Brain structure and function predict different domains of cognitive control in normal aging

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Background

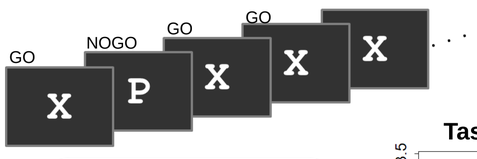
- Cognitive control refers to the flexible allocation of mental resources during goal-directed behavior and comprises three core factors: inhibition, shifting, and working memory[1,2]
- Normal aging is characterized by declines in cognitive control, which have been attributed to both structural and functional alterations in prefrontal and parietal cortices[3,4]
- Our goal was to examine both age and individual differences in the relationship between functional activity for each domain of cognitive control and fronto-parietal gray and white matter structure

Methods

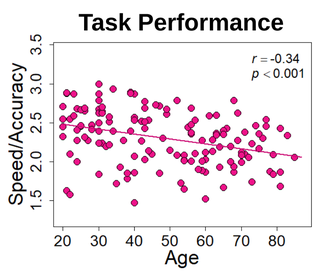
- N = 140 cognitively-normal adults, ages 20-86
- MRI session with: 3 fMRI tasks of cognitive control, T1-weighted imaging, and diffusion weighted imaging
- Partial Least Squares[5] used to examine contributions of age, task performance ,and brain structure to patterns of brain activity for each task (with age removed from performance and structure)

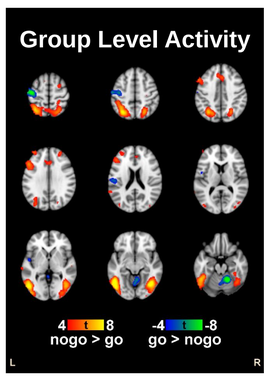
fMRI Measures

Inhibition: Go/NoGo

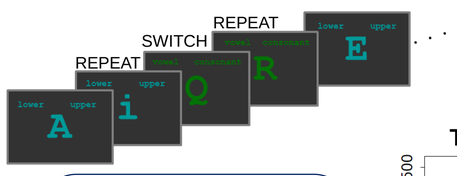


Task Design
- ~6 minutes
- 120 Go, 40 NoGo trials
- Task Performance: **acc NoGo / RT Go *100**
- fMRI Contrast: **NoGo > Go**

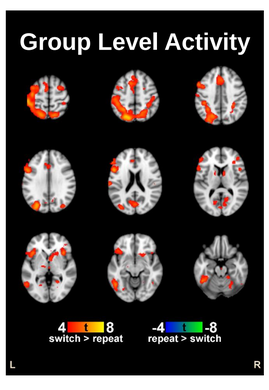




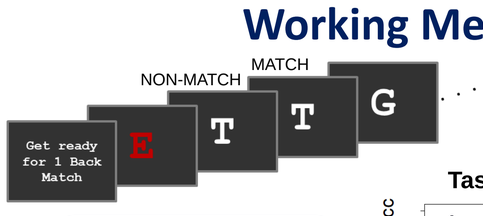
Shifting: Letter Judgment Task Switch



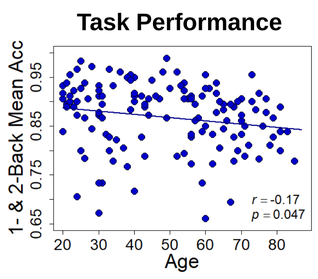
Task Design
- ~7 minutes
- 30 switch, 30 repeat trials
- Task Performance: **RT switch - RT repeat**
- fMRI Contrast: **switch > repeat**

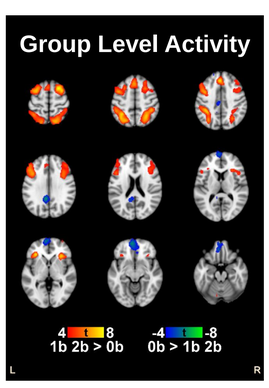


Working Memory: N-Back



Task Design
- ~9 minutes
- 0-, 1-, 2-back blocks
- Task Performance: **1 & 2-back mean acc**
- fMRI Contrast: **1b 2b > 0b**

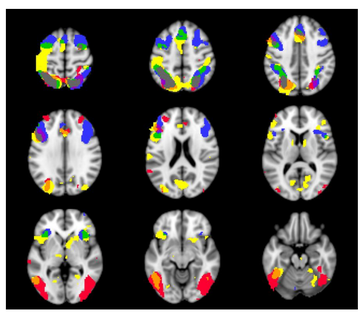




Cognitive Control Functional Activity

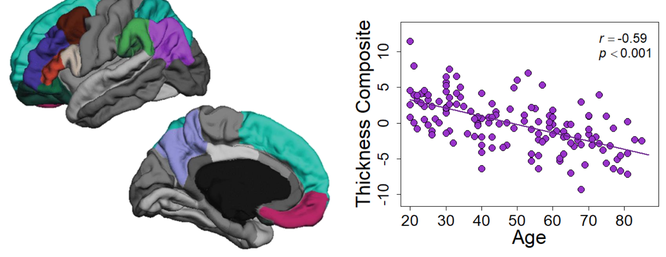
Unique Activity	Shared Activity
NoGo > Go (GNG)	GNG + TSW
Switch > Repeat (TSW)	TSW + NBK
1b 2b > 0b (NBK)	GNG + NBK
	All Three Tasks

All three tasks engaged a common set of fronto-parietal regions, plus a number of unique regions



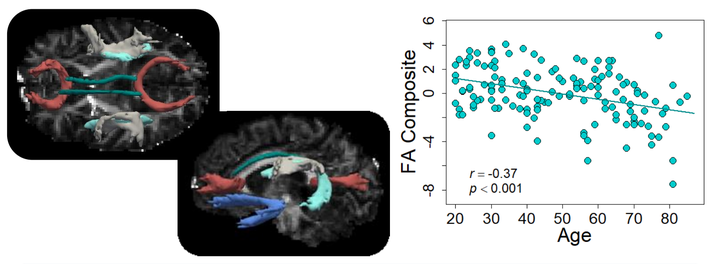
Structural Measures

Cortical Thickness



- FreeSurfer to parcellate subject-specific cortical structure[6]
- Principal Component Analysis of mean thickness of frontal and parietal parcels to generate thickness composite

White Matter Microstructure



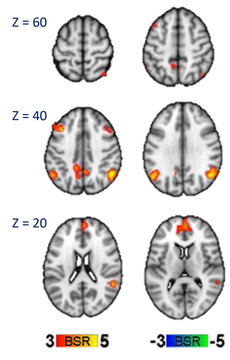
- TRACULA to identify subject-specific white matter pathways[7]
- Principal Component Analysis of mean fractional anisotropy (FA) of fronto-partial pathways to generate FA composite

Partial Least Squares Results

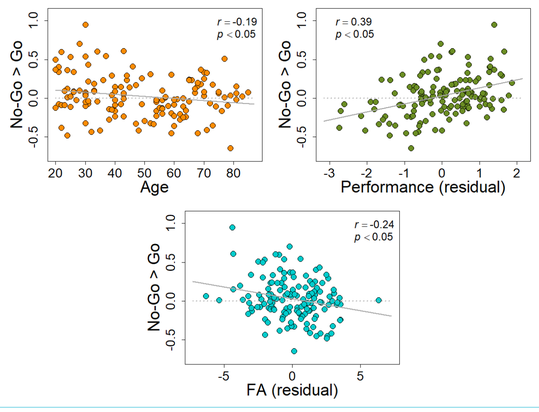
Inhibition: Go/NoGo

- Older age was characterized by overall decreased activity in default regions for NoGo trials and increased activity for Go trials
- After accounting for age, decreased activity for NoGo trials corresponded to greater fronto-parietal white matter FA (but did not correlate with FA in a control CST pathway)
- After accounting for age, decreased activity during Go trials was associated with faster speed-accuracy trade off

LV1: 35% covariance
p = .002



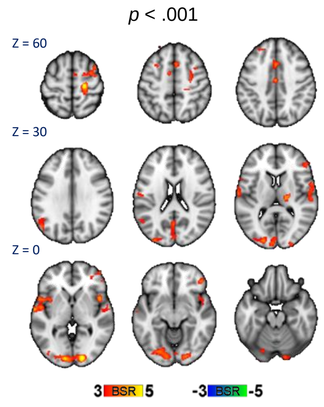
Multivariate Brain Pattern Correlations



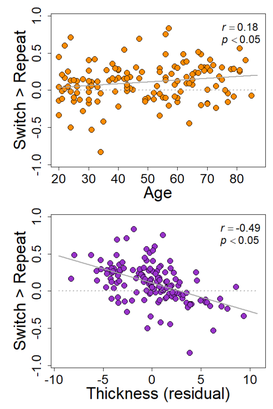
Shifting: Letter Judgment Task Switch

- During shifting, aging was associated with increased activity for switch trials in frontal, insula, and occipital regions
- After accounting for age, decreased activity in these regions corresponded to increased fronto-parietal cortical thickness (but did not correlate with thickness in a control pericalcarine region)

LV1: 46% covariance
p < .001



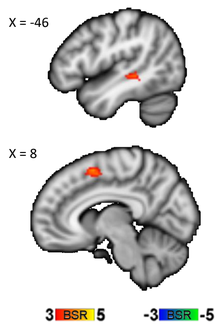
Multivariate Brain Pattern Correlations



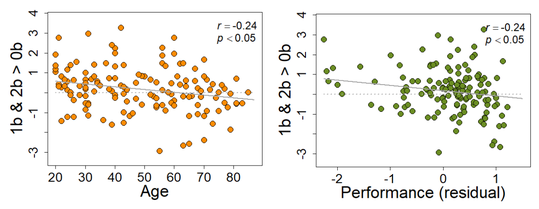
Working Memory: N-Back

- During 1- and 2-back, older adults showed decreased activity in left temporal and supp motor/middle cingulate
- After accounting for age, decreased activity in these regions supported better task performance
- Individual differences in fronto-parietal structural measures did not contribute to functional activity

LV1: 31% covariance
p = .017



Multivariate Brain Pattern Correlations



Discussion

- Inhibition, shifting, and working memory generally engage a common set of cognitive control regions in fronto-parietal cortex; however examining the contributions of age and brain structure to functional activity reveals unique relationships for each domain
- Shifting and inhibition showed greater contributions of individual differences in structure to overall decreases in brain activity (selective to fronto-parietal structure), suggesting that intact fronto-parietal gray and white matter microstructure allows for efficient use of functional resources[8]
- Working memory showed no contribution of structure to functional activity, but had the strongest age effect, suggesting that aging processes may have a stronger influence on the neural correlates of this domain than individual differences in structural integrity

[1] Miyake et al. (2000) *Cog Psych*
[2] Miyake & Friedman (2012) *Curr Dir Psych Sci*
[3] Raz & Rodrigue (2006) *Neurosci & Biobeh Rev*
[4] Spreng et al. (2010) *Neurosci & Biobeh Rev*
[5] McIntosh et al. (2004) *NeuroImage*
[6] Fischl et al. 2004 *Cereb Cortex*
[7] Yendiki et al. (2011) *Front Neuroinform*
[8] Burzynska et al. (2013) *J Neurosci*

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