

Manifold-based exploration of the links between precentral sulcus interruptions and language-associated area 55b

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Introduction

The variability of the cortical folding pattern is so complex [Ono, 1990] that the links with functional architecture have rarely been explored. In our opinion, in order to test the potential meaning of the cortical folding patterns, it is first preferable to discard the single brain template paradigm. Therefore, for each cortical region, we propose to perform a stratification of the population according to the regional folding pattern before performing group analysis of functional maps [Sun et al., 2016]. To illustrate the potential of this strategy, we apply this approach to the study of the unknown link between interruptions of the precentral sulcus and the language-associated area 55b highlighted in the Human Connectome Project (HCP) dataset [Van Essen et al., 2013, Glasser et al., 2016].

Material and methods

The 882 first HCP subjects (2015 release) were processed using the “Morphologist 2012” pipeline [<http://brainvisa.info>] to obtain 129 sulci (see Fig. 1) [Fischer et al., 2012, Perrot et al., 2011]. All brains were affinely normalized to the Talairach space. A group of seven sulci making up the Precentral Gyrus was formed for shape analysis (see Fig. 1). Pairwise shape similarity matrices were computed using rigid alignment. **Isomap** method was used to project the individual gyri into a low dimensional manifold. All gyri were also rigidly aligned to the most typical one, namely the gyrus with the minimum average distance to the set. **Moving local average shapes** were computed in this target space along each manifold dimension for visualization. The evolution of this moving average provides a good description of the shape-feature coded by the coordinates in the manifold. A **fMRI contrast** used to define the language-associated 55b area of the HCP parcellation system was transformed from each subject native space to the gyrus target space, in order to perform the same moving average process.

Results

The third dimension of the manifold codes for the localization and shape of an interruption of the precentral sulcus usually separating the intermediate precentral sulcus from the superior precentral sulcus. The 55b area is systematically located in this interruption, whatever its localization (see Fig. 2). The fourth dimension of the manifold codes for a transition from the interruption of the third dimension to an interruption located higher sometimes occurring between the superior precentral sulcus and the marginal precentral sulcus. While the higher interruption appears, the transverse gyrus corresponding to the lower interruption gets buried in the depth of the precentral sulcus, a phenomenon called “plis de passage” by the neuroanatomists (see the Plis de passage map in Fig. 1 [Mangin et al., 2019]). The 55b area is also systematically located in the lower interruption or in the corresponding buried gyrus. Furthermore, the 55b area gets smaller while the transverse gyrus gets smaller and buried (see Fig. 2). Finally note that each of the two interruptions is located in front of one of the knobs of the central sulcus.

Conclusions

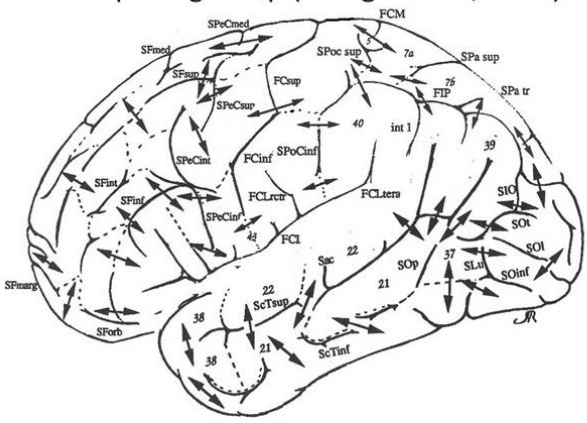
The sophisticated spatial normalization strategy used by the HCP consortium to align subjects is relying heavily on functional MRI. It was shown that with this new strategy providing a better alignment of the functional architecture, the alignment of the folding patterns gets much weaker than with the standard normalization strategy except in primary areas. This has led for instance to consider that the localization of area 55b was not strongly related to the folding patterns [Glasser et al., 2016]. In return, our strategy based on a folding pattern based stratification of the population has shown that this area 55b looks strongly associated with a gyrus transverse to the precentral gyrus, which may result from developmental mechanics of the cortical folding process [Mangin et al., 2019].

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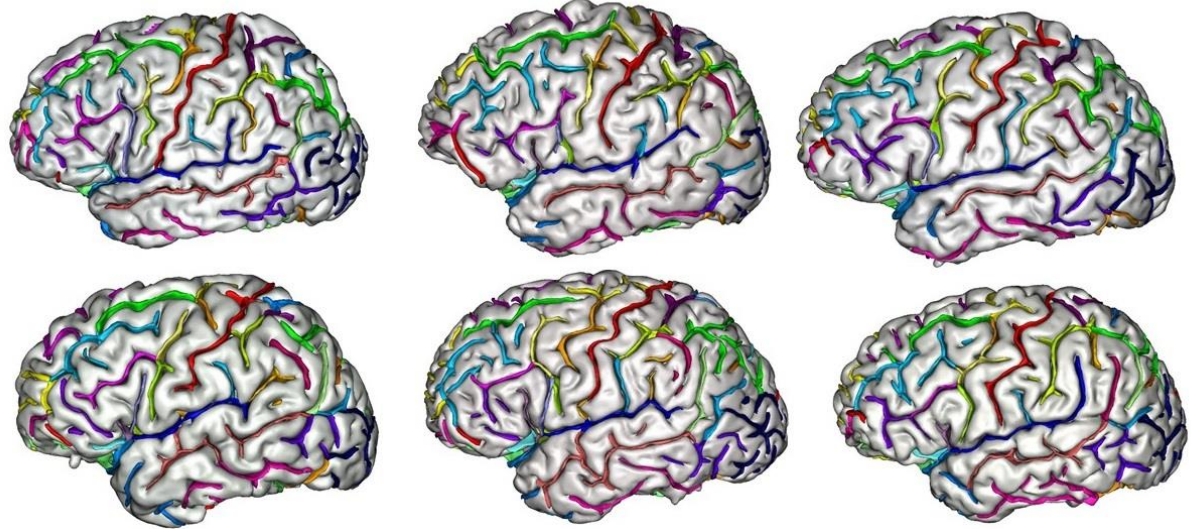
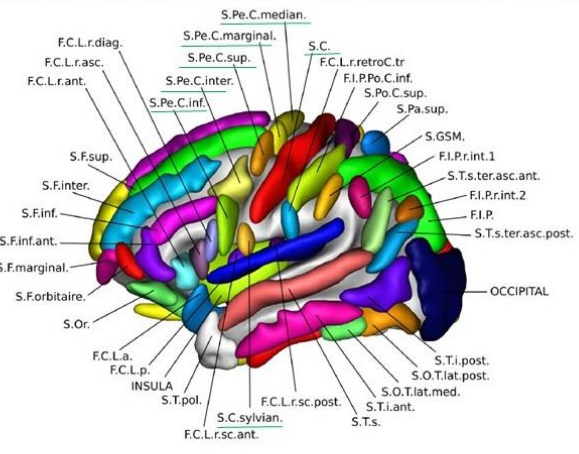
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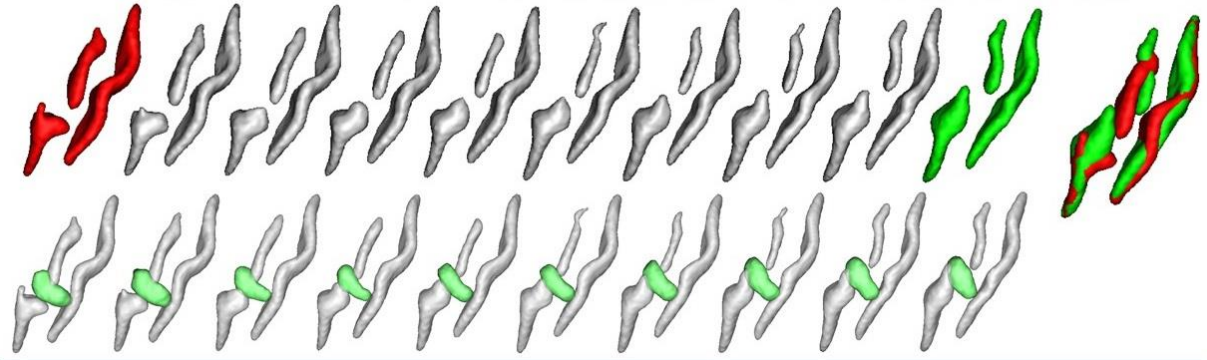
Plis de passage map (Mangin et al., 2019)



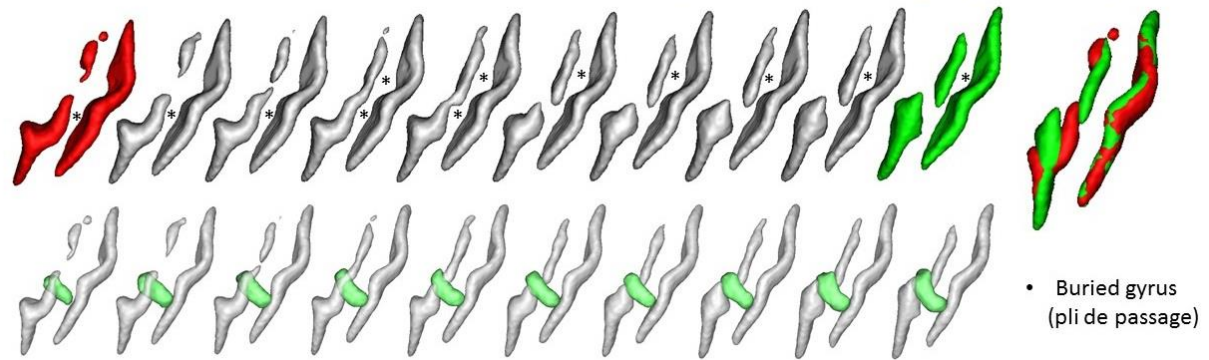
BrainVISA sulcus nomenclature (precentral gyrus outlined)



Precentral gyrus manifold (dim 3) / Left hemisphere, HCP Language 2 Story



Precentral gyrus manifold (dim 4) / Left hemisphere, HCP Language 2 Story



- Buried gyrus (pli de passage)