Bridging Brain Structure and Function by Correlating Structural Connectivity and Cortico-Cortical Transmission

Fabien Almairac, Patryk Filipiak, Lavinia Slabu, Maureen Clerc, Théodore Papadopoulo, Denys Fontaine, Lydiane Mondot, Stéphan Chanelet, Demian Wassermann, Rachid Deriche

Bridging Brain Structure and Function by Correlating Structural Connectivity and Cortico-Cortical Transmission

Fabien **Almairac**[1] Patryk **Filipiak**[2] Lavinia **Slabu**[2] Maureen **Clerc**[2] Théodore **Papadopoulo**[2]
Denys **Fontaine**[1] Lydiane **Mondot**[1] Stéphan **Chanelet**[1] Demian **Wassermann**[3] Rachid **Deriche**[2]
[1]Centre Hospitalier Universitaire de Nice, Université Côte d'Azur, Nice, France [2]INRIA Sophia Antipolis Méditerranée, Université Côte d'Azur, Valbonne, France [3]INRIA, CEA, Université Paris-Saclay, France

Contact - almairac.f@chu-nice.fr, patryk.filipiak@inria.fr

http://team.inria.fr/athena/

1 INTRODUCTION

Elucidating the structure-function relationship of the brain is one of the main open questions in neuroscience.

The capabilities of *diffusion MRI-based* (dMRI) techniques to quantify the connectivity strength between brain areas, namely structural connectivity, in combination with modalities such as *electrocorticography* (ECoG) to quantify brain function have enabled advances in this field.

In this project, **we aim to establish a relationship** between:

> dMRI structural connectivity measures,

> direct measures of electrical properties of the human brain cortex obtained with ECoG,

> response elicited by direct electrostimulation of the brain (DES).

2 STRUCTURAL CONNECTIVITY

The dMRI scans are acquired prior to the surgery, in order to extract structural connectivity indices through probabilistic tractography.

The acquisition protocol is optimized for maximum accuracy of MAPL model under the constraint of 25-minutes scanning time. It contains 99 diffusion weighted imaged and 6 b=0 images as illustrated in Figure 1.

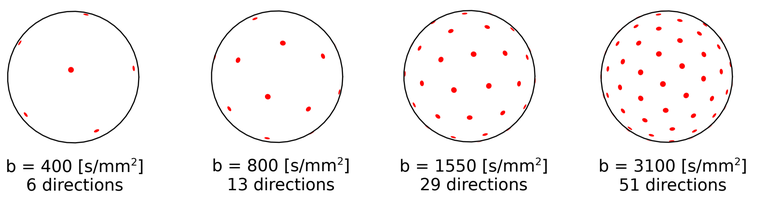


Figure 1: Illustration of the multishell dMRI acquisition protocol.

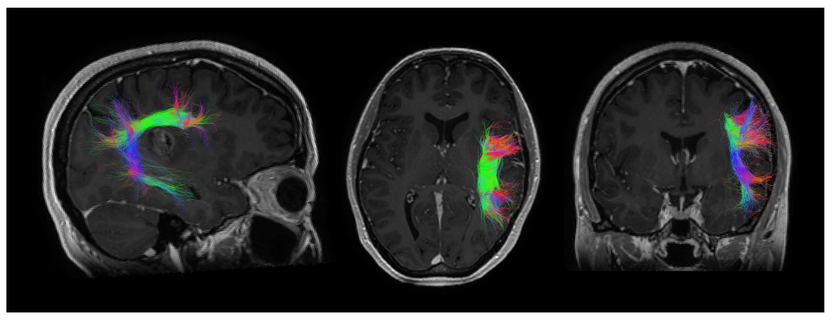


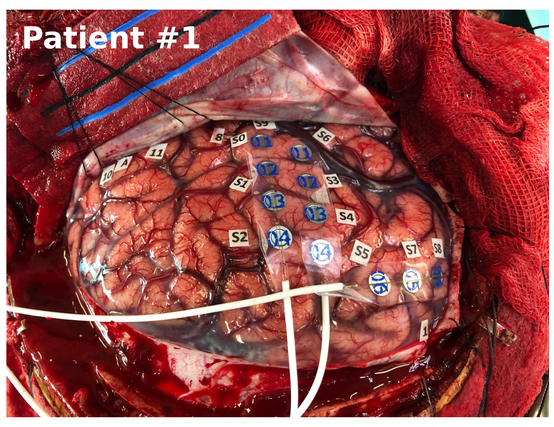
Figure 2: Visualization of Patient's #2 *Arcuate Fasciulus* and *Superior Longitudinal Fasciculus III*.

3 FUNCTIONAL CONNECTIVITY

Following the classical procedure of awake craniotomy, a **brain cartography** is performed using DES (low-intensity current, bipolar electrode) to identify the functional cortical sites for sensory-motor, language, visual and cognitive functions.

To obtain **intrasurgical cortico-cortical electrical measures**, the ECoG electrodes are positioned on the cortical terminations of the designated bundles previously identified by dMRI and DES.

The electrical signal is recorded spontaneously and after DES of the cortex.



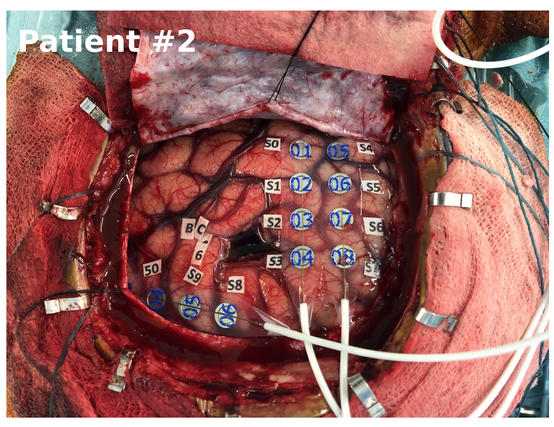
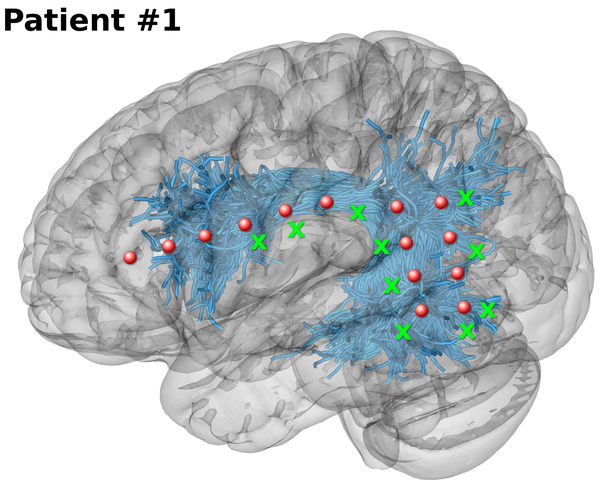


Figure 3: Awake craniotomies of two patients diagnosed with the brain tumor. The ECoG electrodes are placed on the cortical terminations of *Arcuate Fasciculus* and *Superior Longitudinal Fasiculus III*. Stimulation points are marked S0-S9.

4 EXPERIMENTS

Patient #1



Patient #2

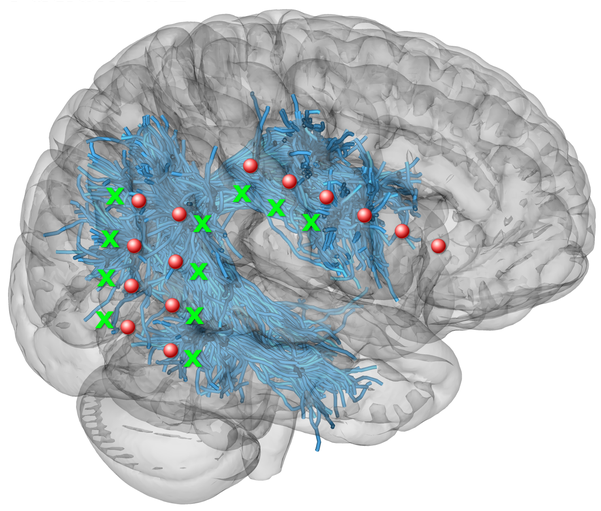


Figure 4: Tractography-based *Arcuate Fasciculus* and *Superior Longitudinal Fasciculus III* (marked as blue streamlines), ECoG electrode placements (red circles), and stimulation points (green crosses).

Stimulation parameters:

> 3.5mA current
> bipoloar, biphasic
> 5Hz frequency
> 4s length

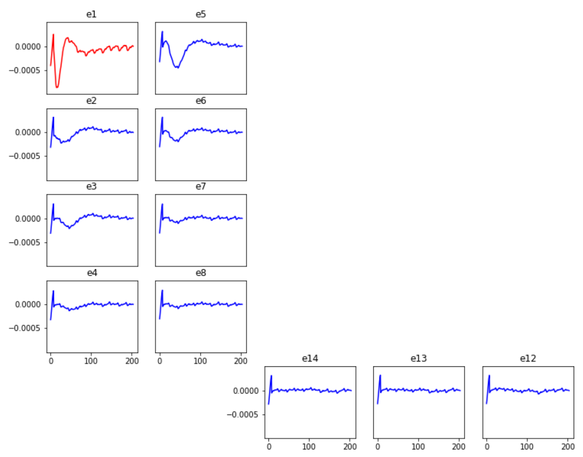


Figure 5: Sample ECoG recordings. The evoked potential propagates from the stimulation site nearest to the electrode e1 (red plot).

5 CONCLUSIONS

The results of this multi-modal approach combining structure and function explorations of the brain should:

> help to **elucidate the relationship between non-invasive (dMRI) structural connectivity measures and cortico-cortical transmission properties** (delays, transfer functions),

> help in **understanding the organization of the brain for cognitive functions** as well as **neurosurgical planning** for resection of brain tumors and drug-resistant epilepsy.

References

[1] M. Vincent, *"Mesure des Effets Electrophysiologiques de la Stimulation Electrique Directe du Cerveau lors des Chirurgies Eveillées des Gliomes de Bas Grade,"* PhD thesis, 2017.
[2] H. Duffau, L. Taillandier, P. Gatignol, L. Capelle, *"The insular lobe and brain plasticity: lessons from tumor surgery,"* Clinical neurology and neurosurgery, 2006.
[3] S. Jbabdi, S. N. Sotiropoulos, S. N. Haber, D. C. Van Essen, T. E. Behrens, *"Measuring macroscopic brain connections in vivo,"* Nature neuroscience, 2015.
[4] Z. M. Saygin, D. E. Osher, K. Koldewyn, G. Reynolds, J. D. Gabrieli, R. R. Saxe, *"Anatomical connectivity patterns predict face selectivity in the fusiform gyrus,"* Nature neuroscience, 2012.
[5] C. Honey, O. Sporns, L. Cammoun, X. Gigandet, J.-P. Thiran, R. Meuli, P. Hagmann, *"Predicting human resting-state functional connectivity from structural connectivity,"* NAS, 2009.
[6] C. R. Conner, T. M. Ellmore, M. A. DiSano, T. A. Pieters, A. W. Potter, N. Tandon, "Anatomic and electro-physiologic connectivity of the language system: a combined DTI-CCEP study," Computers in biology and medicine, 2011.

Acknowledgments

This study received funding from the CHU Nice – Inria Project "Action Marquante" and was promoted by Centre Hospitalier Universitaire de Nice.

Fibre-tracking was performed using the MRtrix package (J-D Tournier, Brain Research Institute, Melbourne, Australia, https://github.com/MRtrix3/mrtrix3) (Tournier et al. 2012)