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White matter correlates of scam susceptibility in community-dwelling older adults

Melissa Lamar, Ph.D.[1,2], **Konstantinos Arfanakis, Ph.D.**[1,3,4], **Lei Yu, Ph.D.**[1,5], **Shengwei Zhang, Ph.D.**[1], **S. Duke Han, Ph.D.**[1,2,5,6,7,8,9], **Debra A. Fleischman, Ph.D.**[1,2,5], **David A. Bennett, M.D.**[1,5], **Patricia A. Boyle, Ph.D.**[1,2]

[1]Rush Alzheimer's Disease Center, 1750 W Harrison Street, Suite 1000, Chicago, IL 60612, USA

[2]Department of Behavioral Sciences, 1645 W Jackson Blvd, Suite 400, Chicago, IL 60612, USA

[3]Department of Biomedical Engineering, Illinois Institute of Technology, Chicago, IL 60612, USA

[4]Department of Diagnostic Radiology and Nuclear Medicine, 1653 W Congress Parkway, Rush University Medical Center, Chicago, IL, 60612, USA

[5]Department of Neurological Sciences, 1653 W Congress Parkway, Rush University Medical Center, Chicago, IL, 60612, USA

[6]Department of Family Medicine, Keck School of Medicine of USC, Alhambra, CA 91803

[7]Department of Neurology, Keck School of Medicine of USC, Los Angeles, CA 90033

[8]Department of Psychology, USC, Los Angeles CA 90007

[9]School of Gerontology, USC, Los Angeles CA 90007

Abstract

Background: Scam susceptibility places older adults – even those with intact cognition – at great risk. Lower grey matter volumes, particularly within right medial temporal regions, are associated with higher scam susceptibility; however, very little is known about white matter associates.

Methods: We investigated associations between white matter integrity measured using diffusion tensor imaging (DTI) and scam susceptibility in 302 non-demented older adults (75% female; mean years: age=81.3±7.5, education=15.7±2.9). Participants completed comprehensive neuroimaging (including DTI, T1- and T2-weighted imaging), a self-report measure of scam susceptibility, and neuropsychological testing. Tract-Based Spatial Statistics (TBSS) investigated associations of DTI-derived measures of fractional anisotropy (FA), trace of the diffusion tensor,

Corresponding Author: Melissa Lamar, Ph.D., Associate Professor, Rush Alzheimer's Disease Center, Rush University Medical Center, 1750 W Harrison Street, Suite 1000, Chicago, IL, 60612. Phone: (312) 942-3365; melissa_lamar@rush.edu.

Conflict of Interest
The authors declare that they have no conflict of interest.

Ethical approval
All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent
Informed consent was obtained from all individual participants included in the study.

axial and radial diffusivity (separately) with scam susceptibility adjusting for age, sex, education, and white matter hyperintensities (WMH; total volume and voxelwise separately). Statistical significance was determined at $p<0.05$, Family Wise Error corrected.

Results: TBSS revealed significant negative associations between FA in tracts connecting a number of right hemisphere white matter regions and scam susceptibility, particularly after additional adjustment for global cognitive functioning. The pathways implicated were mainly in right temporal-parietal and temporal-occipital regions. Association of trace, axial, and radial diffusivity with scam susceptibility were not significant in fully-adjusted models.

Conclusions: Lower white matter integrity within right hemisphere tracts was associated with higher scam susceptibility independent of relevant confounds including global cognition. Thus, a right hemisphere brain network that includes key structures implicated in multi-sensory processing of immediate and future consequences may serve as a neurobiologic substrate of scam susceptibility in vulnerable older adults.

Keywords

aging; scam susceptibility; white matter; DTI; fractional anisotropy

Introduction

It is estimated that 1 of every 18 non-demented, community dwelling older adults 50 years or older experience a range of exploitations, schemes, and scams each year (Burnes et al. 2017), amounting to an approximate loss of $30 billion in funds (True Link Financial 2015) that are difficult, if not impossible, to recover at older ages due to limited earning capacity and short time horizons. These statistics do not include the number of adults susceptible to scams in this same age range or the increasing number of predators targeting elders. Each day, for the next 12 years, 10,000 Americans will turn 65 (Passel and Cohn 2008), increasing the number of older adults that will face the growing likelihood of falling victim to scams. The threats to the projected 50 million Americans 65 and older currently living in the US (US Department of Commerce 2017) – Americans who represent the majority of wealth holders in this country – are such a concern that the National Council on Aging calls scams targeting older adults "the crime of the 21st century." Additionally, the Senate Committee on Aging publishes an annual "Fraud Book" outlining the top scams being perpetrated against seniors as well as information on how to recognize and avoid them. In addition to the dissemination of information about scam susceptibility for older adults, more research is needed in older adults to understand the neurobiologic basis of this vulnerability for better identification of those at increased risk.

Although research on scam susceptibility in the aging population is a relatively new and understudied area, our group (James et al. 2014; Boyle et al. 2012b; Han et al. 2016c; Han et al. 2016b) and others (Spreng et al. 2017; Jackson and Hafemeister 2011; Wood et al. 2016) have examined the behavioral profiles and brain structural basis of scam susceptibility in older adults. Results from the existing studies point towards a model of scam susceptibility (Lichtenberg 2016; Spreng et al. 2016) and decision making more generally (James et al. 2014; Boyle et al. 2012b; Han et al. 2016c; Han et al. 2016b) that involves a complex interplay between diverse resources including social-cognitive skills and knowledge-based contextual factors. Specifically, studies in older adults without dementia reveal a portrait of scam susceptibility associated with higher age, lower wellbeing and social support, lower global cognitive functioning, as well as lower levels of health and financial literacy and income (James et al. 2014; Jackson and Hafemeister 2011; Wood et al. 2016). Furthermore, a more rapid global cognitive decline over time increases scam susceptibility even among non-demented older adults (Boyle et al. 2012b). These results are consistent with and expand upon key components of existing models of risk for financial exploitation that describe the role of psychological vulnerability (Lichtenberg 2016) and reduced cognitive capacity including poor financial knowledge (Spreng et al. 2016) by emphasizing not only social and cognitive factors, but also contextual factors such as financial literacy and income as important determinants of scam susceptibility and decision making more generally.

Very few studies have investigated the brain structural correlates of scam susceptibility in older adults (Spreng et al. 2017; Han et al. 2016c) or have considered how they may fit within the emerging theoretical model of scam susceptibility. A group recently reported preliminary evidence in a sample of 26 older adults that cortical thinning within the right anterior insula and right posterior superior temporal gyrus not only associated with scam victimization when compared to scam avoidance, but also suggested possible neuroanatomical associates for the social-cognitive model of scam susceptibility (Spreng et al. 2017). In a larger study, we reported that lower right hemisphere grey matter integrity within parahippocampal, hippocampal, fusiform, and mid-temporal brain regions is related to scam susceptibility after adjusting for global cognitive functioning (Han et al. 2016c). Thus, these findings lend further support for a similar neuroanatomical profile of scam susceptibility that implicates social-cognitive aspects in particular. We are not aware, however, of studies investigating white matter correlates of scam susceptibility in non-demented older adults.

This study examines the associations between white matter integrity and scam susceptibility in a community-dwelling cohort of non-demented older adults from the Rush Memory and Aging Project to understand how white matter integrity may contribute to scam susceptibility and whether such associations provide further support for the emerging model of scam susceptibility, financial exploitation, and decision making as suggested by prior literature (Lichtenberg 2016; Spreng et al. 2016). Based on previous studies investigating grey matter described above (Spreng et al. 2017; Han et al. 2016c), and functional connectivity showing reduced resting state activation within medial prefrontal and posterior cingulate regions (Spreng et al. 2017), we hypothesized that lower white matter integrity within long association fibers connecting posterior temporal and parietal cortices with prefrontal regions of the right hemisphere would be associated with scam susceptibility after controlling for age and other relevant factors. Additionally, given that older adults may be susceptible to scams regardless of cognitive status (James et al. 2014; Han et al. 2016b; Boyle et al. 2012b) and changes in social cognition may increase risk of financial exploitation (Spreng et al. 2016), we further hypothesized that the association between lower white matter integrity with scam susceptibility would remain significant after further adjusting for global cognitive functioning. To our knowledge, this is the first systematic study of brain white matter associations of scam susceptibility in older adults.

Materials and Methods

Participants

Individuals included in this research were participants from the Rush Memory and Aging Project (MAP; 1997-present), an ongoing longitudinal clinical-pathologic cohort study of aging (Bennett and Launer 2012; Bennett et al. 2012). The Institutional Review Board of Rush University Medical Center approved all studies and participants gave written informed consent for all aspects of the studies in accordance with the Declaration of Helsinki. Participants were enrolled without known dementia and underwent annual clinical evaluations.

MAP started in 1997 with a decision making sub-study that included an assessment of scam susceptibility introduced in 2010 (Boyle et al. 2012a). Neuroimaging was introduced in 2009. At the time of these analyses, 1,848 participants had enrolled in MAP and 1,803 had completed baseline evaluation including a cognitive evaluation for the parent study. Of these participants, 607 had died before the introduction of the assessment of scam susceptibility (n=428) or shortly thereafter (n=179) and 108 had incomplete data. This left 936 participants eligible for inclusion in our analyses. We excluded 55 participants who had dementia at the time of the baseline assessment of scam susceptibility; diagnoses were based on information obtained at the annual MAP visit (see below), which is conducted very close in time to the assessment of scam susceptibility. Of the remaining 881 eligible participants, 566 (64%) received neuroimaging regardless of magnet strength (i.e., 1.5T versus 3T). We excluded individual with 1.5T derived data and only included participants (n=305) with 3T DTI data in our analyses.

Clinical Diagnosis

All participants underwent uniform structured clinical evaluations as outlined elsewhere (Bennett et al. 2012). Briefly, the diagnosis of dementia was made by clinicians experienced in the assessment of older adults and followed the National Institute of Neurologic and Communicative Disorders and Stroke and the Alzheimer’s Disease and Related Disorders Association criteria (McKhann et al. 1984).

Neuroimaging

Whole brain MRI data were acquired on all participants using a Siemens 3 Tesla MRI scanner (Erlangen, Germany). Participants were positioned comfortably on the scanner table and fitted with soft earplugs; foam pads were used to minimize head movement. Participants were instructed to remain still through the scan. On average, participants underwent neuroimaging within 3±1.4 months of completing the scam susceptibility assessment.

The scanning protocol included the following: high resolution T1-weighted anatomical data was obtained using a 3D magnetization-prepared rapid acquisition gradient-echo (MPRAGE) sequence [echo-time (TE)=2.98ms, repetition time (TR)=2.3s, preparation time=900ms, flip-angle = 9°, field-of-view (FOV) = 25.6 cm × 25.6 cm, 176 sagittal slices, slice thickness = 1 mm, no gap, 256 × 256 acquisition matrix, parallel imaging acceleration factor (AF)=2 along the phase encoding direction], for a total imaging time of 5 minutes and

30 seconds. A 2D fast spin-echo sequence was used to collect T2-weighted fluid attenuated inversion recovery (FLAIR) data with parameters as follows: TE=150ms, TR=9s, inversion time=2.49s, FOV = 22 cm × 22 cm, 35 axial slices, slice thickness = 4 mm, no gap, 256 × 256 acquisition matrix, AF=2, scan time=2 minutes and 42 seconds]. Finally, spin-echo echo-planar DTI was also acquired using the following parameters: TE=85ms, TR=8.1s, FOV = 22.4 cm × 22.4 cm, 65 axial slices, slice thickness = 2 mm, no gap, 112 × 112 acquisition matrix with 6/8 partial Fourier acceleration, b = 1000 s/mm^2 for 40 diffusion directions uniformly distributed in 3D space, 6 b = 0 s/mm^2 volumes, for a total scan time of 6 minutes and 37 seconds.

Four DTI measures were utilized to characterize white matter structural integrity in the present study: fractional anisotropy (FA), the trace of the diffusion tensor, axial and radial diffusivity (AD and RD, respectively). Trace is equal to three times the mean diffusivity; thus, results of trace are similar to what would be expected if using mean diffusivity (Mukherjee et al. 2008). TORTOISE (http://www.tortoisedti.org) was used to correct for distortions in the diffusion-weighted volumes caused by eddy-currents and magnetic field non-uniformities, bulk-motion correction, B-matrix reorientation, and generation of FA, trace maps, AD, and RD (Pierpaoli et al. 2010; Le Bihan et al. 2001; Alexander et al. 2001). Quality checks were done at each stage of image processing; three subjects failed final quality checks and were excluded from analyses. This left 302 participants in our sample.

Assessment of Scam Susceptibility

Scam susceptibility was measured using a 5-item self-report scale (Han et al. 2016b; James et al. 2014; Boyle et al. 2012b). Using a 7-point Likert scale (strongly agree to strongly disagree), participants were asked to rate their agreement with the following statements:

1. I feel I have to answer the phone whenever it rings, even if I do not know who is calling.
2. I have difficulty ending a phone call, even if the caller is a telemarketer, someone I do not know, or someone I did not wish to call me.
3. If something sounds too good to be true, it usually is.
4. Persons over the age of 65 are often targeted by con-artists.
5. If a telemarketer calls me, I usually listen to what they have to say.

These statements were derived from findings of the AARP and the Financial Industry Regulatory Authority (FINRA) Risk Meter, a measure of poor and risky financial decision making that is used in many finance studies (AARP 1999; FINRA 2017). Thus, these statements were carefully designed to address specific behaviors and characteristics that, according to the leading authorities on elder fraud, are associated with actual victimization. These include suspiciousness of claims that seem too good to be true, older persons’ being specifically targeted by con artists, and openness to sales pitches. The average of ratings from all 5 items, with items 1, 2, and 5 reverse coded, results in a total score where higher scores indicate greater scam susceptibility. The intraclass correlation coefficient for the measure is 0.63 (James et al. 2014), and responses to this measure have been associated with key characteristics and behaviors that correlate with scam susceptibility as well as fraud victimization including older age, lower financial literacy, lower cognitive function, lower psychological wellbeing, and a diagnosis of MCI (James et al. 2014; Han et al. 2016b; Boyle et al. 2012b).

Covariates

In addition to age, sex, and years of education, we adjusted for white matter hyperintensities, both total volume and voxelwise, as well as global cognitive functioning as outlined below.

White Matter Hyperintensities —Given that white matter hyperintensities (WMH) increase with age and are thought to disrupt, and even disconnect cerebral white matter tracts, we quantified WMH as a total volume and voxelwise for use as covariates in all models.

As previously described (Boyle et al. 2016), quantification of WMH first involved registering the T1-weighted MPRAGE data for each participant to the T2-weighted FLAIR data using affine registration (FLIRT, FMRIB, University of Oxford, UK) (Smith et al. 2004). Brains were extracted from the co-registered MPRAGE and FLAIR image volumes (BET, FMRIB, University of Oxford, UK) (Smith 2002). WMH were then automatically segmented using a support vector machine classifier considering both MPRAGE and FLAIR information for each participant (WMLS, SBIA, University of Pennsylvania) (Zacharaki et al. 2008). WMH volume was then divided by the participant's corresponding intracranial volume (ICV) generated by FreeSurfer to account for individual differences in brain size. This measure was then log-transformed.

In addition to WMH volume, we also adjusted for WMHs voxelwise. This was conducted by creating a WMH mask (0's and l's) where voxels with WMH were given values of 1 in the mask. The WMH mask of each participant was transformed to the space of the corresponding processed DTI data based on the transformation of the FLAIR image volume to the pre-processed $b = 0$ s/mm^2 volume. We have used the above processing approach in previous work (Arfanakis et al. 2013; Han et al. 2016a).

Global Cognitive Functioning —Although older adults may be susceptible to scams regardless of cognitive status, we have shown that global cognition is related to scam susceptibility (James et al. 2014; Han et al. 2016b; Boyle et al. 2012b), and that cognition is also related to white matter integrity (Lamar et al. 2010; Lamar et al. 2011). Thus, to confirm the robustness of our main findings, we controlled for global cognitive functioning. Details of the MAP annual cognitive evaluation have been described in numerous publications (Bennett and Launer 2012; Bennett et al. 2012; James et al. 2012; Boyle et al. 2013). Briefly, a global composite cognitive function score was derived from performance on 19 tests including tests of episodic, semantic, and working memory as well as visuospatial abilities and processing speed. The score was created by converting raw scores on the 19 cognitive tests to standard (z) scores using the mean and standard deviation from the baseline evaluation. A participant's standard scores across all tests were then averaged to yield a single composite score summarizing level of global cognitive function.

Statistical Analyses

Descriptive statistics were conducted for all variables of interest including covariates. First, we tested bivariate associations between key participant characteristics and scam susceptibility scores, using correlations or independent sample t-tests as appropriate. These analyses were conducted using SAS/STAT software, Version 9.4 of the SAS System for Linux (SAS Institute, Cary, NC).

We then used Tract-Based Spatial Statistics (TBSS) (Smith et al. 2006) to investigate the association of white matter diffusion measures (separately for FA, trace, AD, and RD) with scam susceptibility. All participants' FA volumes were non-linearly spatially transformed to the mean FA template of the IIT Human Brain Atlas (v.4.1) (http://www.iit.edu/~mri) (Zhang and Arfanakis 2018). The local FA maxima from each participant's spatially transformed FA volume were then projected onto the white matter skeleton of the IIT Human Brain Atlas. The same projection parameters were then used to project the trace, AD, and RD values (separately) from the same voxels as the local FA maxima. Linear regression was used to test the association of FA along the white matter skeleton with scam susceptibility, controlling for age, sex, education, and presence of WMHs (total volume and voxelwise as separate covariates). Analyses were then repeated further adjusting for global cognitive functioning. Separate linear regression models were used to test the association of the trace, AD, and RD (separately) of the diffusion tensor along the white matter skeleton with scam susceptibility adjusting for the same factors mentioned above. Given the age range of our participants, we grouped participants into those <80 years of age and those ≥80 and added the interaction of age group by scam susceptibility in additional (separate) models for DTI-derived variables.

For each of the linear regression models outlined above, the null distribution was built using the "randomise" tool in FSL (FMRIB, University of Oxford, UK) and 5000 permutations of the data. The threshold for significance was considered $p<0.05$, Family Wise Error (FWE) corrected. The Threshold-Free Cluster Enhancement (TFCE) method was used to define clusters with significant associations (Smith and Nichols 2009). The "regionstat" tool of the IIT Human Brain Atlas (v.4.1) was then used to extract the list of most probable connections passing through the clusters showing significant associations. These connections were determined according to the information contained in the 4-dimensional, connectivity based white matter labels of the IIT Human Brain Atlas (v.4.1), developed using high angular resolution diffusion imaging probabilistic tractography (Varentsova et al. 2015).

Results

Characteristics for our final sample of 302 participants are summarized in Table 1. The mean age was just over 80 years and the mean years of education was approximately 15; over 95% of participants were non-Latino White and the majority (~75%) were female. The mean scam susceptibility score was 2.6. Other covariates are described in Table 1.

Bivariate correlations between key participant characteristics and total scam susceptibility scores are shown in Table 2. Scam susceptibility was positively correlated with age and negatively correlated with global cognitive functioning (both p-values≤0.0001). Independent sample t-tests indicated that men (2.87±0.70) had higher scam susceptibility scores than women (2.60±0.67; p=0.003).

Association of Scam Susceptibility with White Matter Integrity

Fractional Anisotropy — TBSS analysis demonstrated significant negative correlations between scam susceptibility and FA values controlling for age, sex, level of education, and both WMH measures (p<0.05 FWE corrected for multiple comparisons). For example, bilateral association tracts connecting subcortical (i.e., the left thalamus and the left basal ganglia) and frontal regions were highly represented among results. Additionally, scam susceptibility was negatively associated with tracts involving the right cingulate and those connecting temporal and parietal brain regions of the right hemisphere (Table 3, Figure 1A).

Next, analyses were repeated further adjusting for global cognitive function in addition to age, sex, education, and both WMH measures. While several of the same white matter pathways connecting temporal and parietal regions remained significant and association tracts continued to be highly represented (Table 4, Figure 1B), findings were observed mainly in the right hemisphere. Furthermore, the pathways implicated were primarily in the superior and middle temporal as well as the inferior and superior parietal regions. Bilateral involvement was restricted to pathways connecting occipital-temporal regions.

Trace and Axial Diffusivity — TBSS analyses did not reveal any associations between scam susceptibility and the trace of the diffusion tensor or scam susceptibility and axial diffusivity, regardless of adjustments.

Radial Diffusivity — TBSS analysis demonstrated significant positive correlations between scam susceptibility and radial diffusivity values controlling for age, sex, level of education, and both WMH measures (Supplemental Table 1); however, these results did not withstand further correction for global cognition (p<0.05 FWE corrected for multiple comparisons).

Association of Age Group by Scam Susceptibility with White Matter Integrity

TBSS analyses did not reveal any significant associations of the interaction term age group (those less than versus greater than or equal to 80 years of age) by scam susceptibility and any DTI-derived variables, regardless of adjustments (data not shown).

Conclusions

To our knowledge, this is the first study investigating the association of scam susceptibility with white matter integrity. In a community-based study of more than 300 older adults, higher scam susceptibility was associated with lower diffusion anisotropy, an indicator of white matter integrity, within bilateral association tracts connecting subcortical and frontal regions as well as white matter pathways involving the right cingulum and those connecting right temporal and right parietal brain regions after adjusting for demographic factors and WMHs. Importantly, after further adjustment for global cognition, associations were mostly restricted to the right hemisphere, particularly the right temporal and right parietal regions. These results provide a white matter integrity complement to our previous report of associations between grey matter integrity and scam susceptibility in participants from the same cohort (Han et al. 2016c). Taken together, results suggest an important link between scam susceptibility and grey as well as white matter tract integrity within right temporal-parietal pathways that implicate a neurologic basis for scam susceptibility in vulnerable older adults that is consistent with existing and emerging models of financial exploitation risk (Lichtenberg 2016; Spreng et al. 2016) and decision making more generally (James et al. 2014; Boyle et al. 2012b; Han et al. 2016c; Han et al. 2016b).

These results expand the literature on scam susceptibility and brain aging in several important ways. Empirically, we can only find two studies that investigate brain structural correlates of scam susceptibility (Spreng et al. 2017), particularly in community-dwelling older adults as we reported (Han et al. 2016c). Both studies reported on brain structural integrity of grey matter, revealing significant associations between right temporal cortices and scam susceptibility (Spreng et al. 2017; Han et al. 2016c). By contrast, the current study focuses on white matter associations with scam susceptibility, with results mostly implicating temporal-parietal pathways in the right hemisphere. Theoretically, the present results provide a white matter connectivity framework and support for existing and emerging models of scam susceptibility that suggest this behavior relies heavily on social-cognitive capacity (Spreng et al. 2016) and knowledge-based conceptual factors (James et al. 2014; Boyle et al. 2012b; Han et al. 2016c; Han et al. 2016b). Temporal and parietal grey and white matter support prospective planning and consideration of future consequences as related to prior contextual knowledge (Peters and Buchel 2010). Furthermore, these regions' white matter connectivity support the multi-sensory integration of social cognitive processes including the interpretation of actions and attributes of external information and sources (Catani and Bambini 2014; Fischmeister et al. 2017; Bajada et al. 2017) that may be critical to identifying and avoiding scams. When combined with evidence that increased scam susceptibility may a harbinger of earlier negative cognitive outcomes (Boyle et al. 2012b), this study points toward a brain network that may serve as a neuroimaging signature not only to scam susceptibility but to pathological aging in vulnerable older adults more generally.

Additionally, we observed an association between scam susceptibility and pathways involving bilateral occipital-temporal regions independent of global cognition. These regions are highly intra-connected through long association and short u-fiber pathways (Catani et al. 2003; Latini et al. 2017). While the direction of information flow between these two regions cannot be discerned from this study, connections between lingual, fusiform, and other regions of the occipital lobe to superior, middle, and inferior temporal regions have been shown to facilitate the identification and consolidation of the emotional valence of presented stimuli (Kark et al. 2016; Luo et al. 2014) including individual and larger categorical changes in stimulus properties and attentional requirements (Luo et al. 2014; Gratton et al. 2013). This suggests that higher scam susceptibility in older adults may reflect a reduced capacity to discern emotional valence as needed in order to respond accordingly in potentially dangerous situations; perhaps a behavioral consequence of lower white matter integrity in posterior occipital-temporal as well as temporal-parietal pathways.

While the underlying mechanisms linking scam susceptibility and white matter integrity remain to be determined, the nature of the predominantly right hemisphere white matter associates to scam susceptibility were revealed only after controlling for global cognitive functioning. This suggests that the associations found here and in our previous work may be devoid of more anterior, i.e., prefrontal, contributions. This lends further support to existing and emerging models of scam susceptibility and financial exploitation that implicate more posterior right hemisphere mediated social capacity, social cognition (Lichtenberg 2016; Spreng et al. 2016), and knowledge-based contextual factors (James et al. 2014; Boyle et al. 2012b; Han et al. 2016c; Han et al. 2016b). Furthermore, convergence of results across studies (Spreng et al. 2017; Han et al. 2016c) is particularly notable given that distinct laboratories often quantify scam susceptibility differently, e.g., questionnaires regarding hypothetical situations versus self-reported experiences of exploitation. When taken together, the current and previous findings point toward similar empirical as well as theoretical conclusions.

This study has a number of strengths including a measure of scam susceptibility informed by research on victimized older adults implemented in a large community-based cohort free of dementia. Furthermore, by adjusting for key characteristics known to impact scam susceptibility including global cognitive functioning, we were able to determine the independent relationship that traditional metrics of white matter integrity had with scam susceptibility. We examined multiple DTI-derived metrics of white matter integrity although only associations between scam susceptibility and FA withstood final adjustment for global cognition. This suggests that scam susceptibility is linked to white matter tissue with significantly more isotropic diffusion but relatively unchanged mean diffusivity Future studies may further reveal the underlying white matter microstructural alterations driving our reported associations that DTI-derived measures cannot. This study has some limitations. While scam susceptibility does not necessarily equal victimization, endorsement of the behaviors included in the measure does suggest a level of heightened vulnerability in an already targeted older adult population. Furthermore, although our measure of scam susceptibility is relatively brief and has its limitations (e.g., 3 of 5 questions pertain to telephone-based interactions), it is important to note that the items were based on findings from the leading authorities on elder fraud, the AARP and FINRA, and specifically target behaviors and characteristics of older adults who have been victimized. Our study is crosssectional and participants were primarily older-old (in their 70s and 80s despite a wide difference between the minimum and maximum ages), non-Latino White, and highly educated; thus, longitudinal data collection is needed to determine the directionality of our results as well as additional psychometric properties of our measure of scam susceptibility including predictive and discriminant validity. More work is needed in a racially and ethnically diverse population. Additionally, our diffusion data is appropriate for DTI reconstruction but not HARDI, thus, we did not use tractography to investigate targeted analyses regarding white matter connectivity between regions of grey matter loss identified in previous research. Despite this, our TBSS results support emerging models of risk for financial exploitation built upon findings from several neuroimaging modalities. Despite these limitations, this study is the first to suggest a right hemisphere profile of white matter connectivity related to scam susceptibility in older adults that may assist in the identification of vulnerable individuals at risk of experiencing a range of exploitations and potential behavioral targets for possible remediation to protect against future victimization.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgements:

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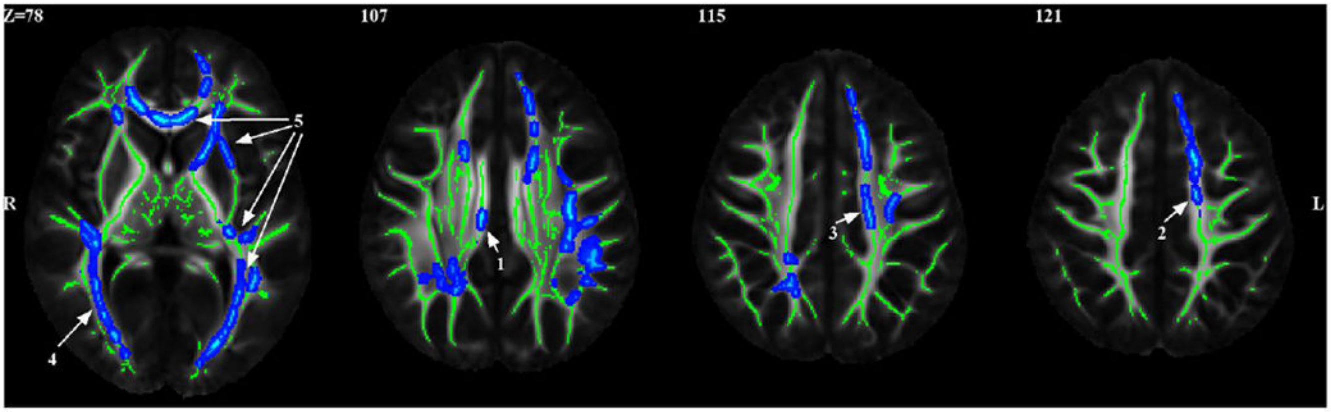
A



B

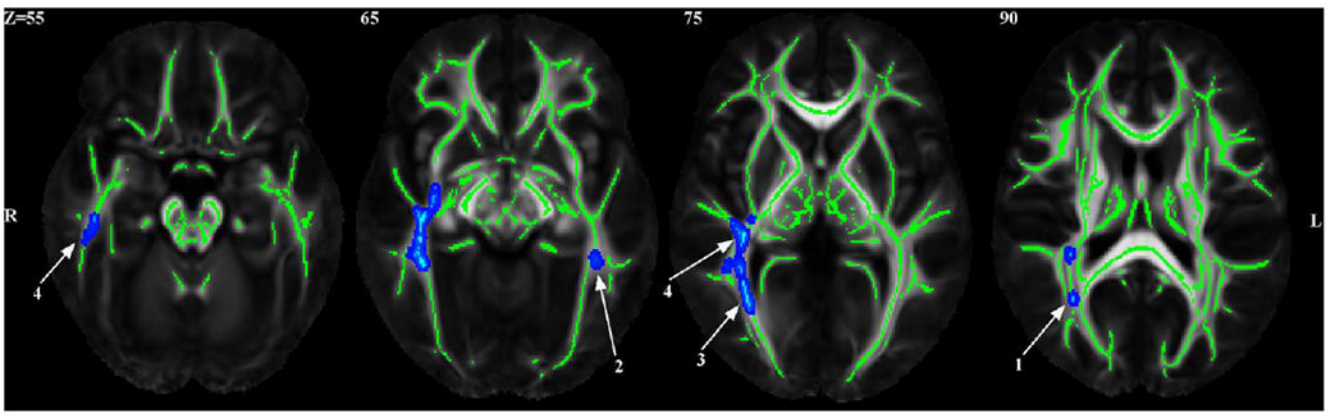


Figure 1.

Voxelwise results of fractional anisotropy negative associations with scam susceptibility scores in linear regression models adjusted for **(A)** age, sex, education, and white matter hyperintensities (volume and voxelwise); **(B)** age, sex, education, white matter hyperintensities (volume and voxelwise), and global cognitive functioning. Each cluster has been numbered, and a list of the most probable connections passing through each cluster is provided in Table 3 for *Figure 1A* and in Table 4 for *Figure 1B*.

Table 1.

Participant Characteristics, and Scam susceptibility

	Values[1]	Minimum - Maximum
Participant Characteristics		
Age (years)	81.37±7.54	58.81 – 99.70
Education (years)	15.76±2.90	8 – 25
Sex (female), n	75.73%, n=232	--
White Matter Hyperintensity (%)	0.29±0.26	−0.93 – 1.20
Global Cognitive Functioning	0.35±0.51	−1.22 – 1.62
Scam susceptibility		
Total Score	2.67±0.68	1.0 – 4.8

[1]Data indicates mean±standard deviation unless otherwise noted. White matter hyperintensity data represents the log 10 transformation.

Table 2.

Correlation[1] of Key Participant Characteristics and Scam susceptibility

	Scam Total Score
Age (years)	**0.31 (<0.0001)**
Education (years)	−0.10 (0.08)
White matter hyperintensity[2] (%)	0.01 (0.77)
Global Cognitive Functioning	**−0.31 (<0.0001)**

[1]Values are Pearson correlation coefficient (p-value) with significance set at p<0.05 and bolded.

[2]White matter hyperintensity data represents the log10 transformation.

Table 3.

List of most probable connections passing through the white matter clusters showing significant associations of fractional anisotropy (FA) with scam susceptibility adjusted for age, sex, education, and white matter hyperintensities (volume and voxelwise) as seen in Figure 1A.

Cluster #	Connection between[1]		Percent[2]
1	R posterior cingulate	R precuneus	27
	R caudal anterior cingulate	R precuneus	22
	R isthmus cingulate	R posterior cingulate	18
	R caudal anterior cingulate	R isthmus cingulate	14
	R caudal anterior cingulate	R posterior cingulate	11
2	L superior frontal	R precentral	31
	L superior frontal	R superior frontal	15
	L thalamus	L superior frontal	10
	L superior frontal	R paracentral	9
	L precentral	L superior frontal	8
	L putamen	L superior frontal	6
	L pallidum	L superior frontal	5
	L caudate	L superior frontal	4
3	L paracentral	R precentral	12
	L paracentral	R paracentral	11
	L thalamus	L paracentral	10
	L thalamus	L precentral	5
	L precentral	R paracentral	5
	L superior frontal	R precentral	5
	L precentral	R precentral	4
	L pallidum	L paracentral	4
	L putamen	L paracentral	3
	L paracentral	R posterior cingulate	3
4	R inferior parietal	R superior temporal	7
	R superior parietal	R superior temporal	5
	R lateral occipital	R superior temporal	4
	R pericalcarine	R superior temporal	3
5	L superior frontal	R superior frontal	3
	L pars opercularis	L superior frontal	2
	L rostral middle frontal	L superior frontal	2

[1] List derived from “regionstat” tool running on the IIT Human Brain Atlas (v4.1).

[2] The last column shows the probability that a fiber passing through a voxel of the cluster belongs to a certain connection. We restricted reporting to probabilities ≥3% with the exception of Cluster 5 given the limited number of connections reported.

Table 4.

List of most probable connections passing through the white matter clusters showing significant associations of fractional anisotropy (FA) with scam susceptibility adjusting for age, sex, education, white matter hyperintensities (volume and voxelwise), and global cognitive functioning as seen in Figure 1B.

Cluster #	Connection between[1]		Percent[2]
1	R inferior parietal	R superior temporal	30
	R superior parietal	R superior temporal	17
	R putamen	R inferior parietal	7
	R putamen	R superior parietal	4
	R interior parietal	R insula	3
	R thalamus	R inferior parietal	3
	R inferior parietal	R middle temporal	3
2	L lingual	L superior temporal	24
	L lingual	L middle temporal	12
	L lateral occipital	L superior temporal	8
	L lingual	L insula	7
	L pericalcarine	L superior temporal	6
	L lateral occipital	L middle temporal	4
	L fusiform	L superior temporal	3
3	R lateral occipital	R superior temporal	13
	R putamen	R lateral occipital	9
	R pericalcarine	R superior temporal	8
	R lateral occipital	R middle temporal	8
	R interior temporal	R lateral occipital	7
	R middle temporal	R pericalcarine	6
	R inferior temporal	R pericalcarine	5
	R hippocampus	R lateral occipital	4
	R putamen	R pericalcarine	3
4	R inferior temporal	R superior temporal	15
	R superior parietal	R superior temporal	11
	R lateral occipital	R superior temporal	6
	R pericalcarine	R superior temporal	5
	banks of the R superior temporal sulcus	R superior temporal	4
	R middle temporal	R pericalcarine	3

[1] List derived from “regionstat” tool running on the IIT Human Brain Atlas (v4.1).

[2] The last column shows the probability that a fiber passing through a voxel of the cluster belongs to a certain connection. We restricted reporting to probabilities ≥3%.