Study of sulcal and anatomical landmarks variability in the inferior frontal lobe.

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INTRODUCTION: The standard approach to asses the localization of fMRI activation areas in a group of subjects relies on the use of a proportional coordinate system such as Talairach space. Despite important development of spatial normalization techniques needed for that purpose, the problem of individual anatomical variability remains a limiting factor for precise localization of activation. The use of non-linear warping procedures to account for intersubject variability is becoming popular, but it may lack precision of individual gyri matching or may result in matching of non-corresponding gyri. An alternative approach to account for intesubject variability is to use strucural/morphological image analysis aimed at identification of individual gyral/sulci patterns [1,2]. In this study, we aim to address the question of anatomical variability in a normal population using publicly available software (http://anatomist.info) for 3D MRI segmentation and sulci identification. Our objective was to define several reliable anatomical landmarks in the frontal lobes in relation to the language function.

METHODS: Standard T1-weighted GRE 3D-MRI (TR/TE/flip 15/4.7ms/25º, 0.98 mm in plane resolution, 1.1 mm slice thickness) was obtained from 24 right-handed normal volunteers. Images were first spatially normalized using SPM (T1-template, affine transformation), and then processed with Anatomist software to obtain individual sulci graphs. The performance of Anatomist for the automatic detection and identification of the main sulci was assessed by an expert neuroanatomist. After visual inspection of individal sulci patterns, three landmarks in the inferior frontal lobes were defined and their coordinates in the MNI space obtained. The choice of the landmarks was based on their relevance to language function (Broca area, BA 44 and 45).

RESULTS: In all the subjects, the main sulci in the frontal lobes were correctly detected by Anatomist. Figure 1 shows a superposition of sulcal graphs from 10 subjects which illustrates the high degree of anatomical variability. Considering individual results, we have chosen three anatomical landmarks (fig. 2) as follows: (1) intersection between inferior frontal and inferior precentral sulci (IF-IPC), (2) caudal end of inferior precentral (cIPC), and (3) caudal end of ascending ramus of the Sylvian fissure (cAR). The first landmark (IF-IPC) was chosen because it was observed in ~90% of subjects (right/left hemispheres 87.5%/91.7%), consistent with [3]. The coordinates (mean±sd) of these landmarks in the MNI space are reported in table 1.

DISCUSSION AND CONCLUSIONS: Sulci extraction shows that the anatomical variablity across subjects is very large even in the normalized space. Sulci differ in position, orientation and shape. We observe that frontal regions implicated in higher cognitive functions exhibit greater variability than primary regions. Nevertheless, it is possible to define landmarks which are present in the majority (90%) of normal subjects. The most important observation from the coordinates of landmarks is the standard deviation of the position which is greatest in the *Z* direction (7.2 mm). Such differences between different brains anatomy may explain the variances in location of activation areas observed in fMRI group studies such as [4]. We think that expressing activation relative to landmarks obtained from individual anatomy, which is now feasible with tools like Anatomist, will allow better analysis of the differences in activation between different subjects.

Landmark	***Right***			***Left***		
	x	*y*	*z*	*x*	*y*	*z*
1. IF-IPC	54.4 ±2.6	13.9±3.7	34.5±4.5	-54.9±2.7	12.9±3.4	33.9±7.2
2. cIPC	58.0±3.6	7.1±4.6	8.9±6.1	-56.9±3.4	7.7±2.8	8.0±5.2
3. cAR	50.7±3.2	15.7±2.8	0.7±3.3	-50.3±2.1	16.7±3.0	0.2±4.1

Table 1: Landmark position (±sd) in the MNI space (mm).

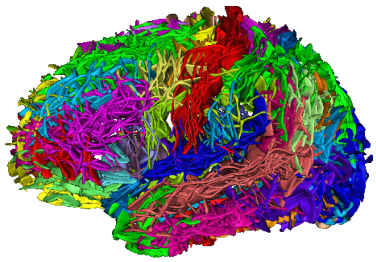

Fig.1: Sulcal variability of 10 subjects

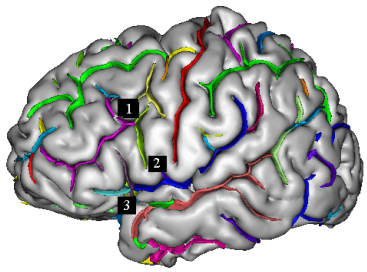

Fig.2: Landmarks definition

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