Classical music enhances the local functional connectivity density in the brain

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INTRODUCTION: The distribution of functional connectivity hubs in the brain may vary across different resting conditions. This hypothesis, however, has not been tested. Here we used magnetic resonance imaging (MRI) and functional connectivity density mapping (FCDM)[1] to map hubs with high local functional connectivity density (*l*FCD; i.e. the number of functional connections per voxel) in 70 healthy men (18-55 years old). Two resting conditions were tested: 1) when the subjects rested with their eyes open (baseline condition), and 2) they were tested while listening to classical music (music condition). Our working hypothesis was that music would increase the *l*FCD and that these increases would correlate across subjects with music "liking" scores, which were collected for 28 of the participants.

METHODS: Functional MRI data with blood oxygenation level dependent (BOLD) contrast were acquired in a 4-Tesla Varian/Siemens scanner using a T2*-weighted single-shot gradient-echo planar imaging sequence (TE/TR = 20/1600 ms, 3.1 mm in-plane resolution, time points = 195) with minimal acoustic noise[2]. Earplugs (28 dB attenuation of sound pressure level) and headphones (30 dB attenuation of sound pressure level) were used to minimize the interference effect of scanner noise during fMRI. During baseline subjects rested with their eyes open. The Death of Aase (Peer Gynt; Suite No.1, Op.46 – 2; Berliner Philharmoniker; 1988) by Edvard Grieg was delivered through MRI compatible headphones to the subjects' ears during the resting scan with music. Immediately after the scan, the subjects rated how much they liked the music (from 0 to10). The fMRI time series were motion-corrected, realigned, spatially normalized and smoothed (8-mm) using SPM2. 3-mm isotropic maps, reflecting the *l*FCD in the brain, were computed for each condition and subject using IDL after removal of signal fluctuations associated with subject's motion (multi regressions with the six realignment parameter) and physiologic noise (0.01~0.1 Hz band-pass filtering)[1].

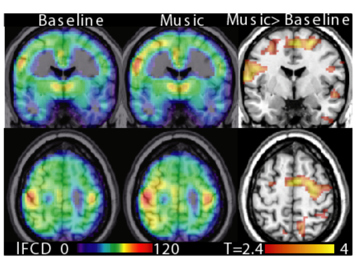

Fig1: Mid sagital and coronal views of the *l*FCD for baseline (left) and music (middle) and the statistical map showing the difference (right)

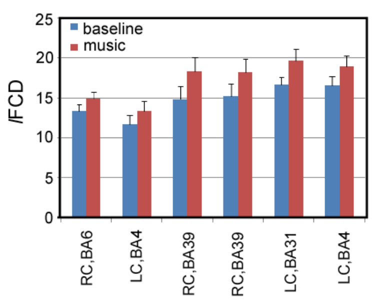

Fig 2: Bar plot showing music-related increases in *l*FCD in selected ROIs (RC/LC = right /left cerebrum)

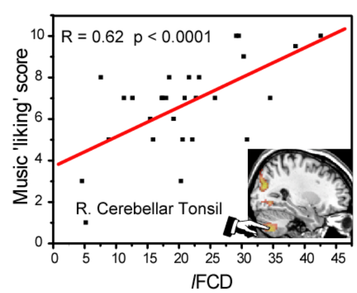

Fig 3: Combined figure showing the correlation between music "liking" scores and *l*FCD in cerebellum

Paired t-tests and simple regression analyses were used to evaluate music-related changes in *l*FCD using SPM2.

RESULTS: Fig 1 shows that compared to the baseline condition, classical music enhanced the strength of the *l*FCD bilaterially in prefrontal (BA 4 and 6) and parietal (31 and 39) brain regions ($P_{corr} < 0.0001$, corrected for multiple comparisons; paired t-test); no brain region exhibited lower *l*FCD for the music than for the baseline condition. The music-related percentage enhancement of *l*FCD in each ROI was ranged from 10 to 18% in these 6 ROIs. Regression analyses across subjects showed that the music "liking" scores had positive correlation with the strength of the *l*FCD in temporal (BA 22 and 38) and occipital (BA 18 and 19) cortices, caudate, pons, and the posterior lobe of the right cerebellum ($P_{corr} < 0.0001$; Fig 3).

DISCUSSION: These findings suggest that in resting conditions, music can increase the local functional connectivity of the brain. These findings are consistent with the involvement of brain regions in processing rhythm (dorsolateral prefrontal and parietal cortices and cerebellum), tonality (temporal and medial prefrontal cortices) and emotions (limbic cortex).

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2. Tomasi, D. & Ernst, T. Echo Planar Imaging at 4Tesla with Minimum Acoustic Noise. *JMRI* **18**, 128–130 (2003).