Semi-automated in-vivo segmentation of visual area V1 based on structural 7 Tesla MRI

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Introduction: We present a semi-automated method for segmenting human visual area V1 based on in-vivo high-resolution structural images acquired at 7 Tesla. The method consists of a sequence of processing steps designed to identify laminar cortical profiles, in particular the stria of Gennari, that are characteristic of V1 and that are identifiable using ultra-high field MR imaging. Although other areas have been identified by the analysis of intra-cortical contrasts [1], for the first time we present the delineation of a cortical area based on the automated analysis of laminar patterns in three dimensions.

Methods: MRI data were acquired on a Siemens MAGNETOM 7T scanner (Erlangen, Germany) in three separate sessions of a 27 year-old healthy female volunteer using a FLASH sequence with flip angle=90^0,TE=18ms,TR=4400 ms, BW=80Hz/px and an MP2RAGE sequence [2] with flip angle=4^0/4^0, TI=1000ms/3500ms, TE=2.89ms, TR=4500ms, BW=260Hz/px. Spatial resolutions for the FLASH data were set to 0.35 mm^{3}in two acquisitions, and to 0.4 mm^3 in the other. For the MP2RAGE, spatial resolution was set to 0.65 mm^3 in two acquisitions and to 0.6 mm^3 in the other. One of the 0.35 mm^3 FLASH data sets was used as a geometric reference to which all other data sets were geometrically aligned and resampled to isotropic voxels of 0.35 mm^3. The FLASH data were bias field corrected. After alignment, an average of all three MP2RAGE and all three FLASH data sets were computed. These two averages were the basis for subsequent data analysis.
First, a semi-automated white matter segmentation of the occipital lobe of the right hemisphere was done on the basis of the MP2RAGE data using the level set based segmentation of ITKSnap [3]. We used our own level set framework [4] to extract a surface representation of the grey-white-boundary, to extend the ITKSnap results to cover the whole cortex and to extract 3D cortical profiles (length=1.75mm) perpendicular to the isosurfaces of the level set function. Along these profiles feature values were computed from the geometrically corresponding FLASH data. The feature vectors were then smoothed along the cortical surface within a radius of 2.8mm. A K-means clustering algorithm was applied to these feature vectors resulting in a cluster map setting the number of clusters to k=3. As a final post-processing step, we applied topological correction to ensure that the resulting clusters were topologically connected and small holes with radius < 2mm filled.

Results: All figures show analyses for the right hemisphere only. Figure 1 shows the clustering result mapped onto the original high-resolution voxel image. Small arrowheads in the left hemisphere mark the well resolved stria of Gennari; CF indicates the calcarine fissure. The cluster displayed in green coincides well with areas where the stria of Gennari is visible. The other clusters do not show the stria of Gennari. Figure 2 shows the cluster results mapped onto an intermediate cortical surface to visualize the location of the identified area.

Conclusions: We have presented initial results of a semi-automated method for segmenting human visual area V1 in vivo based on ultra-high field structural images. Visual inspection shows that our method separates V1 from adjacent areas very well and that the extent of the identified area corresponds with the literature [5]. A quantitative validation is under way. We are currently working on improvements of our image analysis procedures. These first results may be seen as a very promising "proof of concept".

References:
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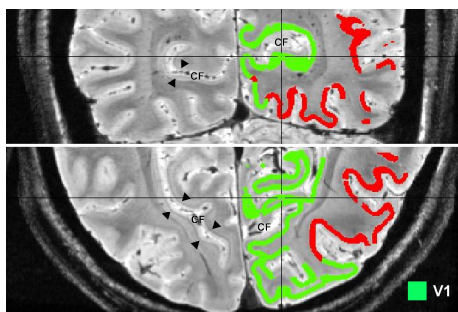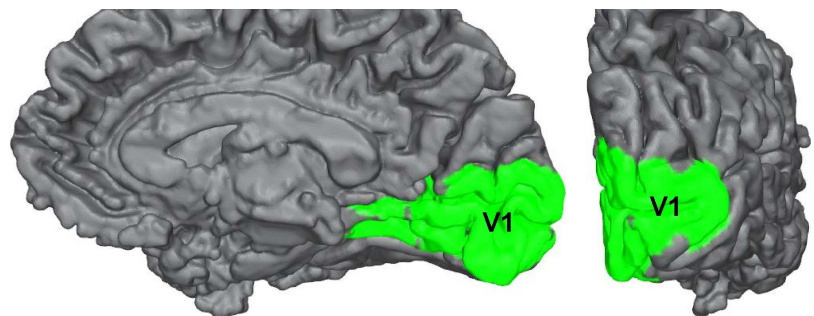
Fig.1: Automatic clustering results; green indicates V1

Fig.2: V1 cluster mapped onto an intermediate cortical surface