Metabolic connectivity mapping:
Directed connectivity in the whole brain guided by energy metabolism

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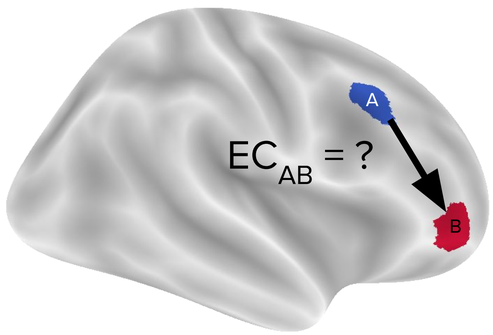
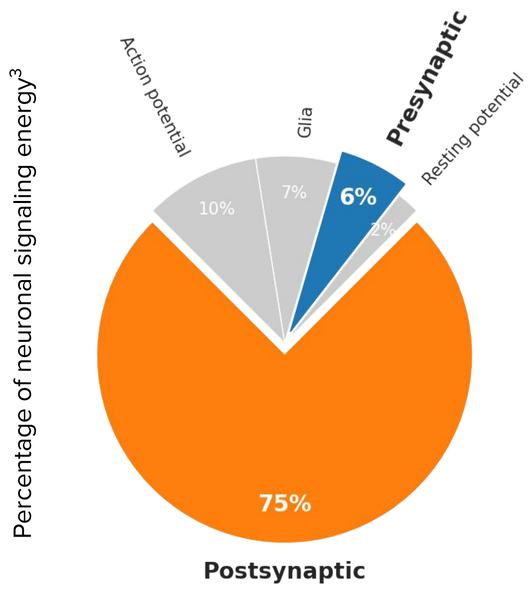
Background



Directed (effective) connectivity is commonly estimated by methods based on Granger causality or Dynamic Causal Modelling.
We develop a novel method to assess directed connectivity. The method relies on principles of neuronal energetics and integrated PET and MRI modalities.
Previous studies applied metabolic connectivity mapping in a limited set of brain regions[1,2]. Here, we use the model for the whole brain.

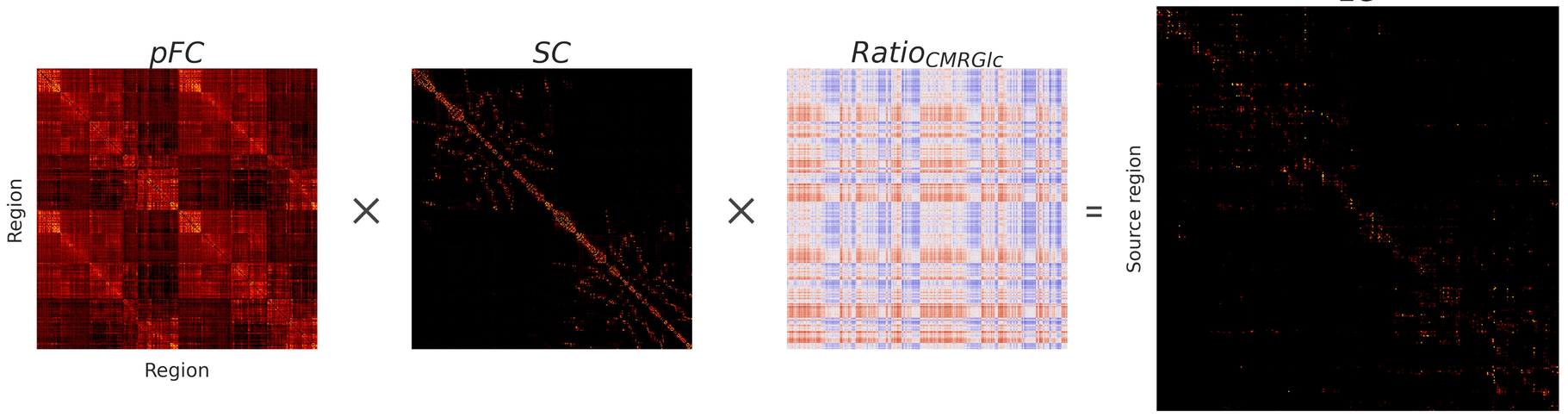


In neuronal signaling, postsynaptic neurons consume the most energy. In particular, the postsynaptic neuron consumes more energy than the presynaptic neuron[3].
We scale this principle to the level of brain regions and networks.
We assume that by aggregation of activity of many neurons, regions that receive the connection, on average, consume more energy than the ones where the connection originates.

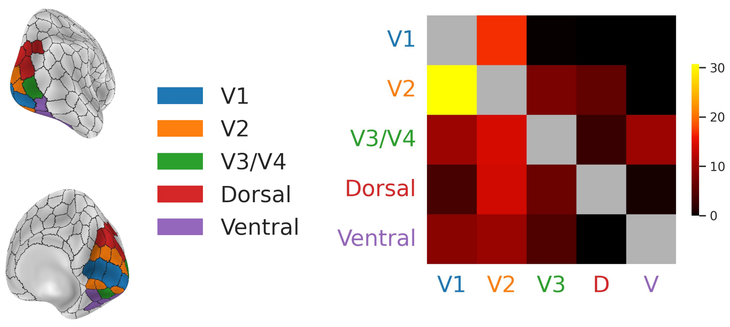
Method

We estimate directed connectivity in three steps:

1. Find similarity between regions' average BOLD fMRI signal with partial correlation (*pFC*).
2. Scale the functional connectivity by structural connectivity (*SC*).
3. Scale by the logarithm of regions' average glucose consumption rate ($Ratio_{CMRGlc}$).
   We use the inverse of the negative values of this matrix in the calculation.



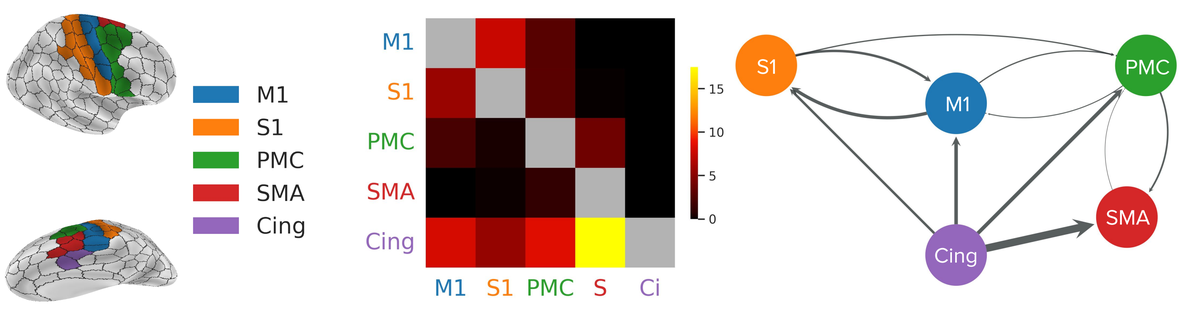
Visual System



- Connectivity along the dorsal and ventral streams.
- Feedback connections are stronger than the feedforward connections.

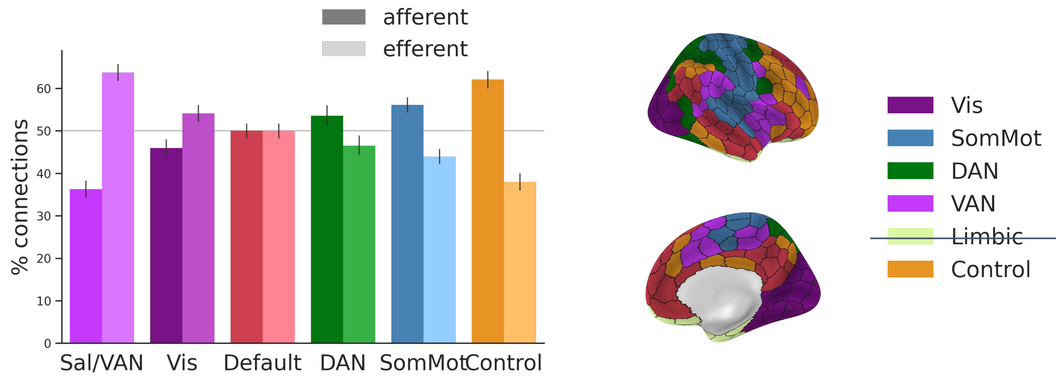
We analyze connectivity in the primary and secondary visual cortices as well as dorsal and ventral areas by overlapping Schaefer (2018) with Glasser (2016) cortical parcellations. The connectivity matrix shows the average percent of connections out of all afferent and efferent connectivity. The arrows' width in the graph is proportional to the percentage of connections.

Sensorimotor System



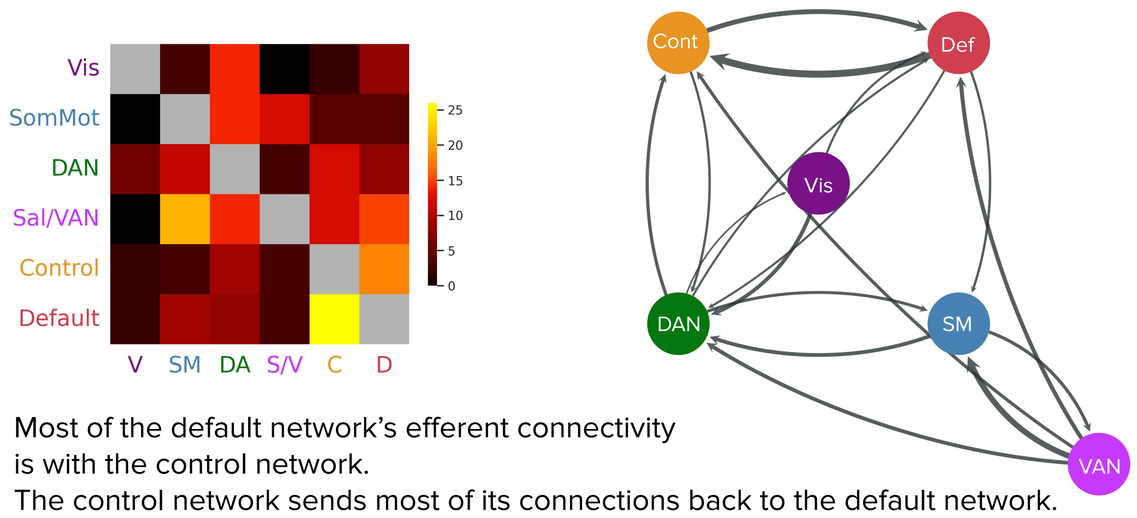
- Bidirectional connectivity between primary sensory/motor cortices.
- Efferent connectivity of the cingulate motor area with the rest of the network. Particularly, the supplementary motor area.

Resting State Networks



- Distinction between the afferent/efferent and the bidirectional networks.

Average afferent and efferent connectivity within Yeo (2011) resting state networks. We excluded the limbic network because of the signal drop-out artifacts in the BOLD data. Values in the bar chart represent the average percent of directed connections within each network.



- Most of the default network's efferent connectivity is with the control network.
- The control network sends most of its connections back to the default network.

The matrix shows directed connectivity between the resting-state networks. Values represent the average percent of connections out of all afferent and efferent connectivity in a network.

References

[1]Riedl, V., Utz, L., Castrillón, G., Grimmer, T., Rauschecker, J. P., Ploner, M., Friston, K., Drzezga, A., & Sorg, C. (2016). Metabolic connectivity mapping reveals effective connectivity in the resting human brain. *Proceedings of the National Academy of Sciences*, *113*(2), 428–433.
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[3]Attwell, D., & Iadecola, C. (2002). The neural basis of functional brain imaging signals. *Trends in Neurosciences*, *25*(12), 621–625.

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