculus - temporal bundle

White matter in the right hemisphere may have more valence for processing information related to the self (Pacella et al., 2019). Our findings concur with the emerging literature wherein right hemisphere regions involving the SLF along with two other tracts (in the cingulum and premotor areas) were the most notable white matter bundles involved in self-monitoring and appraisal for individuals with unawareness of their motor deficits (e.g., hemiplegia) (Pacella et al., 2019). The importance of the right hemisphere in supporting self-awareness has also been found in several previous studies involving different clinical groups such as those with mild cognitive impairment, AD, and behavioral variant frontotemporal dementia (Chavoix & Insausti, 2017). Another avenue of support comes from studies examining financial exploitation and scam risk susceptibility which have also identified right long-range white matter connections as being vital (Lamar et al., 2020).

A novel finding from this study is that the anterior thalamic tracts are also linked to financial awareness. This observation, although needing replication via other studies, broadly concurs with the literature on the role of thalamus in consciousness, attention and arousal. The anterior nucleus of the thalamus projects to the anterior cingulate gyrus, an area that is primarily critical for error-detection and self-monitoring (Mamah et al., 2010; Niida et al., 2018; Orr & Hester, 2012). However, the role of ATR in financial awareness, although plausible needs further replication.

The right CST tracts were involved in financial awareness. The CST, consisting of descending pathways from the cortex to the brainstem (Oishi, Faria, Van Zijl, & Mori, 2010), is typically involved in motor functions. However, the CST also plays a role in processing numerical information, especially those involving smaller numbers and finger counting strategies (Matejko & Ansari, 2015). It should be noted that CST consists of several crossing fibers that are linked to SLF (Matejko & Ansari, 2015). While crossing fibers can result in unreliable measurement (Mito et al., 2018), it is also possible that the CST and financial awareness associations may be partially driven by SLF connections (Matejko & Ansari, 2015). However, higher resolution studies will be needed to study the influence of each of these crossing fibers.

Finally, the ILF was linked to FDM and financial awareness. However, after adjusting for FDM, the involvement of ATR, CST, and ILF was attenuated. Therefore, the ILF's involvement (especially for left- > right-sided connections), along with CST and ATR tracts in financial awareness needs to be tested further.

There are some limitations to this work. First, the study cohort consisted of a highly selective group of older adults who were primarily well-educated and non-Hispanic White. For the study results to be generalized, the findings should be replicated in a more diverse sample. Second, the instrument to measure FDM and the objective items extracted for the current study belong to a standardized, longer instrument that was originally developed in Australia. The psychometric properties of this instrument is still being validated in the United States (Sunderaraman, Cosentino, Lindgren, James, & Schultheis, 2019), and more data will have to be collected across various cohorts using more diverse criteria before it's use can be confidently generalized. However, preliminary evidence indicates that performance in our cognitively healthy individuals is comparable to the normative scores established in the Australian sample (Sunderaraman et al., 2019). Third, although financial awareness is multifaceted, we investigated only one facet of financial awareness. Specifically, we examined participants' awareness of their performance on objectively measured items of the FCAI. The rationale for this approach was multifold, including: (a) awareness of one's current, personal financial circumstances can be challenging to assess without direct knowledge of the individual's actual circumstances, and informants are not always accurate in their impressions of an individual's circumstances or abilities and (b) online assessments using objective metacognitive tasks have been shown to capture day-to-day awareness of one's abilities (Cosentino et al., 2007; Cosentino et al., 2011; Koren et al., 2004). Fourth, the tractography approach could not distinguish SLF from AF tracts, and therefore precluded a fine-grained analysis of these tracts in relation to FDM and financial awareness. The SLF and AF tracts are known to be involved in different aspects of numeracy, and it will be interesting for future studies to understand whether these tracts contribute differently to FDM and financial awareness. Finally, a concern that could be raised is the statistical analysis did not adjust for multiple comparisons. We did not adjust for multiple comparisons at the outset because of the hypothesis-driven nature of hypothesis in which the longitudinal SLF tracts were expected to be associated with FDM and financial awareness. However, even if adjustments for multiple comparisons were to be conducted using Bonferroni corrections (sig. level of .05/18 tracts = 0.003), the right SLF tracts still remained significantly associated with financial awareness, thus further reinforcing the importance of these tracts.

In conclusion, this is the first study to identify the overlapping white matter tracts involved in both FDM and financial awareness in healthy older adults. Albeit the findings are preliminary, the most salient connections were found to be present between FDM and financial awareness with the SLF white matter tracts. Importantly, the right bundles showed a specific role in financial awareness, even after adjusting for FDM. Compared to the nonsignificant associations found between FDM and cortical thickness (Sunderaraman et al., under review), the presence of significant associations between white matter and FDM perhaps points to the greater sensitivity of the white matter tracts to financial management abilities in healthy older adults. This also adds to the growing literature that variability in white matter and thickness may make differential contributions to FDM and financial awareness with the possibility that white matter tracts could play an important role earlier in the process. Future studies should be designed to longitudinally examine the exact links between white matter changes as compared to other changes in neuroimaging metrics in relation to FDM and financial awareness. The importance of the temporal cortex and connected pathways is further reinforced by the current study. In addition, the frontal and parietal connections along with those subsuming the subcortical pathways are identified to be crucial to FDM and financial awareness. To enhance our understanding of how FDM and financial awareness are represented in the brain, future studies may benefit from adopting a multi-modal approach which integrates both structural and functional imaging.

ACKNOWLEDGMENTS

This study was supported by the Ruth L. Kirschstein Predoctoral Individual National Research Service Award [Grant number 5F32AG053035], the National Academy of Neuropsychology Clinical Research Grant presented to PS, the CTSA grant [UL1 TR001873], National Institute on Aging [Grant numbers R01 AG026158 and RF1AG038465].

CONFLICT OF INTEREST

The authors declare no potential conflict of interest.

AUTHOR CONTRIBUTIONS

Conception and study design (**Preeti Sunderaraman**, and **Stephanie Cosentino**); data collection or acquisition and quality control (**Preeti Sunderaraman**, **Silvia Chapman**, **Jillian L. Joyce**, **Stephanie Cosentino**, **Gema Ortiz**, **Christopher Langfield**, **Ashley Mensing**, **Yunglin Gazes**, and **Yaakov Stern**); statistical analysis (**Preeti Sunderaraman**, **Yunglin Gazes**, **Adam M. Brickman**, and **Stephanie Cosentino**); interpretation of results (**Preeti Sunderaraman**, **Stephanie Cosentino**, **Yunglin Gazes**, and **Adam M. Brickman**); drafting the manuscript work or revising it critically for important intellectual content (**Preeti Sunderaraman**, **Silvia Chapman**, **Yunglin Gazes**, **Stephanie Cosentino**, **Adam M. Brickman**, and **Yaakov Stern**); 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).

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ORCID

Preeti Sunderaraman https://orcid.org/0000-0001-6011-8412

REFERENCES

Acierno, R., Hernandez, M. A., Amstadter, A. B., Resnick, H. S., Steve, K., Muzzy, W., & Kilpatrick, D. G. (2010). Prevalence and correlates of emotional, physical, sexual, and financial abuse and potential neglect in the United States: The National Elder Mistreatment Study. *American Journal of Public Health*, *100*(2), 292–297.

Agarwal, S., Driscoll, J. C., Gabaix, X., & Laibson, D. (2009). The age of reason: Financial decisions over the life cycle and implications for regulation. *Brookings Papers on Economic Activity*, *2009*(2), 51–117.

Alzheimer's Disease Facts and Figures. (2020). 2020 Alzheimer's disease facts and figures. *Journal of Alzheimer's Dementia*, *16*(3), 391–460.

Amalric, M., & Dehaene, S. (2016). Origins of the brain networks for advanced mathematics in expert mathematicians. *Proceedings of the National Academy of Sciences of the United States of America*, *113*(18), 4909–4917.

Arsalidou, M., Pawliw-Levac, M., Sadeghi, M., & Pascual-Leone, J. (2018). Brain areas associated with numbers and calculations in children: Meta-analyses of fMRI studies. *Developmental Cognitive Neuroscience*, *30*, 239–250.

Boyle, P. A., Yu, L., Wilson, R. S., Segawa, E., Buchman, A. S., & Bennett, D. A. (2013). Cognitive decline impairs financial and health literacy among community-based older persons without dementia. *Psychology and Aging*, *28*(3), 614–624.

Chavoix, C., & Insausti, R. (2017). Self-awareness and the medial temporal lobe in neurodegenerative diseases. *HAL*, *78*, 1–12.

Conrad, K. J., Iris, M., Ridings, J. W., Langley, K., & Wilber, K. H. (2010). Self-report measure of financial exploitation of older adults. *The Gerontologist*, *50*(6), 758–773.

Consumer Financial Protection Bureau. (2017). Report and recommendations: Fighting elder financial exploitation through community. *Networks*, *9*, 3–48.

Cosentino, S., Metcalfe, J., Butterfield, B., & Stern, Y. (2007). Objective metamemory testing captures awareness of deficit in Alzheimer's disease. *Cortex*, *43*(7), 1004–1019.

Cosentino, S., Metcalfe, J., Cary, M. S., De Leon, J., & Karlawish, J. (2011). Memory awareness influences everyday decision making capacity about medication management in Alzheimer's disease. *International Journal of Alzheimer's Disease*, *2011*, 483897.

Demakis, G. J., Szczepkowski, K. V., & Johnson, A. N. (2018). Predictors of financial capacity in young adults. *Archives of Clinical Neuropsychology*, *34*(4), 503–510.

Dunlosky, J., & Tauber, S. U. K. (2016). *The Oxford handbook of metamemory*. New York, NY: Oxford University Press.

Farrell, J. A., Zhang, J., Jones, M. V., DeBoy, C. A., Hoffman, P. N., Landman, B. A., … Van Zijl, P. C. J. M. R. I. M. (2010). q-space and conventional diffusion imaging of axon and myelin damage in the rat spinal cord after axotomy. *Magnetic Resonance in Medicine*, *63*(5), 1323–1335.

Field, A. (2013). *Discovering statistics using IBM SPSS statistics*. New York, NY: Sage.

Fujiwara, E., Schwartz, M. L., Gao, F., Black, S. E., & Levine, B. (2008). Ventral frontal cortex functions and quantified MRI in traumatic brain injury. *Neuropsychologia*, *46*(2), 461–474.

Gamble, K. J., Boyle, P. A., Yu, L., & Bennett, D. (2015). Aging and financial decision making. *Management Science*, *61*(11), 2603–2610.

Gazes, Y., Lee, S., Sakhardande, J., Mensing, A., Razlighi, Q., Ohkawa, A., … Habeck, C. (2020). fMRI-guided white matter connectivity in fluid and crystallized cognitive abilities in healthy adults. *NeuroImage*, *215*, 116809.

Gerstenecker, A., Hoagey, D. A., Marson, D. C., & Kennedy, K. M. (2017). White matter degradation is associated with reduced financial capacity in mild cognitive impairment and Alzheimer's disease. *Journal of Alzheimer's Disease*, *60*(2), 537–547.

Grotheer, M., Zhen, Z., & Grill-Spector, K. (2019). Separate lanes for math and reading in the white matter highways of the human brain. *Nature Communications*, *10*. https://doi.org/10.1038/s41467-019-11424-1

Han, S. D., Arfanakis, K., Fleischman, D. A., Yu, L., Bennett, D. A., & Boyle, P. A. (2018). White matter correlates of temporal discounting in older adults. *Brain Structure and Function*, *223*(8), 3653–3663.

Han, S. D., Boyle, P. A., Yu, L., Arfanakis, K., James, B. D., & Fleischman, D. A. (2016). Grey matter correlates of susceptibility to scams in community-dwelling older adults. *Brain Imaging and Behavior*, *10*(2), 524–532.

Hu, Y., Geng, F., Tao, L., Hu, N., Du, F., Fu, K., & Chen, F. (2011). Enhanced white matter tracts integrity in children with abacus training. *Human Brain Mapping*, *32*(1), 10–21.

Kershaw, M. M., & Webber, L. S. (2008). Assessment of financial competence. *Psychiatry, Psychology and Law*, *15*(1), 40–55.

Koren, D., Seidman, L. J., Poyurovsky, M., Goldsmith, M., Viksman, P., Zichel, S., & Klein, E. (2004). The neuropsychological basis of insight in first-episode schizophrenia: A pilot metacognitive study. *Schizophrenia Research*, *70*(2–3), 195–202.

Korniotis, G. M., & Kumar, A. (2011). Do older investors make better investment decisions? *The Review of Economics and Statistics*, *93*(1), 244–265.

Lamar, M., Arfanakis, K., Yu, L., Zhang, S., Han, S. D., & Fleischman, D. A. (2020). White matter correlates of scam susceptibility in community-dwelling older adults. *Brain Imaging and Behavior*, *14*(5), 1521–1530.

Lichtenberg, P. A., Ficker, L. J., & Rahman-Filipiak, A. (2016). Financial decision-making abilities and financial exploitation in older African Americans: Preliminary validity evidence for the Lichtenberg Financial Decision Rating Scale (LFDRS). *Journal of Elder Abuse Neglect*, *28*(1), 14–33.

Lichtenberg, P. A., Stoltman, J., Ficker, L. J., Iris, M., & Mast, B. (2015). A person-centered approach to financial capacity assessment: Preliminary development of a new rating scale. *Clinical Gerontologist*, *38*(1), 49–67.

Madhyastha, T., Merillat, S., Hirsiger, S., Bezzola, L., Liem, F., Grabowski, T., & Jäncke, L. (2014). Longitudinal reliability of tract-based spatial statistics in diffusion tensor imaging. *Human Brain Mapping*, *35*(9), 4544–4555.

Mak, A. D. P., Leung, O. N. W., Chou, I. W. Y., Wong, S. L. Y., Chu, W. C.-W., Yeung, D., … Leung, C. M. (2021). White matter integrity in young medication-naïve bipolar II depressed adults. *Scientific Reports*, *11*(1), 1–10.

Mamah, D., Conturo, T. E., Harms, M. P., Akbudak, E., Wang, L., McMichael, A. R., … Csernansky, J. G. (2010). Anterior thalamic radiation integrity in schizophrenia: A diffusion-tensor imaging study. *Psychiatry Research*, *183*(2), 144–150.

Mamah, D., Ji, A., Rutlin, J., & Shimony, J. S. (2019). White matter integrity in schizophrenia and bipolar disorder: Tract-and voxel-based analyses of diffusion data from the connectom scanner. *NeuroImage: Clinical*, *21*, 101649.

Marson, D. (2016). Conceptual models and guidelines for clinical assessment of financial capacity. *Archives of Clinical Neuropsychology*, *31*(6), 541–553.

Marson, D. C., Sawrie, S. M., Snyder, S., McInturff, B., Stalvey, T., Boothe, A., … Harrell, L. E. (2000). Assessing financial capacity in patients with Alzheimer disease: A conceptual model and prototype instrument. *Archives of Neurology*, *57*(6), 877–884.

Martyr, A., & Clare, L. J. (2018). Awareness of functional ability in people with early-stage dementia. *International Journal of Geriatric Psychiatry*, *33*(1), 31–38.

Matejko, A. A., & Ansari, D. (2015). Drawing connections between white matter and numerical and mathematical cognition: A literature review. *Neuroscience & Biobehavioral Reviews*, *48*, 35–52.

Mattis, S. (1988). *Dementia rating scale: Professional manual*. Odessa, FL: Psychological Assessment Resources.

Mito, R., Raffelt, D., Dhollander, T., Vaughan, D. N., Tournier, J.-D., Salvado, O., … Connelly, A. (2018). Fibre-specific white matter reductions in Alzheimer's disease and mild cognitive impairment. *Brain*, *141*(3), 888–902.

Moeller, K., Willmes, K., & Klein, E. (2015). A review on functional and structural brain connectivity in numerical cognition. *Frontiers in Human Neuroscience*, *9*, 227.

Molina, I. S. M., Salo, R. A., Abdollahzadeh, A., Tohka, J., Gröhn, O., & Sierra, A. (2020). In vivo diffusion tensor imaging in acute and subacute phases of mild traumatic brain injury in rats. *eNeuro*, *7*(3). https://doi.org/10.1523/ENEURO.0476-19.2020

Mori, S., & Zhang, J. (2006). Principles of diffusion tensor imaging and its applications to basic neuroscience research. *Neuron*, *51*(5), 527–539.

Mukherjee, P., Chung, S., Berman, J., Hess, C., & Henry, R. (2008). Diffusion tensor MR imaging and fiber tractography: Technical considerations. *American Journal of Neuroradiology*, *29*(5), 843–852.

National Academies of Sciences, Engineering, & Medicine. (2016). *Informing social security's process for financial capability determination*. Washington, DC: National Academies Press.

Nicholas, L. H., Langa, K. M., Bynum, J. P., & Hsu, J. W. (2021). Financial presentation of Alzheimer disease and related dementias. *JAMA Internal Medicine*, *181*(2), 220–227.

Niida, R., Yamagata, B., Niida, A., Uechi, A., Matsuda, H., & Mimura, M. (2018). Aberrant anterior thalamic radiation structure in bipolar disorder: A diffusion tensor tractography study. *Frontiers in Psychiatry*, *9*, 522.

Oishi, K., Faria, A. V., Van Zijl, P. C., & Mori, S. (2010). *MRI atlas of human white matter*. Amsterdam, The Netherlands: Academic Press.

Orr, C., & Hester, R. (2012). Error-related anterior cingulate cortex activity and the prediction of conscious error awareness. *Frontiers in Human Neuroscience*, *6*, 177.

Pacella, V., Foulon, C., Jenkinson, P. M., Scandola, M., Bertagnoli, S., Avesani, R., … De Schotten, M. T. (2019). Anosognosia for hemiplegia as a tripartite disconnection syndrome. *eLife*, *8*, e46075.

Petrides, M., & Pandya, D. N. (2002). Association pathways of the prefrontal cortex and functional observations. In *Principles of frontal lobe function* (Vol. 1, pp. 31–50). New York, NY: Oxford University Press.

Schmahmann, J. D., Smith, E. E., Eichler, F. S., & Filley, C. M. (2008). Cerebral white matter: Neuroanatomy, clinical neurology, and neurobehavioral correlates. *Annals of the New York Academy of Sciences*, *1142*, 266.

Soares, J., Marques, P., Alves, V., & Sousa, N. (2013). A hitchhiker's guide to diffusion tensor imaging. *Frontiers in Neuroscience*, *7*, 31.

Spreng, R. N., Cassidy, B. N., Darboh, B. S., DuPre, E., Lockrow, A. W., & Setton, R. (2017). Financial exploitation is associated with structural and functional brain differences in healthy older adults. *Journals of Gerontology. Series A, Biological Sciences and Medical Sciences*, *72*(10), 1365–1368.

Stern, Y., Habeck, C., Steffener, J., Barulli, D., Gazes, Y., Razlighi, Q., … Salthouse, T. (2014). The reference ability neural network study: Motivation, design, and initial feasibility analyses. *NeuroImage*, *103*, 139–151.

Sunderaraman, P., Barker, M., Chapman, S., & Cosentino, S. (2020). Assessing numerical reasoning provides insight into financial literacy. *Applied Neuropsychology: Adult*, 1–8. https://doi.org/10.1080/23279095.2020.1805745

Sunderaraman, P., Chapman, S., Barker, M. S., & Cosentino, S. (2020). Self-awareness for financial decision-making abilities in healthy adults. *PLoS One*, *15*(7), e0235558.

Sunderaraman, P., Cosentino, S., Lindgren, K., James, A., & Schultheis, M. (2018). Informant report of financial capacity for individuals with chronic acquired brain injury: An assessment of informant accuracy. *Journal of Head Trauma Rehabilitation*, *33*(6), E85–E94.

Sunderaraman, P., Cosentino, S., Lindgren, K., James, A., & Schultheis, M. T. (2019). An examination of financial capacity and neuropsychological performance in chronic acquired brain injury (CABI). *Brain Injury*, *33*(8), 991–1002.

Sunderaraman, P., Lee, S., Varangis, E., Habeck, C., Chapman, S., Joyce, J.L., … Cosentino, S. (2021). Self-awareness for financial decision making abilities is linked to right temporal cortical thickness in older adults. *Brain Imaging and Behavior*, 1–9. https://doi.org/10.1007/s11682-021-00590-w

Vinke, E. J., de Groot, M., Venkatraghavan, V., Klein, S., Niessen, W. J., Ikram, M. A., & Vernooij, M. W. (2018). Trajectories of imaging markers in brain aging: The Rotterdam study. *Neurobiology of Aging*, *71*, 32–40.

Wood, J. L., Heitmiller, D., Andreasen, N. C., & Nopoulos, P. (2008). Morphology of the ventral frontal cortex: Relationship to femininity and social cognition. *Cerebral Cortex*, *18*(3), 534–540.

Yendiki, A., Panneck, P., Srinivasan, P., Stevens, A., Zollei, L., Augustinack, J., … Fischl, B. (2011a). Automated probabilistic reconstruction of white-matter pathways in health and disease using an atlas of the underlying anatomy. *Frontiers in Neuroinformatics*, *5*, 23. https://doi.org/10.3389/fninf.2011.00023

Yendiki, A., Panneck, P., Srinivasan, P., Stevens, A., Zöllei, L., Augustinack, J., … Behrens, T. (2011b). Automated probabilistic reconstruction of white-matter pathways in health and disease using an atlas of the underlying anatomy. *Frontiers in Neuroinformatics*, *5*, 23.

Ziegler, D. A., Piguet, O., Salat, D. H., Prince, K., Connally, E., & Corkin, S. (2010). Cognition in healthy aging is related to regional white matter integrity, but not cortical thickness. *Neurobiology of Aging*, *31*(11), 1912–1926.

SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

How to cite this article: Sunderaraman, P., Gazes, Y., Ortiz, G., Langfield, C., Mensing, A., Chapman, S., Joyce, J. L., Brickman, A. M., Stern, Y., & Cosentino, S. (2022). Financial decision-making and self-awareness for financial decision-making is associated with white matter integrity in older adults. *Human Brain Mapping*, *43*(5), 1630–1639. https://doi.org/10.1002/hbm.25747