Finding Stable Sulcal Subunits : a Group Analysis of Primal Sketches of the Cortex Mean Curvature

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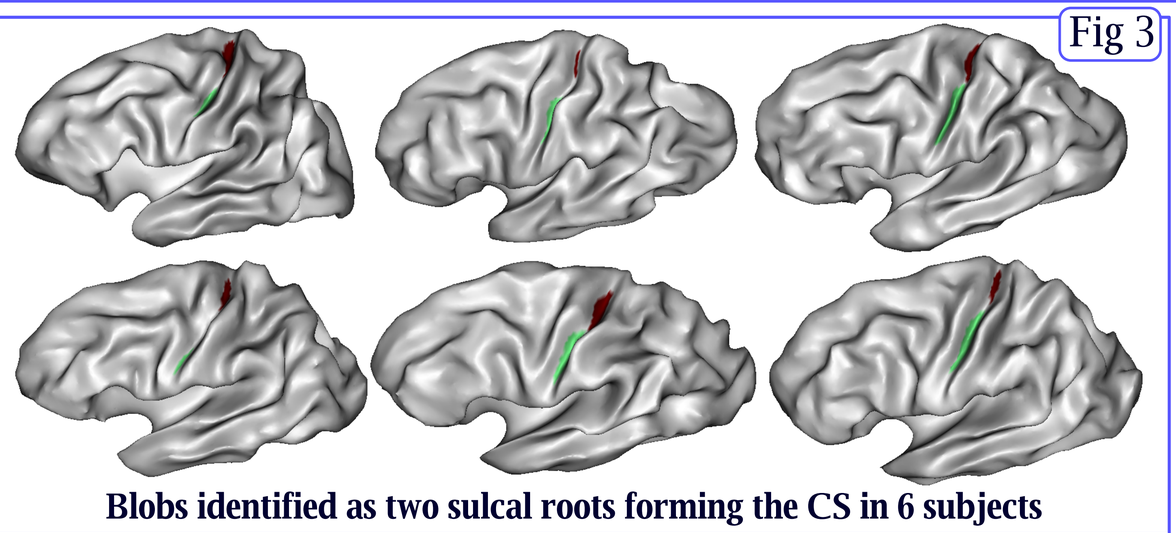
Introduction :

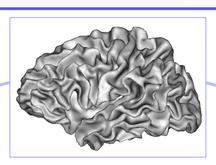
Volume-based and surface-based analyses differ in the way they address the question of intersubject matching. Surface-based approaches can highlight elementary cortical folds [1] or deep sulcal landmarks [2]. In [1], a scale-space primal sketch is built from the cortex mean curvature map to extract multiscale objects from the sulcal fundi, thereby revealing two sulcal roots forming the Central Sulcus (CS). In this work, we show using two distinct cortex-based coordinate systems that these CS subunits are spatially stable across subjects.

Fig 3

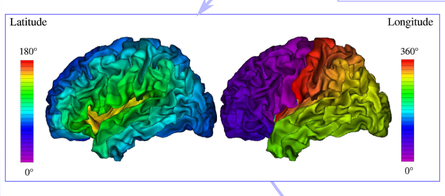


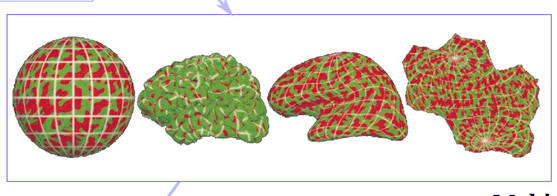
Blobs identified as two sulcal roots forming the CS in 6 subjects

Method :



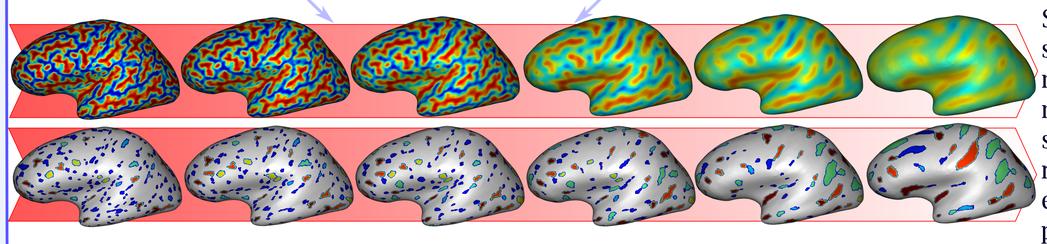
Preprocessing using BrainVisa T1 pipeline (*http://brainvisa.info*) bias correction, hemispheres and tissues segmentation, and definition of cortical triangulated meshes





Parameterization :

using FreeSurfer and BrainVisa [3] surface-based coordinate systems on each cortical mesh



Multiscale structural representation :

Surface-based scale-space primal sketches [1,5] are built from the mean curvature maps of these meshes: this procedure results in sets of multiscale objects (blobs) representing curvature patterns, each with an associated projection (latitude / longitude) in the 2D cortex-based space.

Results :

The method was applied to 12 subjects (NMR database [6]). Resulting maps are presented for the entire left hemisphere in figure 1.

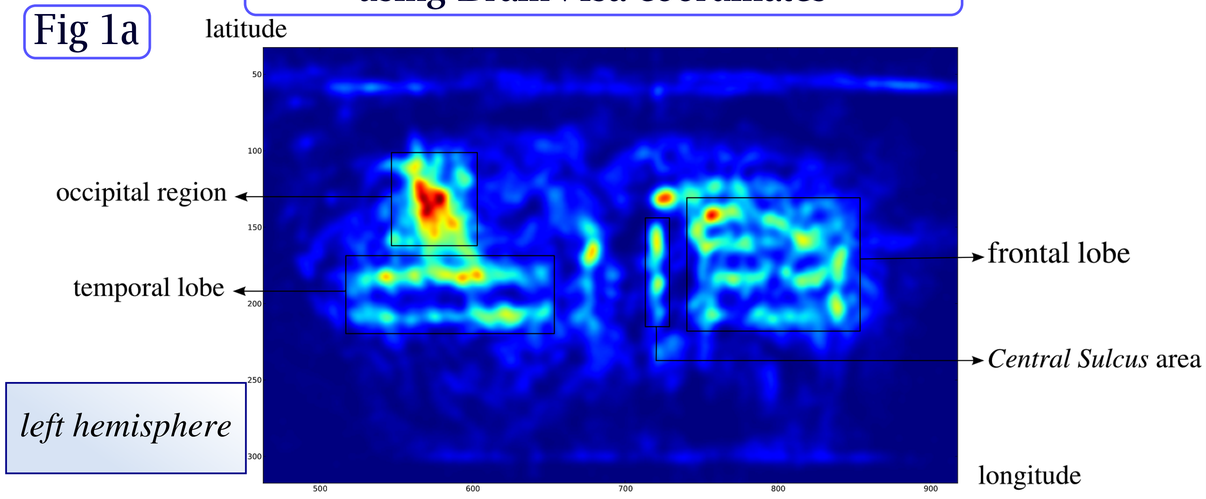
A global organization with orthogonal meridians / parallels is visible after using BrainVisa coordinates. This organization is linked to the nature of the constraints, which are different from those used in FreeSurfer. Focusing on the CS area (fig 2), we find that the blobs are arranged along a remarkable axis in the 2D space. Greater overlap is seen around several focal points, suggesting the existence of CS subunits. These subunits correspond to the sulcus' putative sulcal roots [4]. Hence, we identify for each subject two CS sulcal roots, each represented by the closest blob to the corresponding center (fig 3). The clear interruptions between them are likely to reveal the underlying plis-de-passage.

Group analysis :

We create a cross-subject frequency map plotting the latitude / longitude of all the nodes of each blob at every scale. Two frequency maps were computed respectively using the coordinate system from BrainVisa and FreeSurfer. The resulting maps therefore allow to visualize areas or foci showing blobs robustness across scales and spatial stability in the group (identifiable as local maxima in the map). Comparing different localization systems is here essential to avoid mistaking effects of the system's constraints for significant foci. Significant foci can finally be associated to existing cortical folds subunits. It is then possible to map these foci back on individual cortical meshes (fig 3) and associate one blob to one particular sulcal root [4].

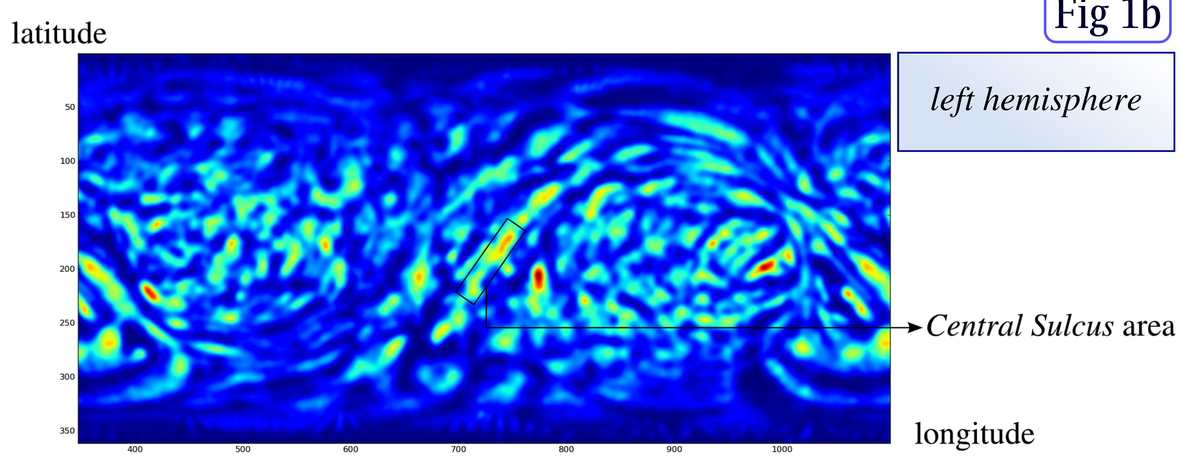
using BrainVisa coordinates

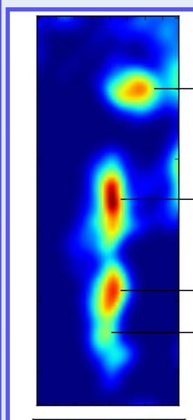
Fig 1a



using FreeSurfer coordinates

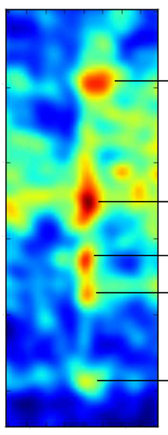
Fig 1b





Central Sulcus left hemisphere

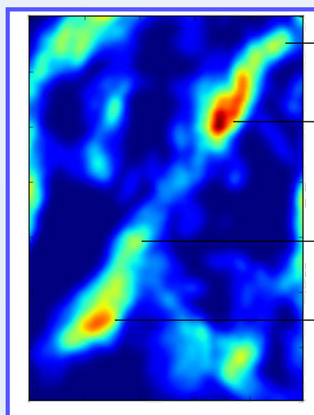
- lat = 65, lon = 2 — *Central Sulcus (CS)* - medial face
- lat = 80, lon = 360 — superior part of CS — ***Centralis Superior***
- lat = 95, lon = 360 — middle - inferior part of CS — ***Centralis Inferior***
- lat = 100, lon = 360 — inferior part of CS



Central Sulcus right hemisphere

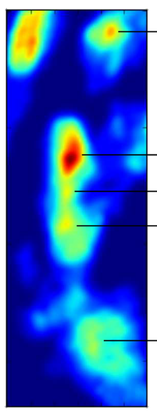
- lat = 65, lon = 360 — CS - medial face
- lat = 80, lon = 360 — superior part of CS — ***Centralis Superior***
- lat = 87, lon = 360 — median area of CS — ***Centralis Inferior***
- lat = 92, lon = 360 — inferior part of CS
- lat = 105, lon = 360 — lowest part of CS

Fig 2a



Central Sulcus left hemisphere

- lat = 75, lon = 20 — inferior part of CS — ***Centralis Inferior***
- lat = 90, lon = 10 — median area of CS
- lat = 115, lon = 355 — superior part of CS — ***Centralis Superior***
- lat = 125, lon = 345 — uppermost part of CS



Central Sulcus right hemisphere

- lat = 75, lon = 355 — CS - medial face
- lat = 102, lon = 347 — uppermost part of CS — ***Centralis Superior***
- lat = 109, lon = 347 — superior part of CS
- lat = 115, lon = 347
- lat = 145, lon = 355 — inferior part of CS — ***Centralis Inferior***

Fig 2b

Future work :

Future work will extend the scope of the analysis to other sulcal regions on the cortical surface. In particular, we plan to adapt the structural surface-based analysis [5] to cortical curvature maps.

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[3] C. Clouchoux et al. (2010) Model-driven parameterization of the cortical surface for localization and inter-subject matching, Neuroimage
[4] J. Régis et al. (2005) Sulcal roots generic model: a hypothesis to overcome the variability of the human cortex folding patterns, Neurol. Med. Chir.
[5] G. Operto et al. (2008) Surface-based structural group analysis of fMRI data, MICCAI
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