Age-Related Changes in Cerebral White Matter Integrity: Fiber Tracking from DTI

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INTRODUCTION

Previous research has established an age-related decline in cerebral white matter integrity, especially in anterior brain regions. Yet it is unknown whether specific fiber tracts contribute differentially to age-related white matter decline. In addition, decline in white matter integrity is a contributing factor to corollary declines in performance of cognitive and attentional tasks. We used diffusion tensor imaging (DTI) fiber tracking to investigate age-related differences in frontoparietal regions relevant to attention: the genu and splenium of the corpus callosum, and the superior longitudinal fasciculus (SLF). The primary dependent variable derived from the fiber tracking was fractional anisotropy (FA), a measure of white matter integrity. To examine the effect of tissue integrity on attention, the FA data were analyzed with behavioral data in a task switching experiment.

The goal of this study was to determine age-related decline of white matter integrity, and to identify the effect of FA decline in task switching performance. In addition to expected anterior FA decline, we also hypothesized age-related posterior losses pertinent to attentional demands that our previous studies have documented.

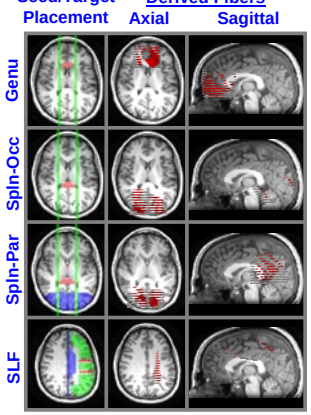
METHODS

Participants:

Twenty younger (20-28 years, *M* = 23.90 years) and twenty older (63-78 years, *M* = 69.58 years) neurologically intact adults participated in this experiment.

Diffusion Tensor Imaging & Fiber Tracking:

Magnetic resonance imaging was conducted at 3T with 52 contiguous near-axial slices parallel to the AC-PC, 2.4 mm thick; TR = 17000; per slice, diffusion measured in 15 directions (b = 1000 sec/mm^2) plus one image with no diffusion weighting (b = 0). Fibers were derived from non-normalized and non-smoothed DTI tensors on per-subject basis to preserve anatomical distinctions. Fibers were generated for three primary pathways: the genu and splenium pathways of the corpus callosum, and the SLF. The splenium was further subdivided into those fibers projecting to the parietal cortex and those into occipital cortex.

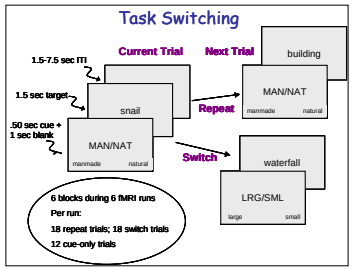


Software utilized:
ROI drawing: ITK_SNAP (www.itksnap.org)
Tensor creation: DTITrack2005 (wwwsop.inria.fr/asclepios/software/MedINRIA)
Tractography: FiberTrack 2.2.1 (www.ia.unc.edu/dev)
Fiber analyses: FiberViewer 1.2.3 (www.ia.unc.edu/dev)

Supported by NIA grants T32 000029, R01 AG011622

Lab website: http://www.geri.duke.edu/cogpsych/

BEHAVIORAL TASK



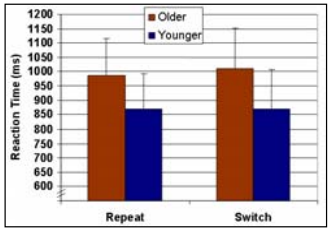
Task Instructions: Subjects indicated the category of the target word presented after a category cue.

Task Categories:
Man/Nat = Manmade or natural.
Lrg/Sml = Large or small.

Task Conditions:
Repetition: Current trial category same as previous trial category
Switch: Current trial category switches from previous trial category

Behavioral Task Results:

Significant main effects of group and condition, and an interaction of group x condition. For both conditions, younger adults were faster than older adults. Only older adults showed a significantly higher RT for switch trials than for repeat trials (22 ms; $p < .001$). Error rates were low (< 7%) and did not indicate a speed-accuracy trade off.

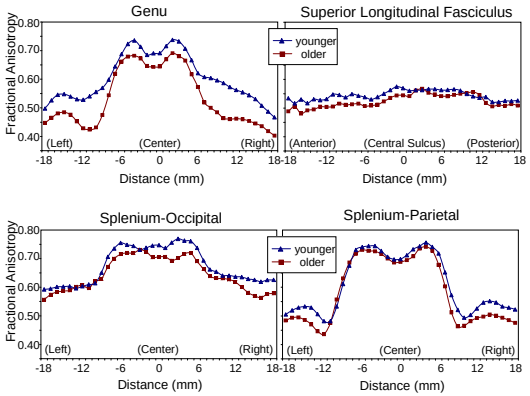


FIBER TRACKING ANALYSES

Mean FA values were derived at each 1 mm point from midline along the fiber bundle.

Corpus Callosum fiber bundles were subsequently binned for analyses:
» Central (-5 to +5 mm): genu or splenium proper.
» Left (-6 to -18 mm) and Right (+6 to +18 mm) cortical extensions.

SLF fiber bundles were derived in both left and right hemispheres, with anterior (0 to -18 mm) and posterior (0 to +18 mm) sections; 0 = central sulcus.



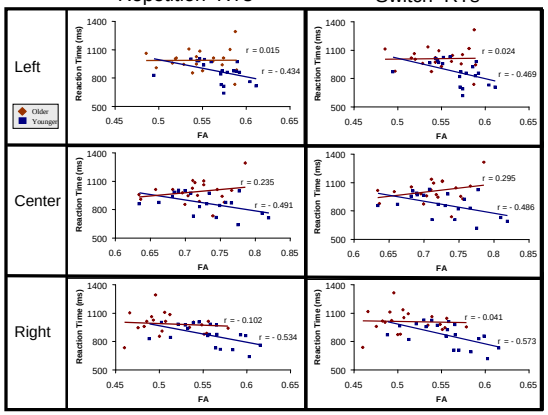
FIBER TRACKING RESULTS

ANOVA Results:
•Significant age group main effects for FA in genu, splenium-parietal, splenium-occipital and SLF
•Significant age group x region interactions for:

- Genu (left, center right): Older adults had significantly lower FA values than younger adults in the left, center and right portions of the genu. This overall reduction was most prominent in the periphery (left and right) cortical extensions of the genu fiber bundle.
- SLF (anterior, posterior): Older adults had significantly lower FA values than younger adults in the anterior portion of the SLF when averaged over left and right hemispheres.

RT & FA CORRELATIONS IN SPLENIUM–PARIETAL

Regression analyses examined the relation of mean FA (all 13 regions) and RT (both switch and repeat) in the task. There were no significant effects found with older adults. For younger adults, FA values in the splenium-parietal were significant predictors ($p < .05$) of reaction times in task switching.



The correlation between mean RT (on both switch and repeat trials) and FA in central splenium-parietal fibers differed significantly between the age groups ($p < .05$). A similar trend (though not significant) was evident in the left and right extensions of this tract.

In all cases, increasing FA was associated with faster responding for younger adults. Older adults did not exhibit a significant relation between RT and FA.

CONCLUSIONS

❖*Aging accompanies an overall lowering of white matter integrity:*
❖Older adults exhibited widespread decreases in FA in nearly all examined fiber bundles. The age-related decline in the genu was strongest in the cortical extensions of those fibers, and for the SLF was greatest in the anterior portion of that fiber bundle.

❖*The relation between white matter integrity and behavioral performance varies as a function of adult age.*
❖Younger adults exhibit an association between increased white matter integrity (FA) in central splenium-parietal fibers and increased response speed, whereas older adults do not.

❖*The effect of aging on the frontoparietal network is multifaceted:*
❖These results suggest a complex portrait of white matter losses accompanying aging along the frontoparietal network: While there are clear and well-known anterior declines, there are also age-related changes in posterior regions that are related to attentional task performance.