DTI of Choice Reaction Time Performance

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Introduction

- Humans exhibit significant interindividual variability in behavioral reaction time (RT) performance yet the underlying neural mechanisms for this variability remain largely unknown.
- It has been proposed that interindividual variability in RT performance may be due to differences in white matter (WM) physiological properties although such a relationship has never been demonstrated in young healthy adults.
- The present study sought to test whether diffusion fraction anisotropy (FA) is regionally correlated with RT on a visual self-paced choice RT (CRT) task in young healthy adults. CRT was found to be significantly correlated with FA in association and projection pathways supporting visuospatial attention including the right optic radiation, right posterior thalamus, and right medial precuneus WM.

Methods

Data acquisition Twelve young healthy participants (age: 23.2±1.6 years) were scanned on an 1.5 T Siemens Sonata MRI scanner (TR/TE=9000/68 ms, 2 mm isotropic, b=700 s/mm^2, 6 DWI + 1 T2, 8 averages). **Behavioral paradigm** Participants performed a self-paced, visual CRT task using a 4-key button response. Four empty boxes were presented on a computer monitor. One of the four boxes was pseudo-randomly filled in solid and the participant responded by pressing the corresponding button. The task was repeated in 6 blocks of 72 trials for a total of 432 trials. The mean RT for block 1 provides an index of native RT and the ΔRT between blocks 1 and 6 provides an index of motor learning. The CRT data were collected as part of a larger study of implicit learning.

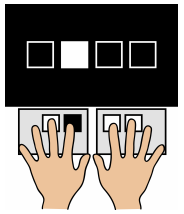


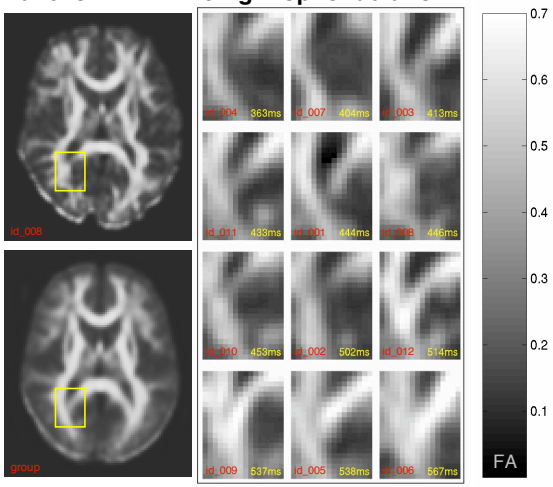
Illustration of CRT task

Analysis Each participant's FA volume was corrected for motion and eddy current distortion and then MNI-normalized using the FSL FLIRT registration tool [1]. The FA volumes were then smoothed using a 3D Gaussian kernel (6 mm FWHM, 6 mm extent). The correlation between CRT and FA (and between ΔCRT and FA) was calculated in atlas-space using non-parametric Spearman rank regression. Multiple comparisons correction was performed at the cluster level using the Monte Carlo permutation method with 10^4 trials [2]. Confirmatory ROI analysis was also performed using 10 manually defined ROIs.

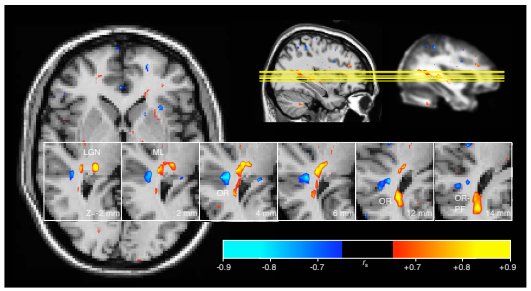
Results

Region	size [voxels]	peak r_s (p)	p_{corr}	x	y	z
CRT1						
Positive correlations						
Left temporal stem between the superior temporal sulcus and the hippocampal fissure	48	0.96 (0)	1.6×10^{-2}	-40	-23	-8
Left superior parietal lobule, rostral and superior to the parieto-occipital sulcus	26	0.97 (0)	ns	-15	-69	64
Right medial precuneus WM	73	0.96 (0)	6×10^{-3}	11	-64	34
Right posterior thalamus, Meyer's loop, and the anterior segment of the optic radiation	92	0.94 (0)	3×10^{-3}	22	-27	0
Right optic radiation at the intersection with the posterior forceps of the corpus callosum	41	0.90 (6.0×10^{-6})	2.4×10^{-2}	30	-60	13
negative correlations						
Left superior temporal sulcus WM	100	-0.94 (0)	2×10^{-3}	-54	-20	-2
Left parietal operculum / inferior posterior insula	31	-0.98 (0)	4.8×10^{-2}	-38	-12	-6
Left anterior insula	20	-0.89 (9.2×10^{-5})	ns	-32	13	-10
Left superior cerebellum	28	-0.93 (0)	ns	-17	-75	-17
Right precentral sulcus WM posterior to the inferior frontal gyrus	21	-0.95 (0)	ns	34	9	30
ΔCRT						
Positive correlations						
Left posterior thalamus	39	0.93 (0)	2.7×10^{-2}	-24	-27	-4
Right lateral precuneus WM	53	0.92 (0)	1.3×10^{-2}	16	-52	36
Right posterior thalamus	20	0.94 (0)	ns	24	-29	-2
Right parietio-occipital-temporal WM, at the junction between the arcuate fasciculus and the superior longitudinal fasciculus	24	0.90 (0)	ns	32	-66	17
negative correlations						
Left parietal operculum / inferior posterior insula	27	-0.88 (1.9×10^{-4})	ns	-36	-10	-2
Right superior cuneus WM	43	-0.94 (0)	2.2×10^{-2}	20	-75	30
Right superior temporal sulcus WM	35	-0.85 (9.7×10^{-4})	3.5×10^{-2}	42	-35	2

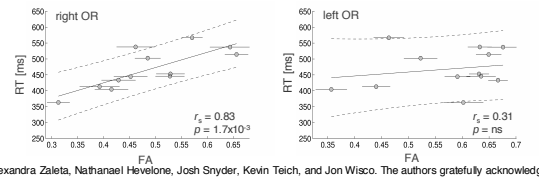
Individuals with fast choice reaction time have low FA in the right optic radiation



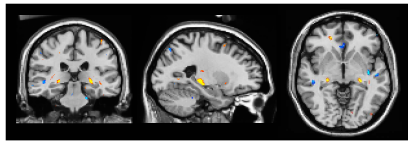
Choice reaction time performance correlates with FA in the right visual pathway

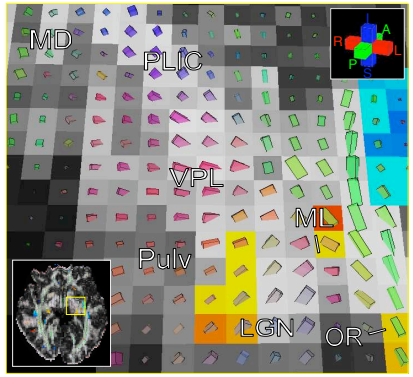


FA correlates with choice reaction time in the right but not the left optic radiation



Within-session improvement correlates with FA in posterior thalamus





Discussion

- CRT performance was significantly correlated (corrected p<0.05) with FA in right occipital, right parietal, and left temporal WM pathways. Within-session improvement in CRT was found to be significantly correlated (corrected p<0.05) with FA in left thalamus, right parietal, and right superior temporal WM.
- Right visual and right parietal cortices are specialized for visuospatial attention [3]. The pulvinar nucleus is a key node in the visuospatial attention network [4]. Superior temporal gyrus has been implicated in visual awareness [5] and voluntary control of visuospatial attention [6]. No significant correlations were observed in the posterior limb of the internal capsule or the corpus callosum for either experiment.
- These results indicate that native performance and within-session improvement in CRT are associated with variations in the WM supporting visuospatial attention as opposed to pathways supporting motor movement or interhemispheric transmission.
- Madden et al. [7] showed that RT performance on a visual oddball task is correlated with FA in the splenium of the corpus callosum. The present study showed that RT performance and FA are also correlated in the thalamus and projection and association pathways; the correlation can be lateralized; and the correlation also holds for within-session improvement.
- Candidate mechanisms for the observed CRT-FA correlation include myelination, axon caliber, ultrastructure, and membrane composition. Future work will investigate the physiological mechanisms for the correlation.

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