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Imaging the functional and structural language network – lessons learned from preoperative fMRI

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Objective

The structural and functional neuronal networks underlying atypical language lateralization (ALL) in epilepsy patients are largely unknown. ALL comprises right-lateralized, bi-lateralized and crossed-lateralized functional cortical language representations. This study aimed to identify functional and structural connectivity differences between temporal lobe epilepsy (TLE) patients with ALL and TLE patients with lefthemispherical language lateralization (LLL) in order to test the hypothesis that TLE similarly affects typical and atypical language networks ipsilateral to the seizure onset zone.

Methods

The lateralization indices of 50 TLE patients, who underwent 1.5 or 3 Tesla BOLD fMRI for preoperative language evaluation, were calculated for the frontal and temporal lobes separately using the bootstrap method, implemented in the LI-toolbox which runs with SPM12. A total of 22 TLE patients with ALL (rTLE: n=9, 4 lesional; ITLE: n=12, 4 lesional) and 28 TLE patients with LLL (rTLE: n=13, 6 lesional; ITLE: n=16, 7 lesional) were identified and included in this study. The fMRI pattern analysis was performed using SPM12. The CONN-toolbox was used for the functional connectome analysis (FCA). The structural connectome analysis (SCA) was performed with MRtrix3, based on a single-shell DTI sequence.

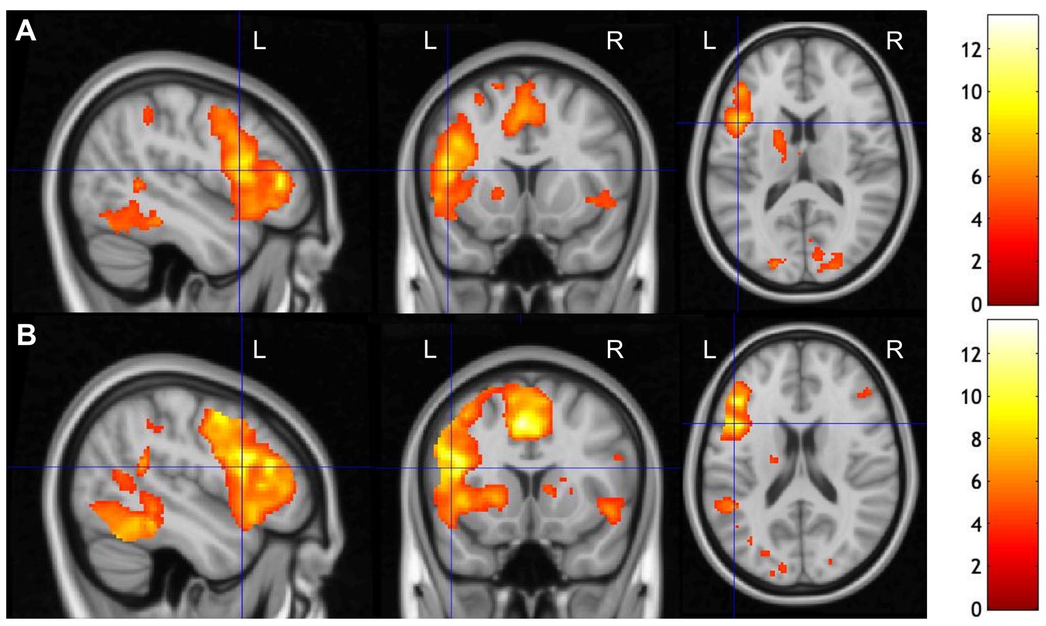

Figure 1

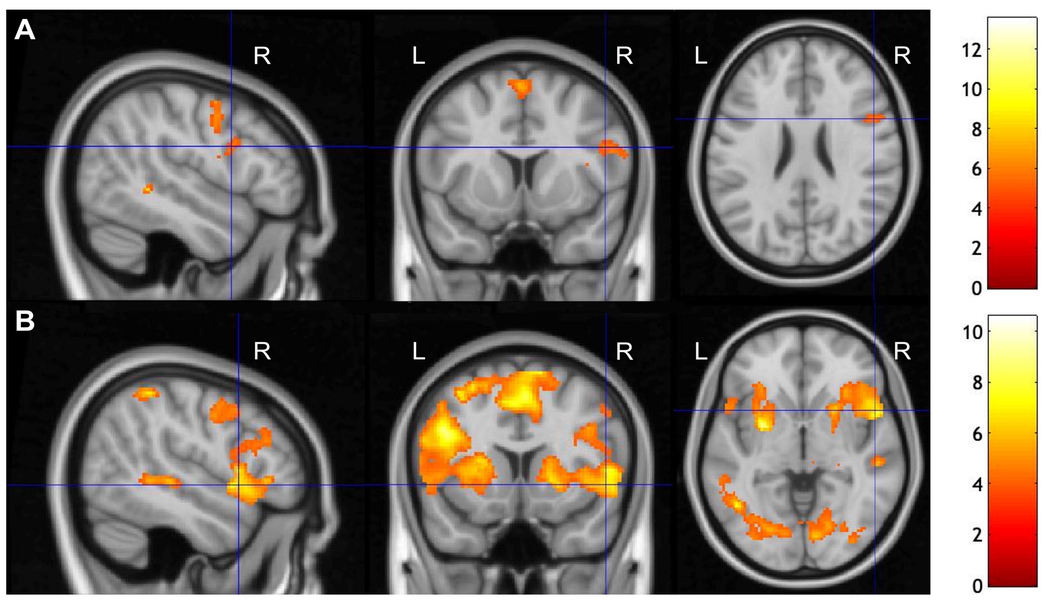

Figure 2

Results

rTLE patients with ALL showed a sparse AP and weak functional language network. In contrast there were strong but more variable individual activations in the same group that may explain sparse activations by reduction in AP overlap (figure 1).
The functional connectome analysis showed significantly ($p_{FDR\text{-}corrected} < 0.05$) more extensive intrahemispherical connectivity between Broca and Wernicke area in the left hemisphere in patients with LLL.
The structural connectome analysis showed a lateralisation of the structural connectivity of the inferior frontal gyrus to right hemisphere (mean laterality index: -0.04) in patients with ALL. In other words: The structural language network is more extensive in the right hemisphere in atypically lateralized patients (figure 5). In patients with LLL the structural connectivity lateralized to left hemisphere (mean laterality index: 0.03). There was a significant difference between ALL and LLL (two-tailed test: p-value:<0.001).

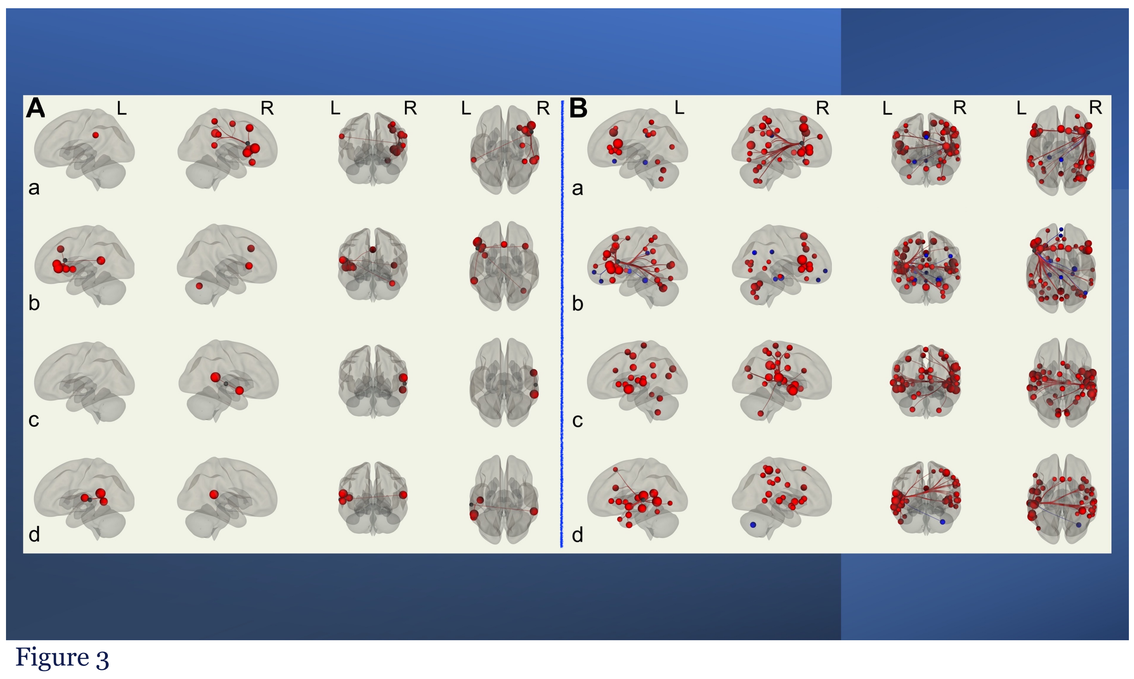

Figure 3

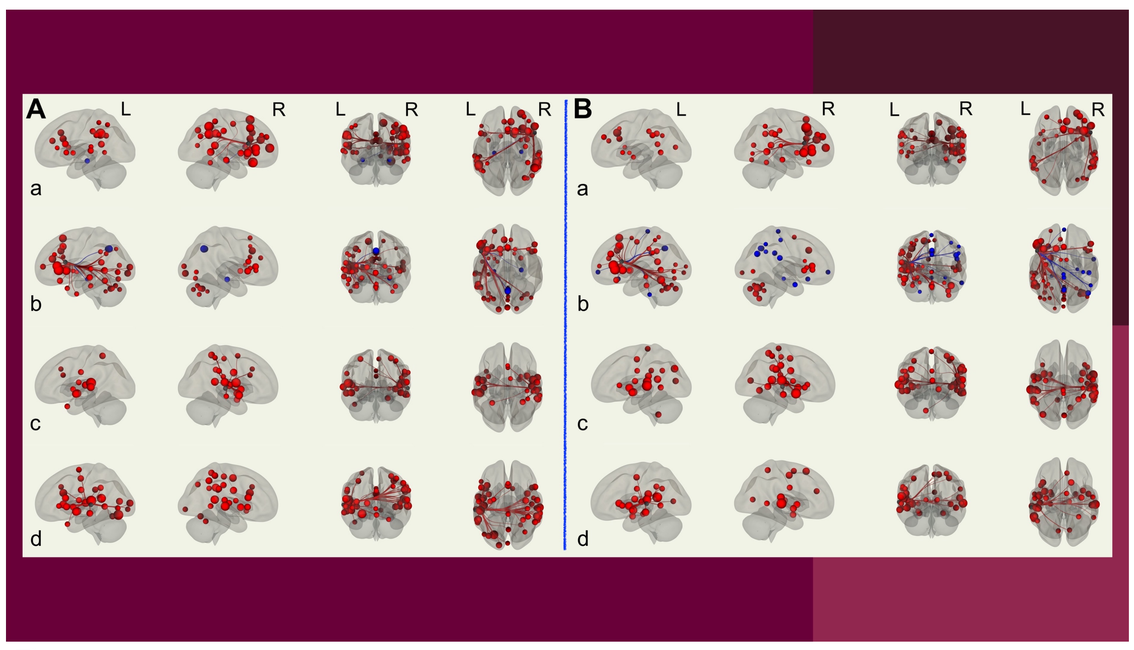

Figure 4

Conclusion

Language networks share a range of commonalities amongst right and left TLE patients and patients with typical and atypical language dominance. Atypical language pattern shows larger variability in TLE - especially in patients with rTLE. LLL and ALL language networks are supported by specific and asymmetric structural connectivity networks of the right and left hemisphere. Improved imaging based understanding of structural and functional language networks opens new diagnostic possibilities in modern neuroradiology.

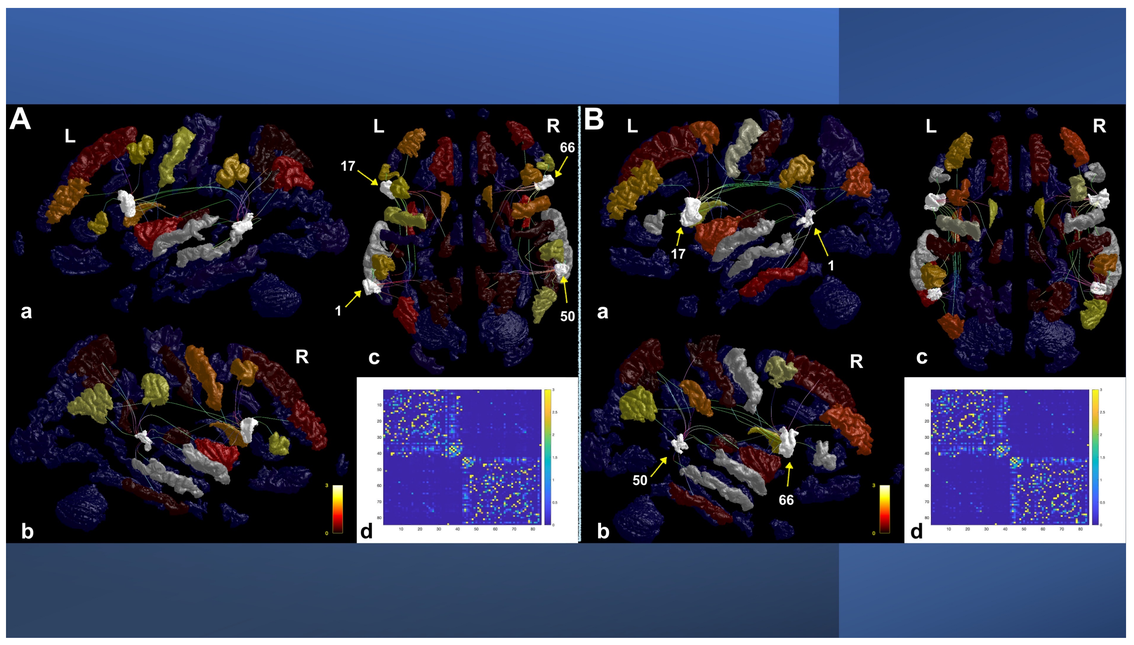

Figure 5

Figure 1: The second-level fMRI activation pattern analysis of rTLE patients (A, n=13) and ITLE patients (B, n=16) with lefthemispherical language lateralization was done using SPM12.
Figure 2: The second-level fMRI activation pattern analysis of rTLE patients (A, n=9) and ITLE patients (B, n=13) with SPM12. atypical language lateralization performed using SPM12.
Figure 3 and 4: The functional connectivity analysis performed with CONN-toolbox. a: right pars opercularis of the inferior frontal gyrus, b: left pars opercularis of the inferior frontal gyrus, c: right posterior segment of the superior temporal gyrus, d: left posterior segment of the superior temporal gyrus.
Figure 5: The visualisation of the structural connectome analysis of right (66) and left (17) pars opercularis of the inferior frontal gyrus and right (50) and left (1) banks of the superior temporal sulcus of single subject with rTLE (A) and ITLE (B) with atypical language lateralization. Dark blue brain areas are not included in the structural language network. White areas represent the region of interest (origin area). a: view of the left hemisphere, b: view of the right hemisphere, c: view of both hemispheres, d: connectome matrix of single subject