Structural MRI measures can be affected by brain activity during image acquisition

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Target audience

Neurologists, neuroradiologists, researchers using functional imaging

Purpose

Structural brain images acquired by MRI are frequently used to measure morphological aspects of brain anatomy and their changes. Based on such images a large body of research has reported variations in grey and white matter associated with e.g. psychiatric disorders, behavioural interventions or habitual tendencies. Here we test the underlying assumption that such structural images are not affected by concurrent brain function.

Methods

The following protocols were run on two Siemens 3-T-scanners with equal 12-channel head coils: i) T1-weighted gradient echo imaging (MPRAGE, TR/TE/TI = 2300/3.03/900 ms, voxel size = 1 × 1 × 1 mm3, GRAPPA acceleration factor r = 2); ii) T1-weighted spin echo imaging (TIRM, TR/TE/TI = 1560/9.2/692.8 ms, voxel size = 1.2 × 1 × 1 mm3, r = 3, 3 averages); iii) resting-state fMRI (EPI, TR/TE= 2000/30 ms, voxel size 3 × 3 × 3 mm3, matrix = 72 × 72, 36 axial slices); iv) DTI (single-shot diffusion-weighted spin-echo-refocused EPI, TR/TE = 8000/93 ms, voxel size = 2 × 2 × 2 mm3, matrix = 112 × 112, 62 slices, b = 1000 s/mm2, r = 2, 60 non-collinear gradient orientations). A total of 48 healthy subjects (mean age 27.8 y, range 19–42 y, 17 f) participated. MPRAGE images were acquired from all subjects, TIRM images from a randomly selected subset of 17, resting state fMRI and DTI from a second, non-overlapping subset of 18 subjects.

All anatomical, fMRI, and DTI images were acquired twice per subject, with their eyes once open and once closed (randomized order, counterbalanced), and analyzed for morphometric and resting-state map differences. Voxel-based morphometry (VBM) and fMRI analyses were carried out using SPM[1].

Results

For images acquired using MPRAGE, VBM indicated larger grey matter (GM) volume of the bilateral primary visual cortex for the eyes open (EO) compared to the eyes closed (EC) condition (Fig. 1). Regions with reliable VBM differences overlapped with regions showing a difference in the amplitude of low frequency fluctuation (ALFF) resting-state maps for EO vs. EC. Comparison of GM volume probabilities in the primary visual cortex region identified from these analyses with respect to EO and EC condition yielded a significant difference for the MPRAGE (0.214 ± 0.006 vs. 0.199 ± 0.007, $p < 0.01$), but not for the TIRM images (0.189 ± 0.009 vs. 0.190 ± 0.008, $p = 0.563$). A 2 x 2 ANOVA showed a significant interaction of the factor Sequence (MPRAGE vs. TIRM) with Condition (EO vs. EC) ($p < 0.01$, Fig. 2). For this cohort of 17, whole brain analysis on the MPRAGE images resulted in higher GM volume in the left visual cortex (-10, -102, -3) for EO compared to EC but no significant effects for the TIRM images. This is in contrast to fractional anisotropy and mean diffusivity maps resulting from DTI which did not show any differences between EO and EC.

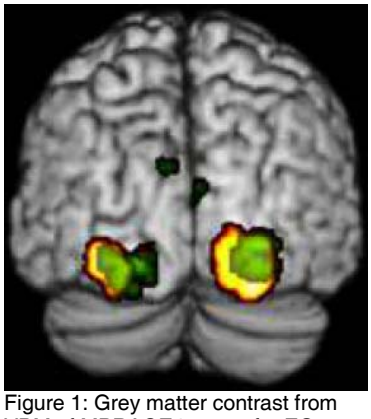

Figure 1: Grey matter contrast from VBM of MPRAGE images for EO vs. EC ($p < 0.001$, yellow) and contrast of ALFF resting-state maps for EO vs. EC ($p < 0.001$, green).

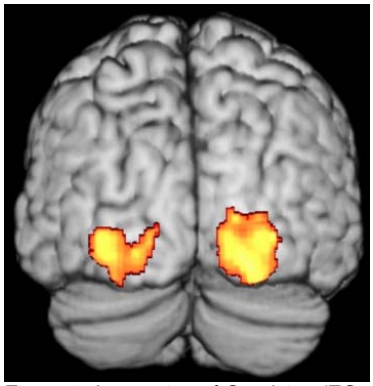

Figure 2: Interaction of Condition (EO vs. EC) and Sequence (MPRAGE vs. TIRM) in bilateral visual cortex (ANOVA, n = 17).

Discussion

The apparent GM volume differences between EO and EC could be explained by different cell swelling[2] or blood flow during the two conditions. The former is less likely as it should have affected the DTI data as well[3]. The apparent morphometric effects on images acquired using MPRAGE, however, may be caused by its slight but non-negligible sensitivity to T2* and thus blood flow, blood volume and magnetic susceptibility[4]. This is supported by the finding that images measured with a pure spin-echo-based sequence, TIRM, do not exhibit such functional effects. However, for further clarification our finding needs more quantitative evaluation.

Conclusion

We recommend that data acquisition for volumetric assessments should be performed under standardized conditions, i.e. with eyes closed, without concurrent administration of a cognitive task, and, ideally, without being sensitive to functional contrast.

References

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