Browsing the Connectome: 3D Functional and Structural Brain Networks in the Cloud

Katja Heuer, Ralph Schurade, Joachim Böttger, Daniel S. Margulies, Thomas R. Knösche, Angela D. Friederici & Alfred Anwander

Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany

heuer@cbs.mpg.de

Introduction

This project aims at providing a user-friendly platform for the publication of functional & structural connectivity data in an interactive 3D visualization directly linked to your paper.

- Multimodal visualization allows associating the functional coupling between brain regions to structural connections
- Despite wide range of available methods [1], visualization of 3D structure in 2D images drastically reduces information content
- To overcome this loss: directly publish interactive 3D models based on the platform independent webGL technology [2].
- now: **extended multi-modal open source platform brainGL-web**
  - to interactively publish functional & structural connectivity data
  - for a direct visualization in the web browser and
  - to develop full-fledged applications based on JavaScript & WebGL
- Interactivity allows new insights into the relation of the multi-modal networks, here exemplified by the language network.

Methods

Visualization based on brainGL (desktop software)

- selection of major fascicles
- production of surface connectivity maps from the correlation matrix and computation of edge-bundled representations of thresholded functional connections between ROIs [4]
- export for visualization in the brainGL web application (braingl-web.googlecode.com)

Most user-friendly design

- **Simple structure of configuration files:** the template website can easily show new data by adaptation of only four files (index-, elements-, scenes- and ui-files; mainly the file names)
- **Elements files:** specify file names and modify parameters of single elements (color; transparency; lines versus tubes)
- **Scene-files:** define which elements should be displayed at once and which should additionally be available for interaction; define focus by position of camera with smooth transition from previous position. From there users can continue to explore the data by themselves.
- **Viewer can easily be integrated into any website**
- tutorial available at braingl-web.googlecode.com

Data

Example data

Functional connectivity was calculated from rs-fMRI data (900vol, n=65) from the enhanced NKI-Rockland sample [3]. After standard preprocessing, the functional connectivity matrix for the average brain surface was computed.

For comparison of the "bundled" functional data with the **structural connectivity** and the location of the fascicles we computed full-brain diffusion MRI tractography (MedINRIA) and selected the 9 major long-range fascicles (AF, SLF, IFOF, UNC, ILF, CG, CST, TR and CC). These were extracted form a representative subject selected at random from a large database of dMRI data acquired with high spatial and angular resolution (1.7 mm iso, 60 dir, Siemens Trio, Grappa 2, av 3). The preprocessing included motion correction and registration to the single subject T1 anatomy.

Results

Surfing the connectome: An interactive combined visualization of structural and functional connectivity

1 Template website at openscience.cbs.mpg.de/brainnetworks.

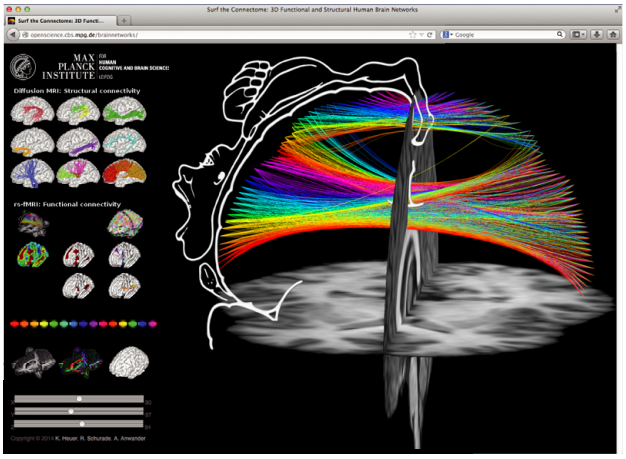


Fig 1. Transcallosal functional connectivity of the precentral gyrus. The end points on the right motor cortex are rainbow coded and show an asymmetric devision into two functional "bundles".

2

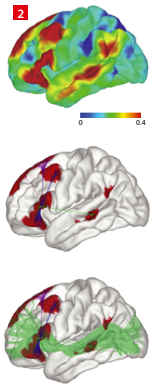


Fig 2. rs-functional connectivity (unthresholded), "bundled" functional connectivity seeded in Broca's area (BA 45) and the underlying inferior fronto-occipital fascicle.

3

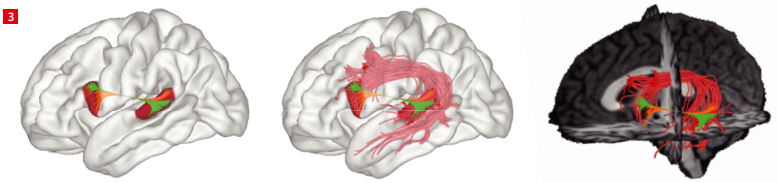


Fig 3. "Bundled" functional connectivity seeded in Broca's area (BA 44) and Wernicke's area and the underlying arcuate fascicle of the language network in relation to anatomical slices and surface.

4

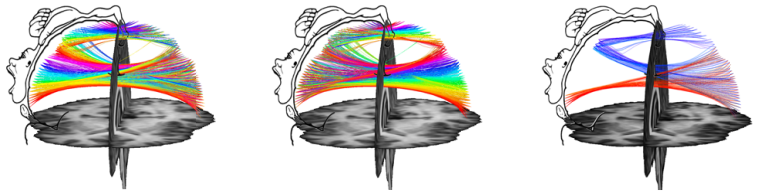
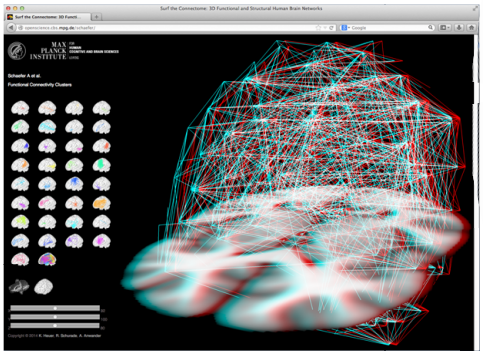


Fig 4. Transcallosal functional connectivity of the precentral gyrus. The end points on right and left motor cortex are rainbow coded for a detailed visualization of the single properties.

Applications

Surfing the connectome: Functional connectivity clusters [3]

5 Publication-specific website at openscience.cbs.mpg.de/schaefer.



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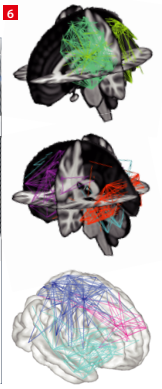
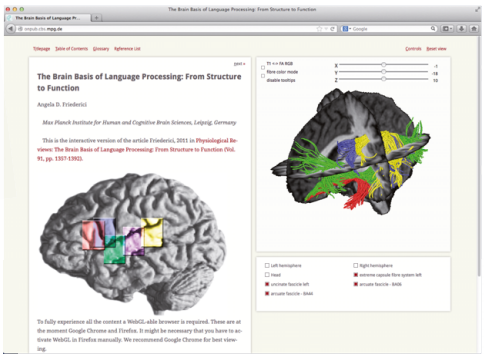


Connectivity networks. Fig 5. All 33 connectivity networks found in the hierarchical cluster analysis of group averaged connectivity. Fig 6. Individually chosen connectivity networks from the 33 found in the hierarchical cluster analysis of time and group averaged connectivity. Networks can be inspected interactively and in three dimensions in relation to anatomical slices and surface and combined to study their interaction.

Surfing the connectome: The brain basis of language processing [2]

7 Publication-specific website at onpub.cbs.mpg.de.



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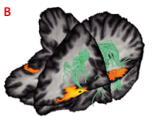
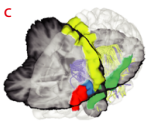


C



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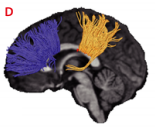

Fig 7. Online-publication with interactive viewer. Each text section is associated with a dedicated scene displaying the currently discussed data from the appropriate camera angle. A. The functional language areas are connected by specific fiber bundles which are color coded. B. Functional connections of the language network with the underlying arcuate fascicle. C. Parcellation of the language cortex and the underlying structural connectivities between the language cortices. D. Interaction of syntax and prosody: The role of the corpus callosum. Option to visualize all other provided fiber tracts by click.

Conclusion

- 3D visualization enhances the **research dissemination process**
- Beneficial for connectome research, task based fMRI or new structural MRI sequences
- Our intuitive webGL based application provides an **easily usable platform for the community**
- Improved ways of online data visualization in terms of scientific content and understanding
- The interactive presentation opens a **new access to the data** which allows new scientific findings
- Improved accessibility of the research results fascilitates **public visibility** of the results
- The **open source** platform is ready to be used as a platform for the next generation of neuro-scientific 3D publications and might become a community driven standard platform.

Outlook: Use as platform for visual exploration and communication between neuroscientists and medical doctors (exchange 3D pictures without installation of any additional visualization software).

References

1 Margulies DS et al. (2013), 'Visualizing the human connectome', NeuroImage, 15: 445–461.

2 Friederici AD (2011), 'The brain basis of language processing: From structure to function', Physiol Rev, 91: 1357–1392. Interactive version available at onpub.cbs.mpg.de.

3 Nathan Kline Institute-Rockland Sample: fcon_1000.projects.nitrc.org/indi/enhanced/.

4 Schaefer A et al. (2014), 'Dynamic network participation of functional connectivity hubs assessed by resting-state fMRI', Front Hum Neurosci, 8: 1–13.

5 Böttger J et al. (2014), 'Three-dimensional mean-shift edge bundling for the visualization of functional connectivity in the brain', IEEE TVCG, 20: 471–480.

brainGL open-source software available at braingl.googlecode.com

brainGL web application available at braingl-web.googlecode.com

Info

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Wednesday & Thursday
June 11 12:45–14:45

openscience.cbs.mpg.de/brainnetworks/Heuer_OHBM_2014.pdf