

Manifold-based exploration of the links between cortical morphology and functional architecture

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Introduction:

The variability of the cortical folding pattern is so complex [1] that the links with functional architecture and behavior have rarely been explored. With the aid of BrainVISA [2,3], an automatic sulcus recognition platform, studies have been carried out revealing for instance the link between the interruption of a sulcus along the fusiform area and reading accuracy [4]. Defining more sophisticated characteristics of sulci shapes, however, is very difficult when dealing with individual morphologies. Therefore, we have recently proposed to exploit the sulcus 3D representations generated by BrainVISA to build digests of the bewildering inter-individual variability based on manifold learning [5,6]. Hence, the first dimensions of the manifold provide shape-based features of low complexity that can be used to analyze the variability of functional or tractography individual maps. Here, we describe the application of this approach to the HCP dataset [7].

Methods:

The 882 first HCP subjects (2015 release) were processed using the "Morphologist 2012" pipeline [<http://brainvisa.info>] to obtain 129 sulci. All brains were affinely normalized to the Talairach space. Three groups of sulci were formed for shape analysis: "Central Sulcus", "Precentral Gyrus" (central and precentral sulci), and "Superior Temporal Sulcus" (stem and posterior branches). Right hemisphere sulci were flipped to the left hemisphere space. For each group, pairwise shape similarity matrices were computed using rigid alignment. Isomap method was used to project the sulci into a one dimensional manifold. All sulci were also rigidly aligned to the most typical one, namely the sulcus with the minimum average distance to the set. Moving local average shapes were computed in this target space along the manifold for visualization. The evolution of this moving average provides a good description of the shape-feature coded by the coordinates in the manifold. FMRI contrasts used to define the HCP parcellation system were transformed from each subject native space to the sulcus target space, in order to perform the same moving average process. This strategy was also applied to the HCP subjects' long fiber bundles automatically defined using Connectomist, the dMRI toolbox associated with brainVISA [9].

Results:

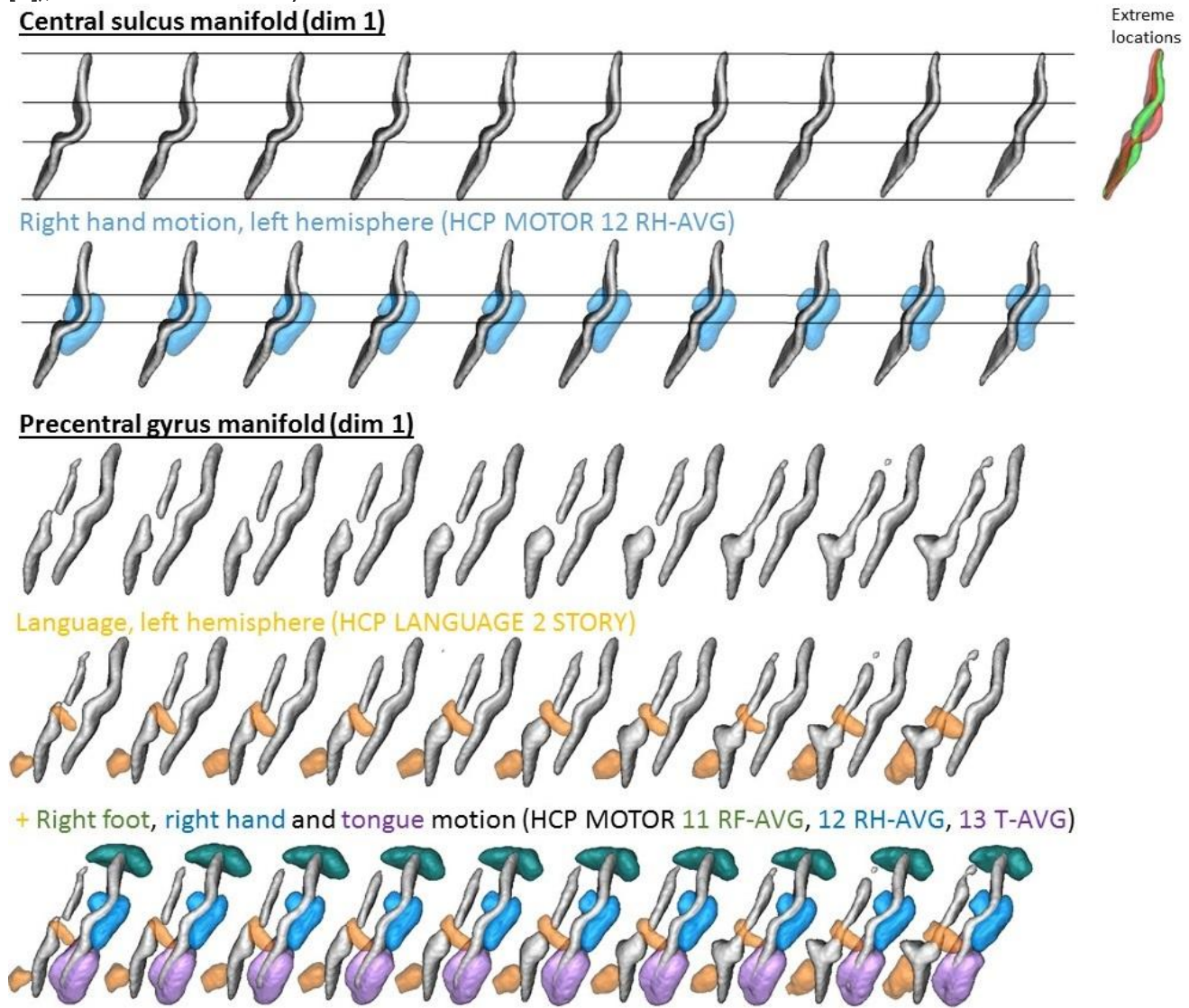
Three kinds of observations were allowed by our methodology:

1. A morphological feature associated with the localization of a functional area (Central Sulcus, Fig 1): the

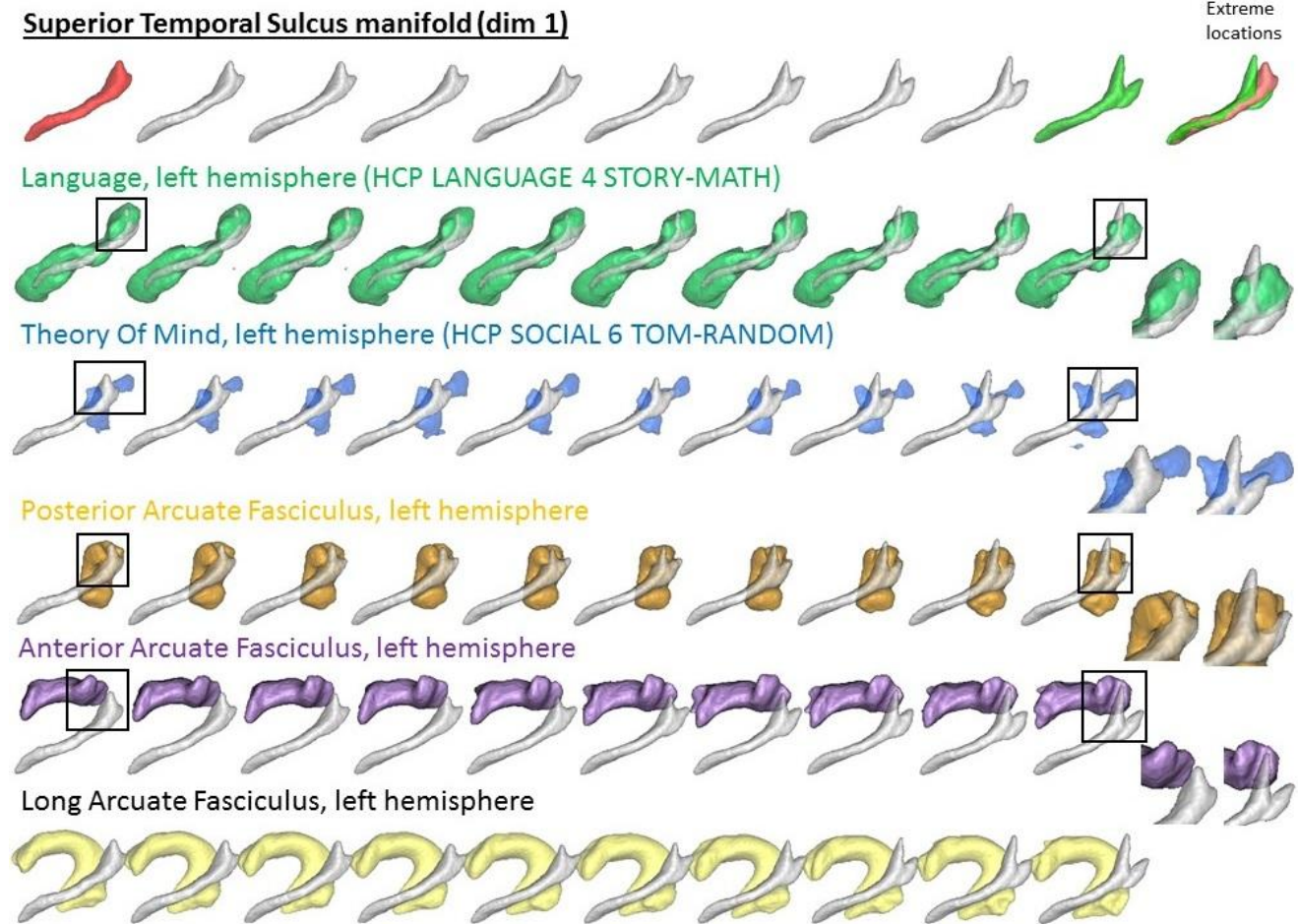
manifold codes for a transition from a single to a double knob configuration, confirming previous results with other datasets [5,6]. During this transition, the main knob moves from the center of the sulcus to an upward position. The right hand motor area follows the displacement of this knob, as already shown with another dataset [6].

2. A morphological feature indicating the size of a functional area (precentral gyrus, Fig. 1): the manifold codes for a transition from a vertical to an horizontal intermediate precentral sulcus. The size of the language area associated to Brodmann area 44 [8] is growing at the same time, while 3 motor areas obtained by the same process remain stable.

3. A morphological feature modulating the link between morphology and architecture (superior temporal sulcus, Fig. 2): the manifold codes for a transition from a long to a short stem of the sulcus and from short to long posterior branches. A language area (STSvp in [8]) and the posterior/anterior Arcuate Fasciculi reaching it move from a position anterior to the anterior STS branch to a posterior position. Two nearby areas (STSva and TPO1 in [8]), associated to a Theory Of Mind contrast seem also modulated to a lower extent.



•Fig. 1: Central Region



·Fig. 2: Superior Temporal Region

Conclusions:

By highlighting the main variants of the folding patterns, manifold learning could help us decipher the complex interactions between the development of the functional architecture and the dynamics of cortical folding.

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Imaging Methods:

Anatomical MRI

Informatics:

Brain Atlases

Modeling and Analysis Methods:

Image Registration and Computational Anatomy ¹

Neuroanatomy:

Anatomy and Functional Systems
Cortical Anatomy and Brain Mapping ²

Keywords:

Atlasing

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Other - sulci

¹/₂ Indicates the priority used for review