# Cortical thickness is linked to executive functioning in adulthood and aging.

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**Introduction:** Normal aging is accompanied by a decline in executive functioning (Bäckman et al. 2000) and reduction in cortical thickness (Salat et al. 2004). The relationship between age-related structural alterations and executive functioning is, however, not well understood. In healthy adults, performing the Wisconsin Card Sorting Test (WCST), a standard neuropsychological index of executive functioning results in increased brain activity within a distributed fronto-parietal network, with the most consistent activations in the right prefrontal cortex (Buchsbaum et al. 2005; Nyhus and Barcelo 2009). In light of these previous results from functional neuroimaging studies, the goal of this study was to characterize the relationship between behavior and cortical thickness of brain regions associated with WCST performance.

**Methods:** 129 neurologically healthy adults (73 younger: 40 men, M = 25.6 ± 3.1years; 56 older: 29 men, M = 64.8 ± 2.6 years) participated in the study. Executive functions were measured using a computer version of the standard 128-cards WCST. Cortical thickness was assessed at each location of the cortical mantle using surface-based segmentation procedures (Freesurfer software, version 4.4 (http://surfer.nmr.mgh.harvard.edu/)) on high-resolution T1-weighted images (3D gradient-echo T1-weighted FLASH sequence: TR = 20 ms; TE = 5 ms; FA = 30°; matrix = 256 x 256; FOV = 256; 180 slices; resolution = 1x1x1 mm on a 1.5 Tesla MR Siemens Magnetom Vision scanner with a conventional head coil). Correlation between executive functioning (% of correct responses) and cortical thickness was computed at each vertex (measurement point at the cortical mantle), statistically controlling for age. Region-of-interest (ROI) analysis was used to illustrate characteristics of the correlations in the largest regions. Statistical analysis was performed using SPSS (v.16, SPSS Inc., Chicago, IL, USA).

**Results:** Older adults performed less accurately on WCST than younger adults ($M_{younger}$ = 80.7% ± 6.9, $M_{older}$ = 62.2% ± 15.0 $p < 0.001$). Better executive performance was associated with thicker cortical mantle in the frontal and parietal cortices (Fig. 1-A).

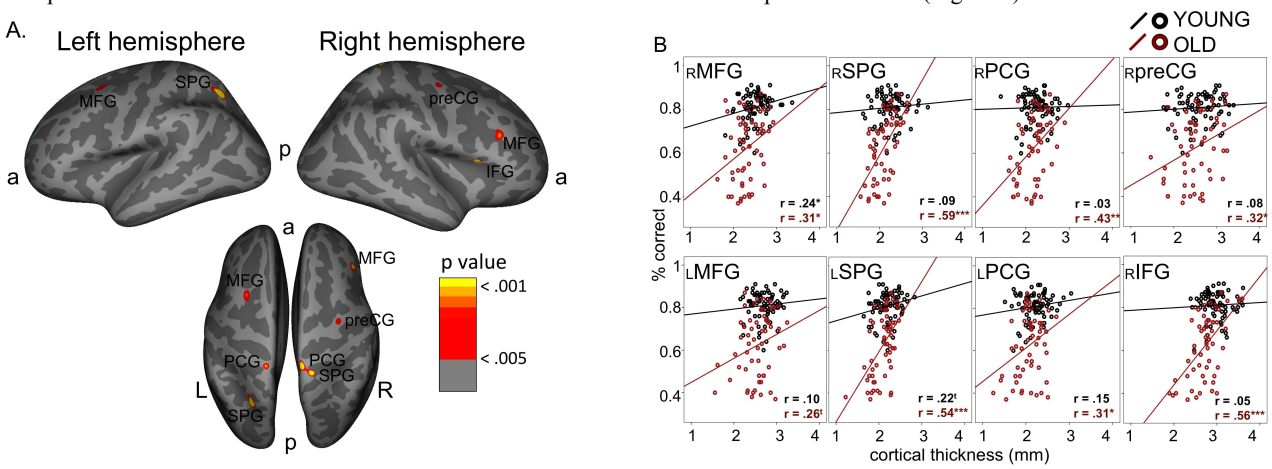


**Fig. 1**. Relationship between executive performance and cortical thickness. A: Thicker cortical mantle was associated with better performance (red-yellow) on WCST for younger and older adults (controlled for age). B: Mean cortical thickness from regions in A regressed on WCST accuracy. x-axis: cortical thickness in mm, y-axis: WCST accuracy (% correct responses). r: Pearson's correlation coefficients, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, $^t$ : trend ($0.07 > p > 0.05$). MFG: middle frontal gyrus, IFG: inferior frontal gyrus, SPG: superior parietal gyrus, preCG: precentral gyrus, PCG: post-central gyrus. a: anterior, p: posterior, L: left, R: right.

In most of the ROIs (left SPG, right SPG, IFG, PCG, preCG) there was a stronger positive correlation between executive performance and cortical thickness in older than in younger adults (Fisher's z-score p-values < 0.05, Fig.1-B). In the left MFG, PCG, and right MFG the correlation did not differ significantly between older and younger adults, and only in the right MFG the correlation was significant in both younger and older adults.

Next, we split older adults into low (n = 21) and high performers (n= 20) on WCST. Old low, but not old high, performers had lower WCST accuracy than younger adults ($p < 0.001$ and $p = 0.1$, respectively). In all regions from Fig.1-B the old high performers did not differ in their cortical thickness from that of the younger adults, but old low performers had significantly thinner cortex than the other two groups.

**Discussion:**
We showed that cortical structural underpinnings largely overlap with previously defined functional patterns for WCST and the structure-performance relationship was stronger in later than in earlier adulthood. In addition, our data suggest that the extent of structural preservation of regions involved in performing a task in old age differentiates between high and low performing individuals, underscoring the need of taking performance level into account when studying changes in brain structure from early to late adulthood (cf. Nagel et al., 2009).