1/*f* noise is related to age, but not short-term memory or sensorimotor reaction time.

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Abstract

Recent evidence points towards an increase in 1/*f* neural noise (noise with decreasing power in higher frequency bands) with age. Previous evidence related this increase to a decrease in working memory performance. Here, we attempted to replicate previous findings with data from the Cam-CAN project. We used two minutes of a resting-state recording to estimate the power-spectral density of neural activity. We then correlated the β of a regression of noise on frequency with age, sensorimotor reaction times, and short-term memory performance. We reproduced previously demonstrated increases in 1/*f* noise with age, but although 1/*f* noise mediated a relationship between age and working memory, it did not independently predict working memory performance. These results indicate that 1/*f* noise is a result of ageing, but that may contribute little to cognitive effects of ageing.

Keywords: MEG; noise; ageing

Introduction

One feature of the power spectrum of human brain activity obtained through electrophysiological imaging is a decrease in power with increasing frequency. This relationship between power and the inverse of frequency (often described as 1/*f*, or pink, noise) has recently been linked to ageing (Voytek et al. 2015). Voytek and colleagues found that the linear relationship between frequency and noise was steeper in younger individuals, with less electrophysiological noise in high frequency bands. They were able to show this relationship using both intracranial electrocorticography (ECoG) and electroencephalography (EEG). Voytek and colleagues also demonstrated a relationship between the levels of 1/*f* noise and visual working memory, and that 1/*f* noise mediates impairments of visual working memory in ageing.

Here, we wanted to reproduce the finding and test its central hypoethis of a relationship between in a public dataset: the Cambridge Center for Ageing and Neuroscience data repository (Cam-CAN, Taylor et al. 2017). We therefore tried to replicate the finding of 1/*f* noise increasing in age, as well as the relationship between 1/*f* noise and working memory performance.

Methods

The Cam-CAN data includes one 8m40s resting-state and one 8m40s sensorimotor task MEG recordings for 647 participants. Resting-state recordings were conducted with eyes closed, and the sensorimotor task required button response to bilateral sine grating and concurrent audio tone presentation. Participants also completed behavioural tasks outside the MEG scanner. Here, we analysed a visual short term memory (VSTM) task: matching a sequence of hues, storing 1 to 4 hues in short-term memory.

MEG recording methods are fully described in Taylor et al. (2017). Out of 647, we analysed 643 resting-state and 606 task recordings. This subset of subjects had an average age of 54.5 years (st.dev.: 18.3, range: 18-88).

All data analysis was performed using `MNE-python` (Gramfort et al. 2014). We chose a random two-minute segment from the full recording. We performed temporal space-signal separation [tSSS, Taulu, Simola, and Kajola (2005), correlation threshold 0.98; 10s sliding window], followed by ICA decomposition and removal of ICA components based on the highest correlation with the HEOG, VEOG and ECG channels. We then computed the log of the power-spectrum from 2 Hz to 7 Hz and from 14 Hz to 24 Hz, avoiding the alpha range, using Welch's method (2s sliding window, 50% overlap). We calculated a linear regression of this semi-log data for each gradiometer for each individual and removed any sensors for which the intercept of this linear regression was two standard-deviations above or below the average for an individual was removed.

Results

The relationship between 1/*f* noise slope and age replicated both during rest ($r(641) = .32$, $p < .001$) and task (Figure 1, $r(604) = .31$, $p < .001$). The 1/*f* slope during the two recordings predicted each other, although 1/*f* noise fell more steeply during task (Figure 2, $r(602) = .79$, $p < .001$). We also found a strong relationship between the 1/*f* noise slope during resting state and task (Figure 2, $r(602) = .79$, $p < .001$).

There was no evidence for a relationship between 1/*f* noise and VSTM ($r(604) = -.03$, $p = .435$) or sensorimotor reaction time ($r(599) = -.01$, $p = .783$). However, in a mediation analysis with age as predictor and 1/*f* slope as mediator, we found that 1/*f* noise partially mediated a strong relationship between age and VSTM (total effect: $b = -0.00196$, $p < 0.001$; indirect effect: $b = 0.000158$, $p = 0.013$)

We also analysed the relationship between 1/*f* noise and age at each sensor for each recording (Figure 3). We found differences between the two recordings in two clusters (Figure 4).

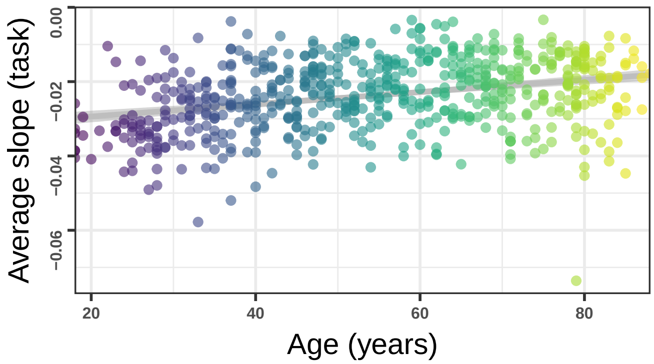

Figure 1: *Relationship between 1/f noise during a sensorimotor task and age.*

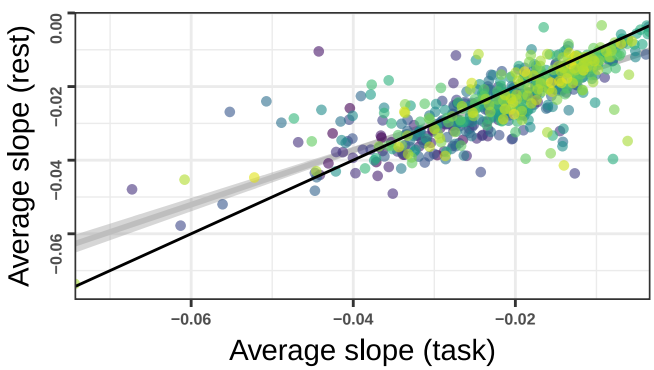

Figure 2: *Relationship between 1/f slope during task and rest.*

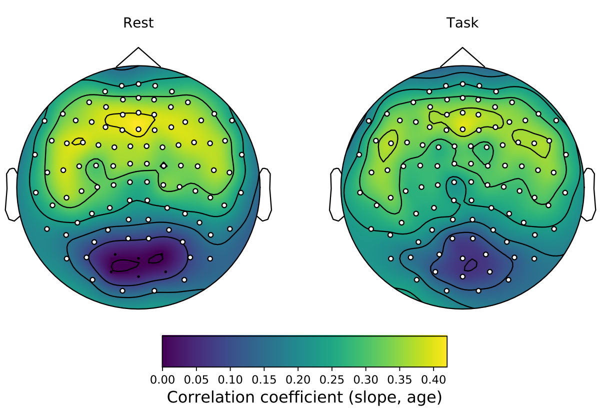

Figure 3: *Correlation coefficients between age and 1/f noise for each sensor. Sensors for which this relationship was sigificant at cluster-corrected alpha level 0.05 are indicated by white circles.*

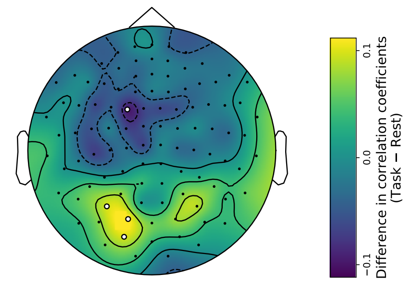

Figure 4: *The difference between the correlation of 1/f noise and age at each sensor. Sensors for which bootstrapped estimates of this difference were significant are highlighted.*

Conclusions

This analysis replicates reports of increased 1/*f* noise with age. We were unable to replicate a correlation between 1/*f* noise with VSTM, and also found no relationship between 1/*f* noise and sensorimotor reaction times. The difference between this and previous reports may stem from the fact that the MEG recordings took place separately to the VSTM task. Physiological noise occurring during the memory task would likely affect performance on that task more strongly. We believe that this analysis significantly adds to our understanding of how 1/*f* noise in old age affects cognitive performance.

References

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