Subject-specific cortical cerebellar mapping at 3T and 7T

P.-L. Bazin, J. Kipping, C.J. Steele, D. Margulies, R. Turner and A. Villringer

Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany
bazin@cbs.mpg.de

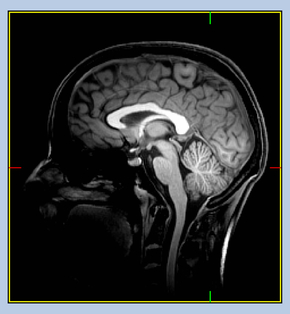
MAX PLANCK INSTITUTE FOR HUMAN COGNITIVE AND BRAIN SCIENCES LEIPZIG

Introduction

Cortical mapping has helped to improve functional MRI analysis in experiments focused on the cerebral cortex [5]. Many advanced tools are available for cortical segmentation, mapping and smoothing of functional data, group normalization, cortical inflation and visualization. The cerebellum, in contrast, has received much less attention, partly due to its small size and complex folding. With advances in high field MRI, these limitations start to disappear, but the automated tools available for cerebellar processing have so far been limited to segmentation and mapping of subject data onto a cerebellar template based on non-linear volumetric registration [3]. We present here a new computational pipeline for subject-specific cortical segmentation, mapping and inflation of the cerebellum.

Methods

Structural MRI and resting-state functional MRI (rs-FMRI) were acquired from 12 individuals at 3 Tesla and processed as follows.



3T MPRAGE

Starting from the structural MRI (T1-weighted MPRAGE, 1.0 mm isotropic resolution), we first perform skull stripping [2] followed by full brain segmentation with topology-preserving multi-object geometric deformable models [1].

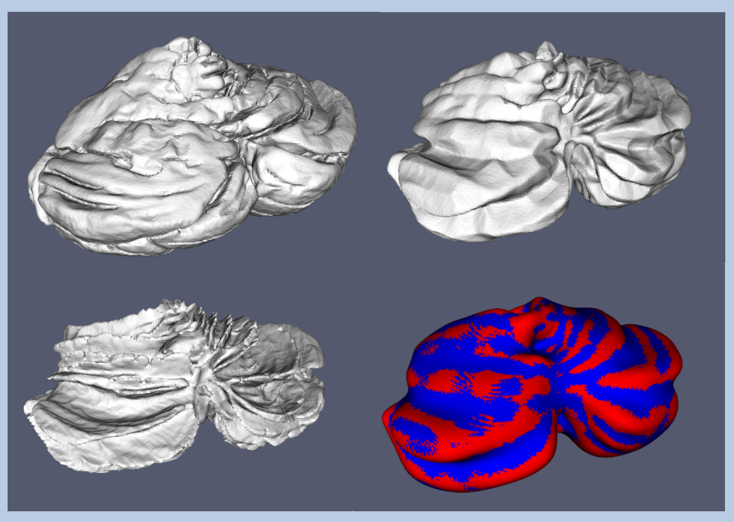
Skull-stripping & inhomogeneity correction

Intensity inhomogeneities are corrected in two steps, first for the whole brain then for the cerebellum only with the N3 algorithm [6].

Whole-brain segmentation

The cerebellar WM/GM interface, CSF/GM interface and a central cortical surface are extracted with the CRUISE method [5], transposed from cerebral to cerebellar cortex. The extracted surfaces have spherical topology and thus can be inflated for mapping and visualization (Fig. 1).

Cerebellum-only segmentation



GM/CSF interface — Central surface

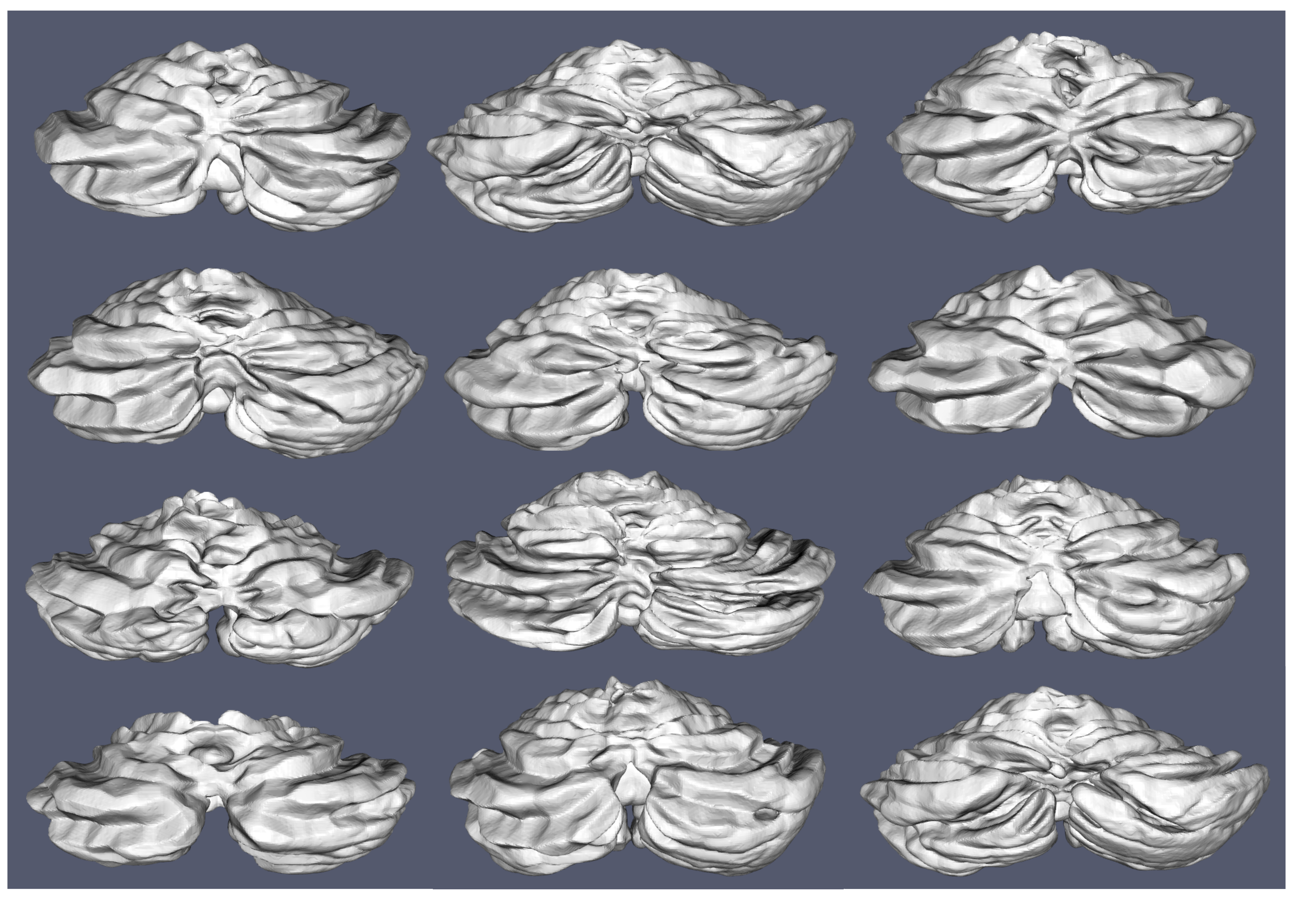
WM/GM interface — Inflated surface

For group averaging, the central surfaces are co-registered to the corresponding cerebellar cortex segmented from an ultra-high resolution T1 template obtained from groupwise averaging of 24 subjects scanned at 7 Tesla with a MP2RAGE sequence (0.7 mm isotropic resolution). Cerebellar lobules are defined manually on the template and transformed to individual subject space (Fig. 2).

rs-fMRI were pre-processed in volumetric space. Cerebellar functional data was then mapped and smoothed along the cortical surface rather than isotropically (4mm Gaussian Kernel). Time series of two adjacent lobules (V and VI) and a distant lobule (VIIIb), which are involved in action control, were extracted and correlated voxelwise with cerebral-only time series (Fig. 4). Lobularwise connectivity maps were obtained with one-sample t-tests (<0.01, cluster corrected).

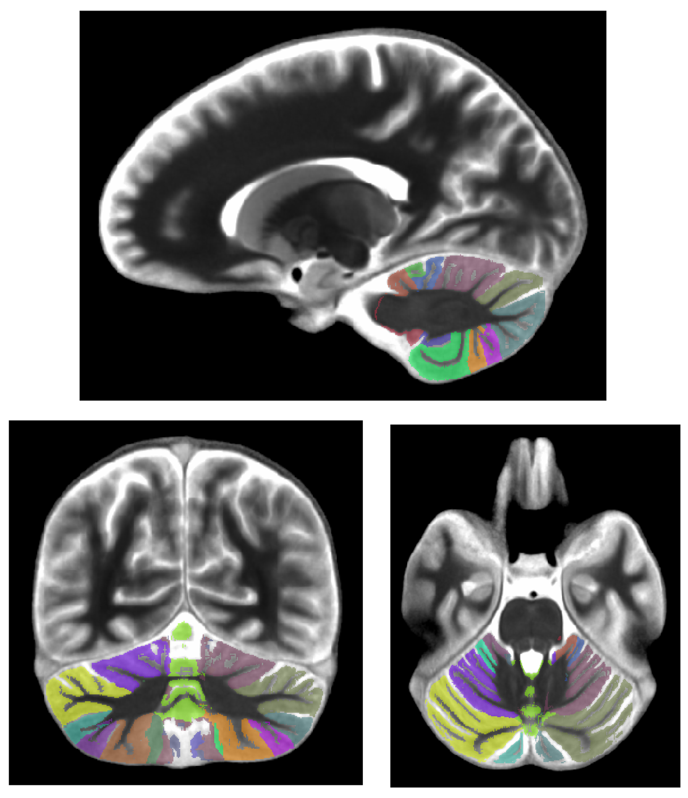
Results

1 Cerebellar cortical reconstruction at 3T



Central cerebellar surfaces for the 12 processed subjects. The cerebellar surfaces obtained exhibit a good level of detail in large lobules, with only occasional merging of the smaller lobules.

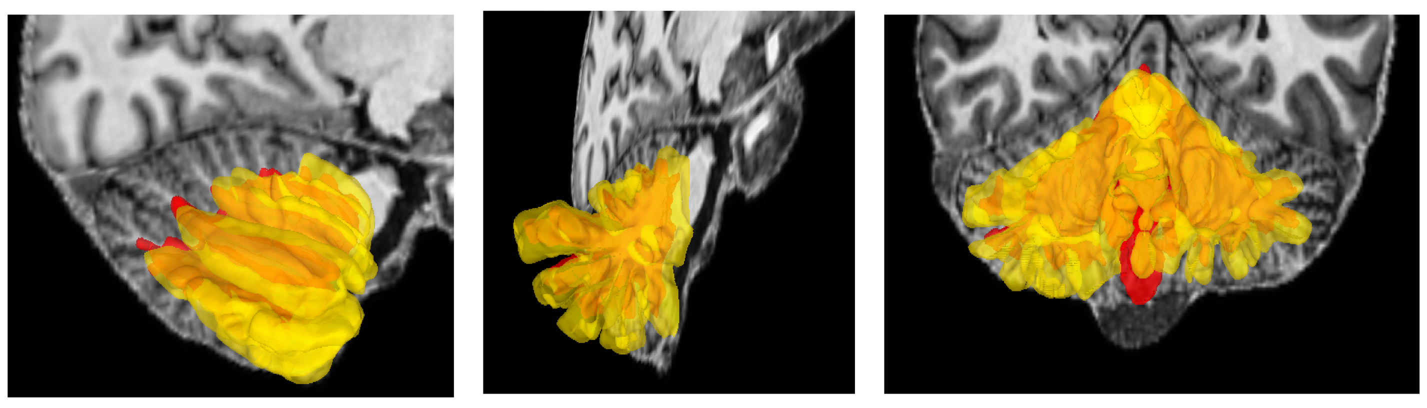
2 7T cerebellar atlas



Quantitative T1 atlas (0.7 mm MP2RAGE, 24 subjects average) with labelled lobules

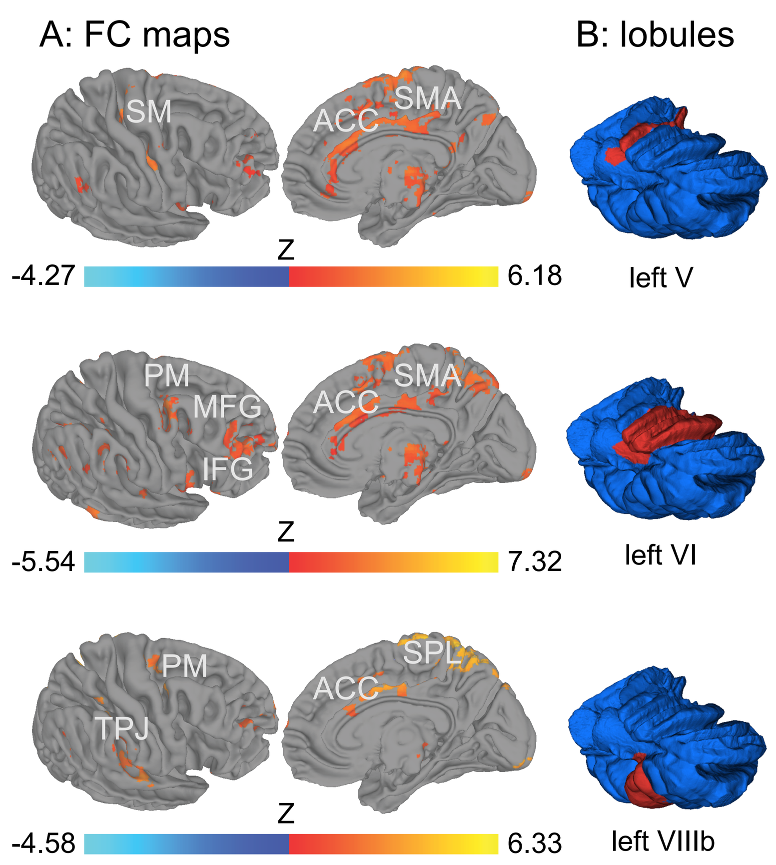
(more on ultra-high resolution T1 atlases: see Poster # 3384 W-Th)

3 7T vs. 3T segmentation



Comparison with surfaces obtained from 0.7 mm isotropic resolution 7 Tesla data (in red) shows good agreement with 3T surfaces (in yellow), although the 7T data reveals much greater detail.

4 Cerebello-cerebral connectivity

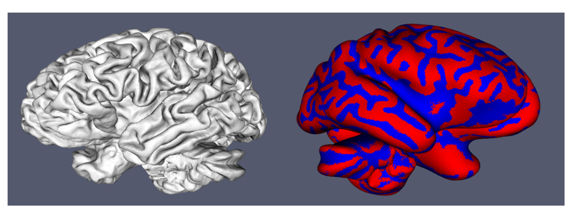


The functional connectivity maps on the right cerebral cortex (A) correspond to the signal of left hemispheric lobules V, VI, VIIIb displayed on our canonical cerebellar surface (B).

The functional connectivity analysis reveals separate connectivity of the lobules to networks of action control: primary sensorimotor (SM) and V, prefrontal (MFG/IFG) and VI, and premotor-parietal networks (PM,SLP) and VIIIb. All lobules show overlapping functional connectivity to secondary motor-related areas as anterior cingulate cortex (ACC) and supplementary motor cortex (SMA).

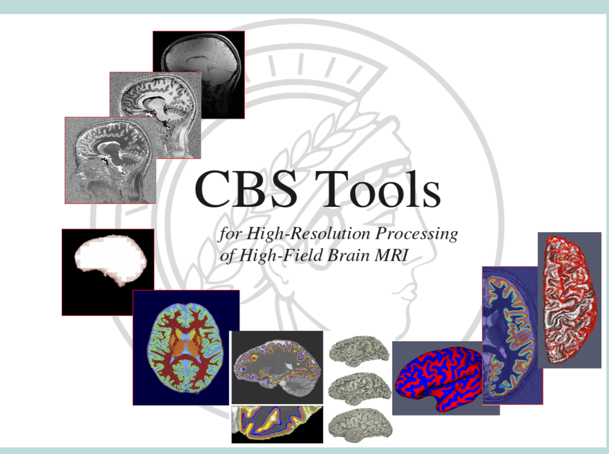
5 *Coming soon: HCP segmentations*

Cortical cerebral and cerebellar segmentations at the original 0.7 mm resolution for the Human Connectome Project data soon available.



Conclusions

We presented a fully automated, subject-specific processing pipeline for cerebellar cortical surface extraction and functional analysis based on high-resolution MRI. The resulting surfaces have good detail at 3T, further refined at 7T. An ultra-high resolution 7T template allows cerebellar surfaces to be normalized, while taking into account their intricate folding. fMRI data can be processed along the cortical surface, eliminating the smoothing effect across lobules which can create false positive activations due to partial voluming with cerebellar white matter and neighboring lobules. Results can be visualized on partially inflated surfaces both in subject and template space and can be further utilized for sublobular analyses.



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Get our processing tools online:

http://www.cbs.mpg.de/institute/software/cbs-hrt/

http://www.nitrc.org/projects/cbs-tools/

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