Neural Network Decorrelation for Healthy Brain Aging: A Cross-sectional and Longitudinal MEG study

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Introduction

Neural network decorrelation is fundamental to information processing. Specifically,ensemble freedom is constrained by correlations among network elements: a network with least correlated elements provides maximum independence (i.e., zero mutual information) and hence entails maximum possibilities for encoding information.

We have previously demonstrated that neural decorrelation, primarily involving temporal regions, distinguishes healthy veterans from those with psychiatric disorders, and have hypothesized that network decorrelation underlies healthy brain functioning by permitting neural flexibility (James et al., JAMA Psychiatry 70: 410-418). In the present study (http://healthybrain.umn.edu/), we tested the hypothesis that in cognitively healthy individuals, decorrelation would increase with age, serving as a mechanism that promotes efficient information processing and neural flexibility to maintain healthy brain functioning across the lifespan.

Materials & Methods

Participants

We studied 171 cognitively healthy (MoCA score > 25) individuals (155 women, 16 men). Age ranged from 28-98y (mean 61y, SD 16y).

Data acquisition

Participants underwent a 1-min resting-state magnetoencephalographic (MEG) scan (248 axial gradiometers, BTi Magnes 3600W, sampled at 1.017 kHz); Georgopoulos et al. J Neural Engineer 4: 349-355, 2007).

Data analysis

We computed all pairwise crosscorrelations (CC; -50 to +50 lags, 0.974 ms/lag) between prewhitened MEG sensor time-series (Georgopoulos et al. J Neural Engineer 4: 349-355, 2007) and regressed them against age (in months) to assess neural network functional connectivity across ages and lags. For statistical analyses, CCs were z-transformed, z = atanh(CC), to normalize their distribution. Then, the following linear regression model was fit:

$$\mathbf{z = a + b(Age)}$$

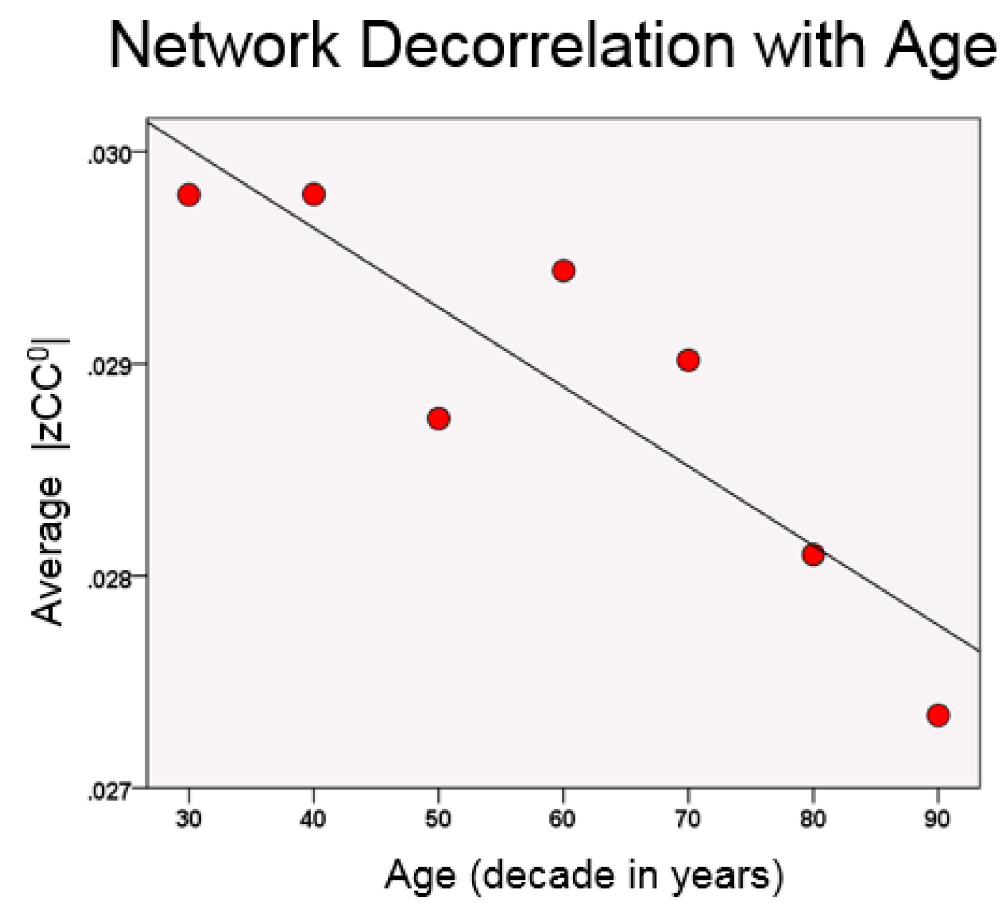
The sign of coefficient **b** indicates the direction of neural correlation change with age, a negative sign meaning **decorrelation.**

Results

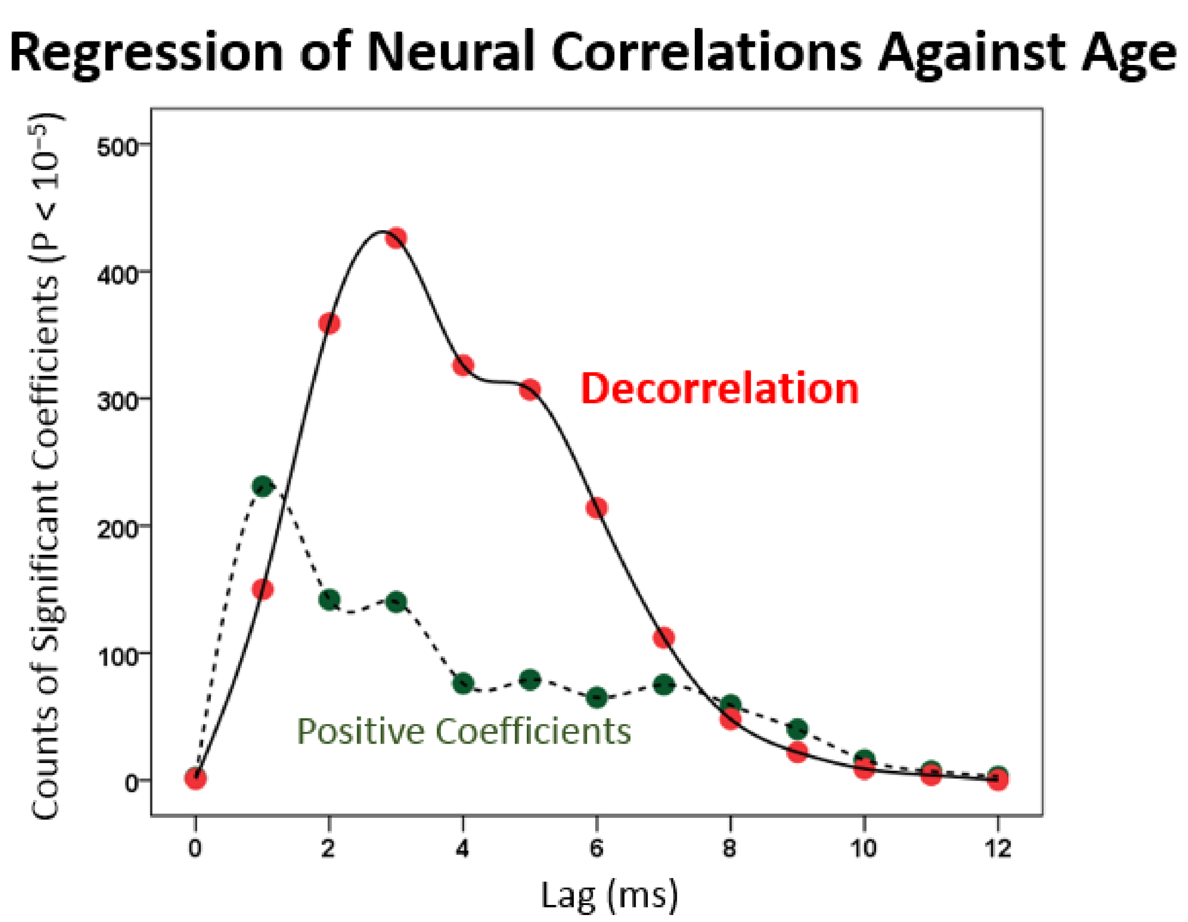
Cross-sectional studies

We found the following.

(1) **Overall**, the strength of zero-lag correlation decreased with age, i.e. the brain network became decorrelated.

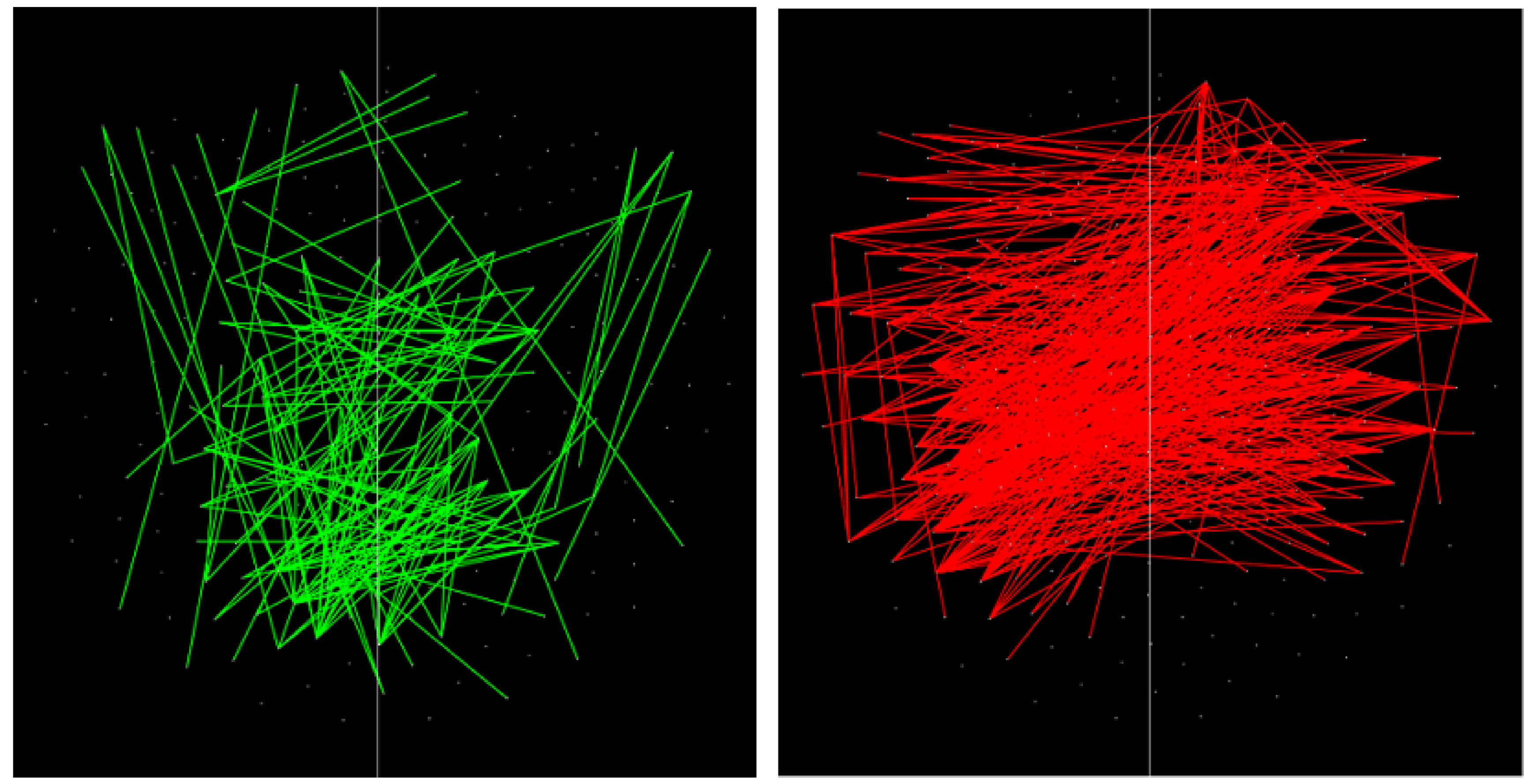


(2) With respect to effects for **individual sensor pairs**, negative regression coefficients (decorrelation) outnumbered positive ones, and depended on the lag.



(3) The **regional distribution** of significant coefficients differed for positive and negative (decorrelation) :

- Positive: posterior/central
- Negative (decorrelations): Wide range and temporal.



Lag: 3 ms

Longitudinal Studies

Preliminary analyses indicate similar lag-dependent decorrelation with age. These analyses are ongoing.

Conclusions

As expected, results suggested that among cognitively healthy individuals, decorrelation increased with age both cross-sectionally and longitudinally, and involved primarily the temporal lobes, within and across hemispheres. Furthermore, the amount and location of decorrelation varied across lags, providing robust real-time evidence of the active neural processes involved in decorrelation. **These findings support our hypothesis above that neural network decorrelation underlies healthy brain functioning by maintaining adequate capacity of the networks for information processing.**