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Methods for naturalistic neuroimaging

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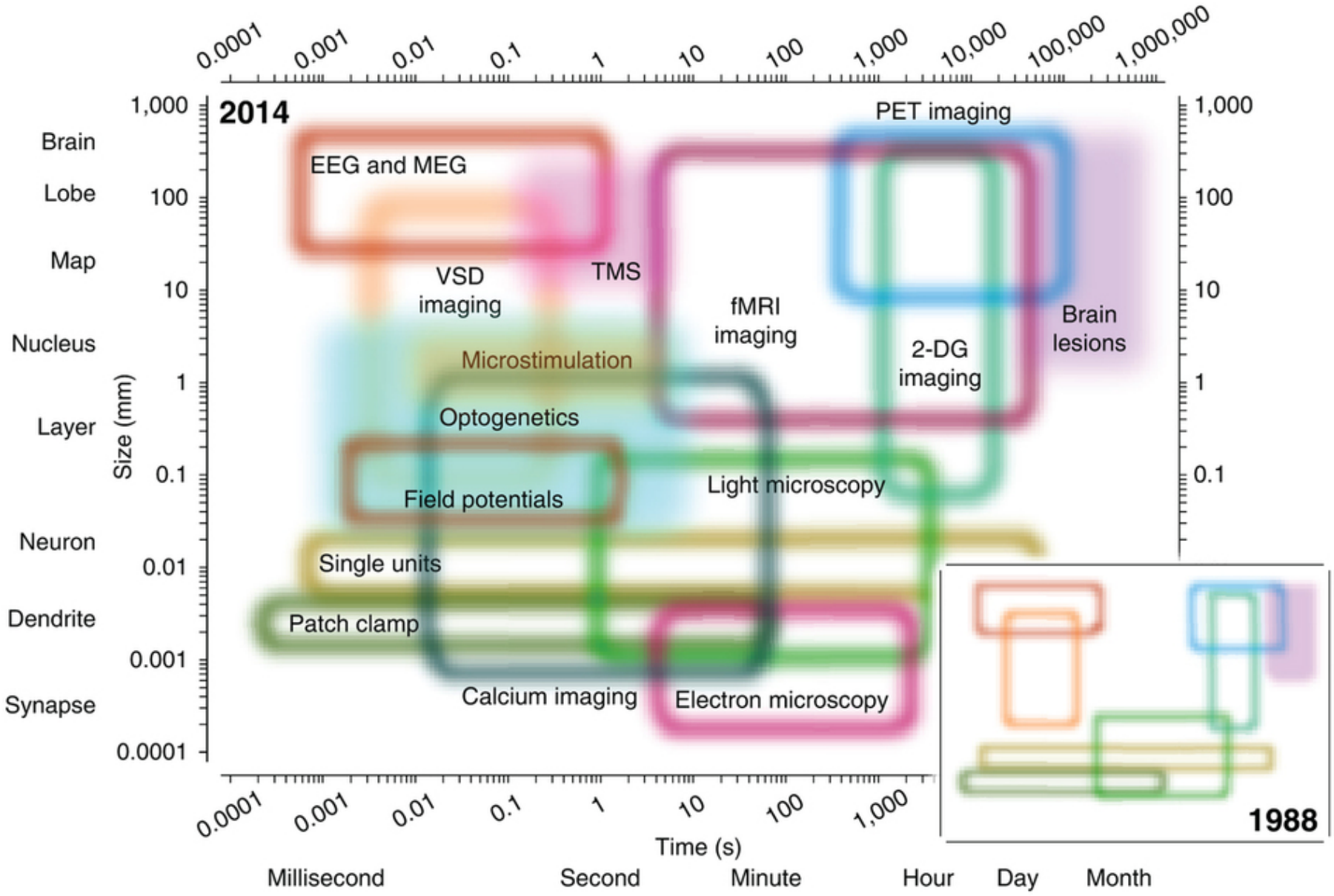
Methods for naturalistic neuroimaging –Outline

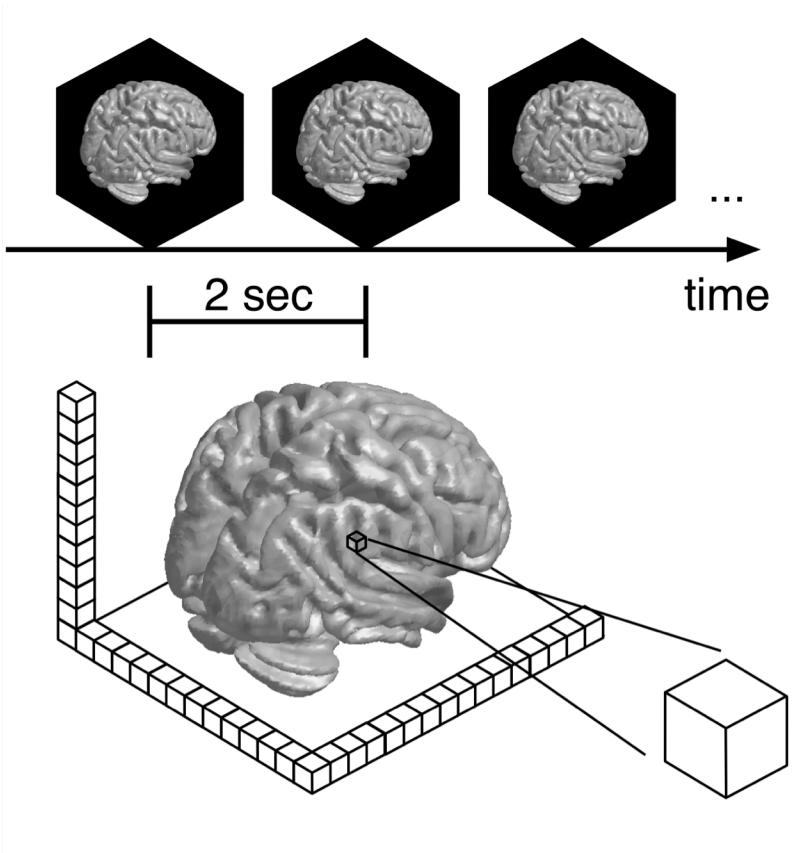
- **Why naturalistic neuroimaging?**
  - ***fMRI + movies***
- **Complex stimuli bring new methodological challenges**
  - ***Intersubject correlation***
  - ***Intersubject phase synchronisation***
  - ***Intersubject functional correlation***
  - ***Intersubject representation similarity analysis***
- **Statistical modelling**
  - ***Statistical considerations***
  - ***Brain & behaviour modelling***
- **Reflections and future directions**

Space and time in neuro-data



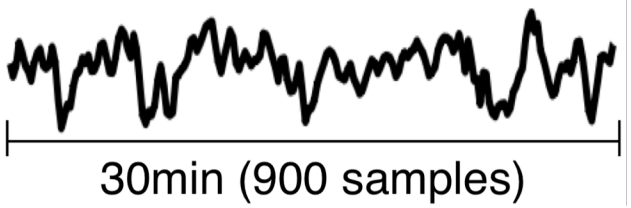
Bassett & Sporns (2017). Network neuroscience. Nature neuroscience.

Functional magnetic resonance imaging (fMRI)



- We measure **multiple time series** at once
- **NOTE:** 1 voxel -> 5.5e6 neurons 4e10 synapses (density ~1/1000) [Logothetis 2008 Nature]

Blood Oxygen Level signal



Why naturalistic neuroimaging?

- **Naturalistic paradigms:** using movies, audio narratives, music, videogames and other engaging activities during brain scanning (usually fMRI or M/EEG).
  NeuroImage S.I. curated by Vanderwal, Finn and Glerean.

Why naturalistic neuroimaging?

- **Naturalistic paradigms**
  - *Pro:* ***closer to real life, only way to study some mental processes*** *(e.g. processing structure in narratives or movies)*
  - *Pro: growing number of labs agree this is* ***the way to go in the future*** *(see Gallant's lab work in Nature 2016)*
  - *Cons: reviewers complain:* ***lots of uncontrolled stimulus features***
  - *Cons:* ***stimulus is the same for all subjects***

Some essential reviews from past months:

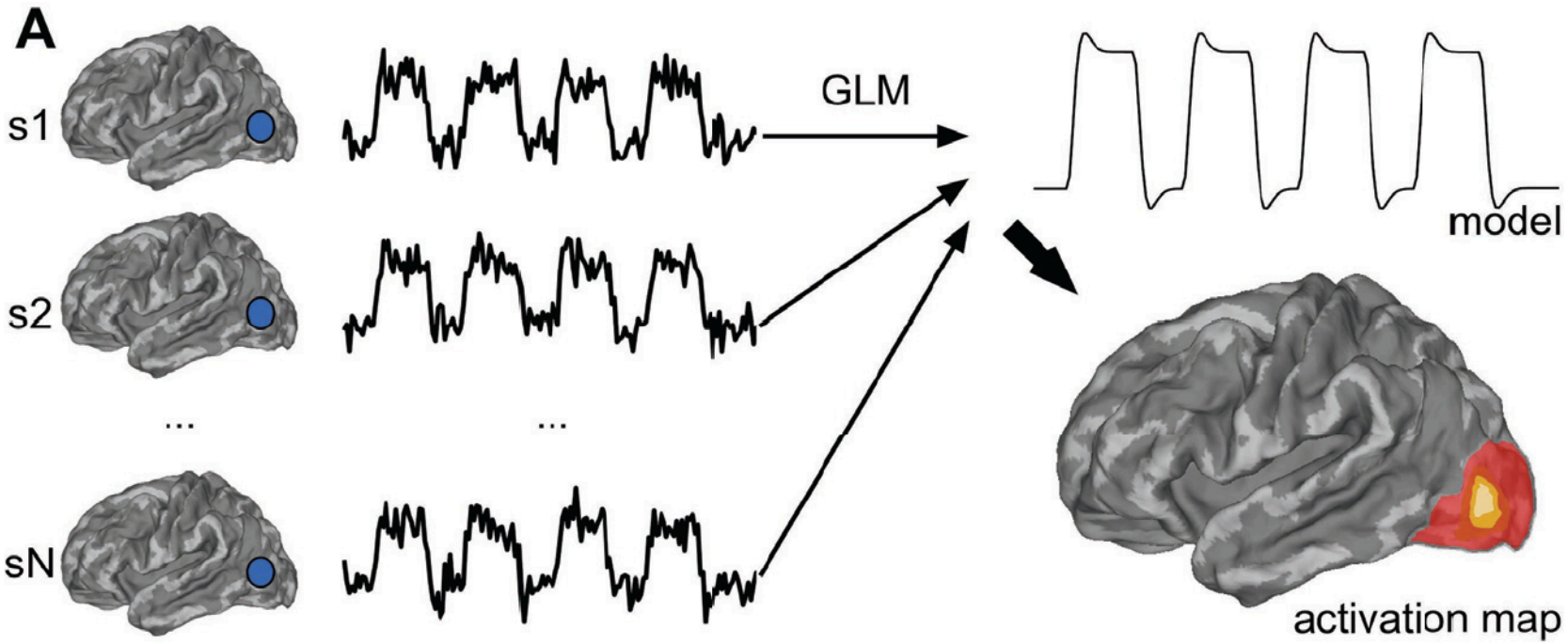
- Sonkusare, S., Breakspear, M., & Guo, C. (2019). Naturalistic stimuli in neuroscience: Critically acclaimed. *Trends in cognitive sciences*.
- Eickhoff, S. B., Milham, M., & Vanderwal, T. (2020). Towards clinical applications of movie fMRI. *NeuroImage*, 116860.

Analysing naturalistic imaging data

1) Intersubject correlation

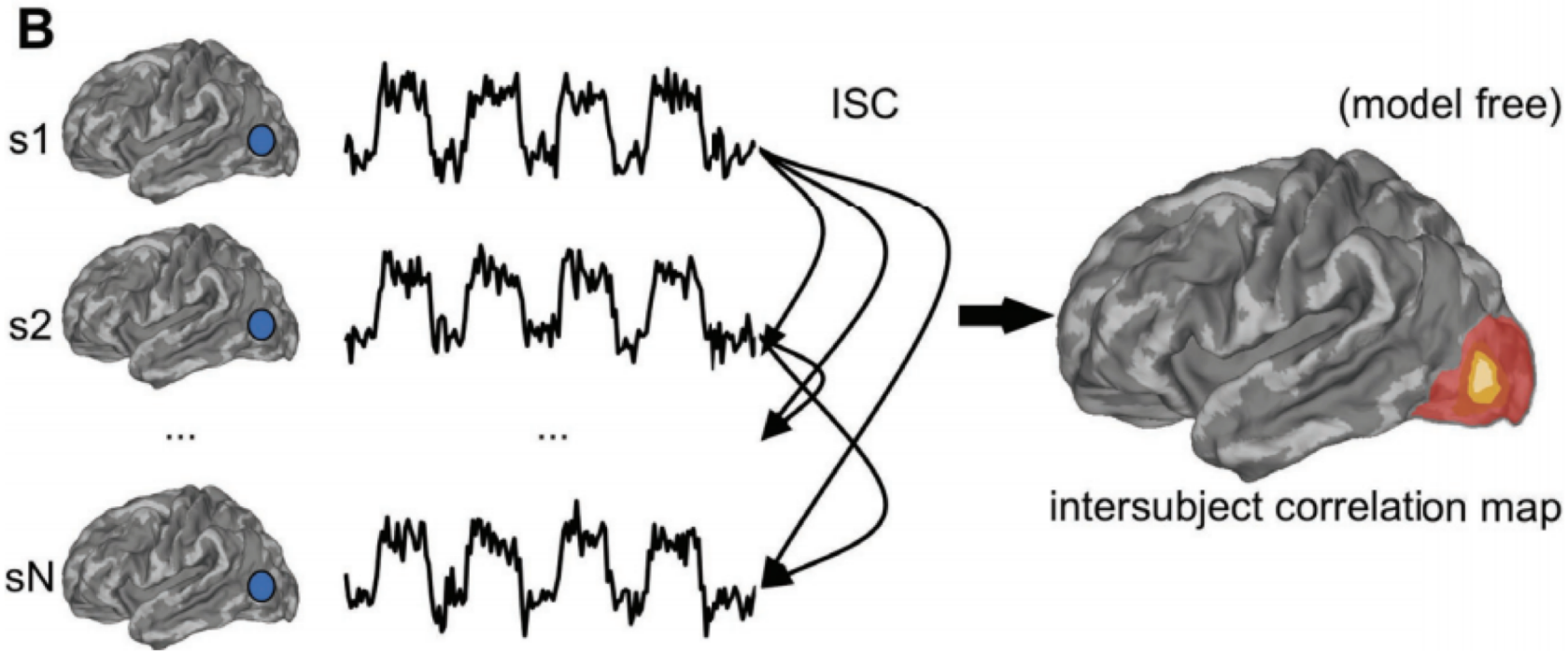
Individual responses to a model

Controlled experiments with a known model (General linear model)

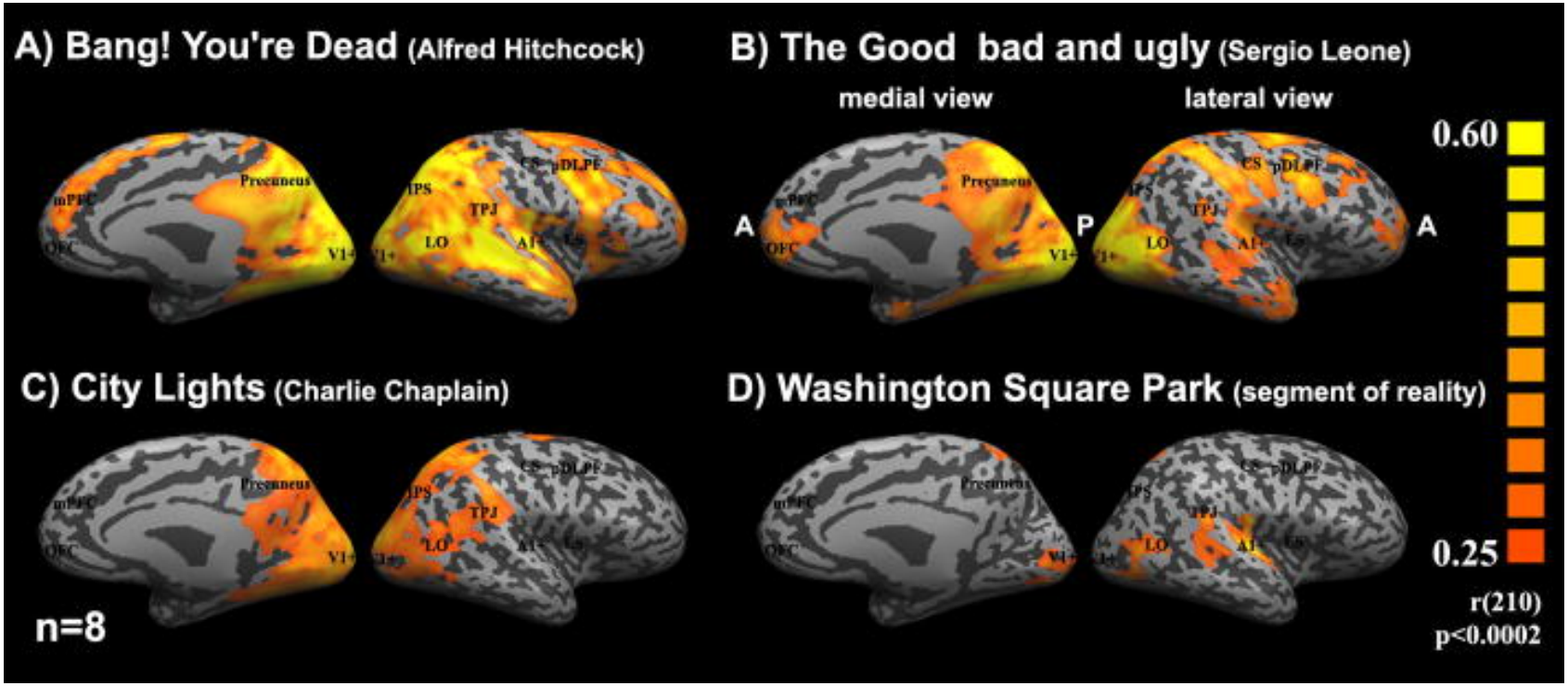


Intersubject Correlation (ISC)

Model unknown (e.g. complex audio/visual stimulation). Other subjects' activity becomes the model!



Measuring functional similarity – Intersubject Correlation (ISC)

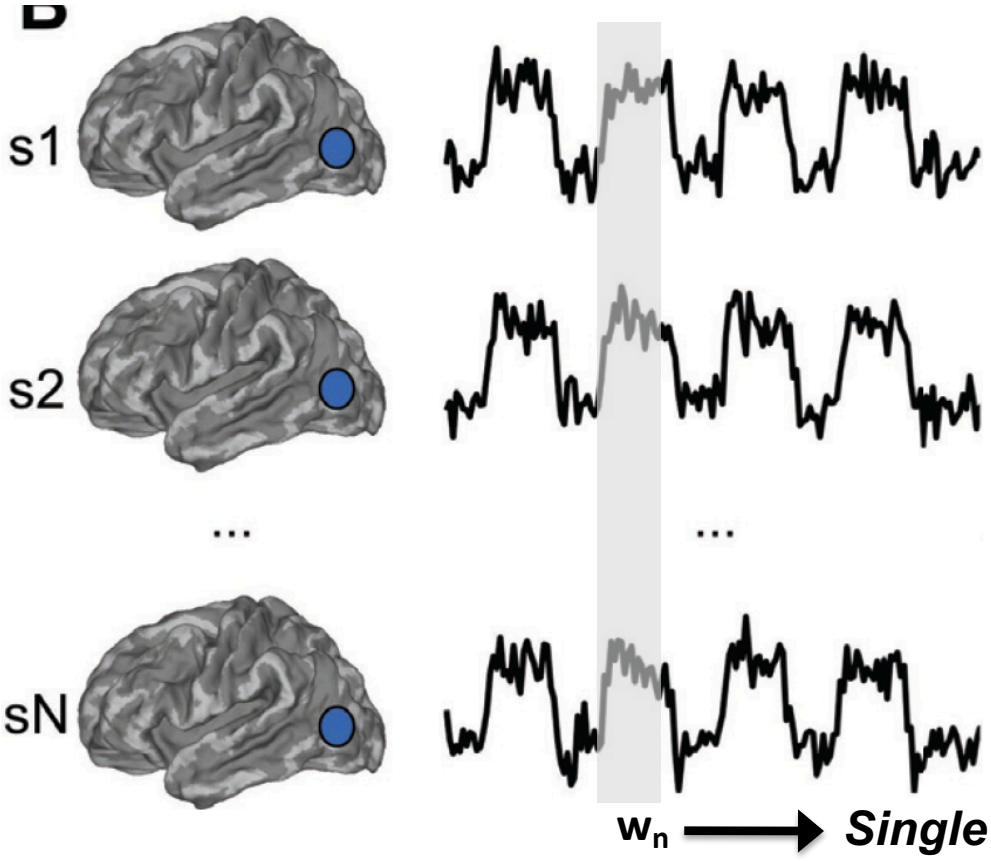


Hasson et al. (2010) Trends in Cognitive Sciences

Complex stimuli are constantly changing

2) dynamic ISC

Dynamic ISC: functional similarity in time

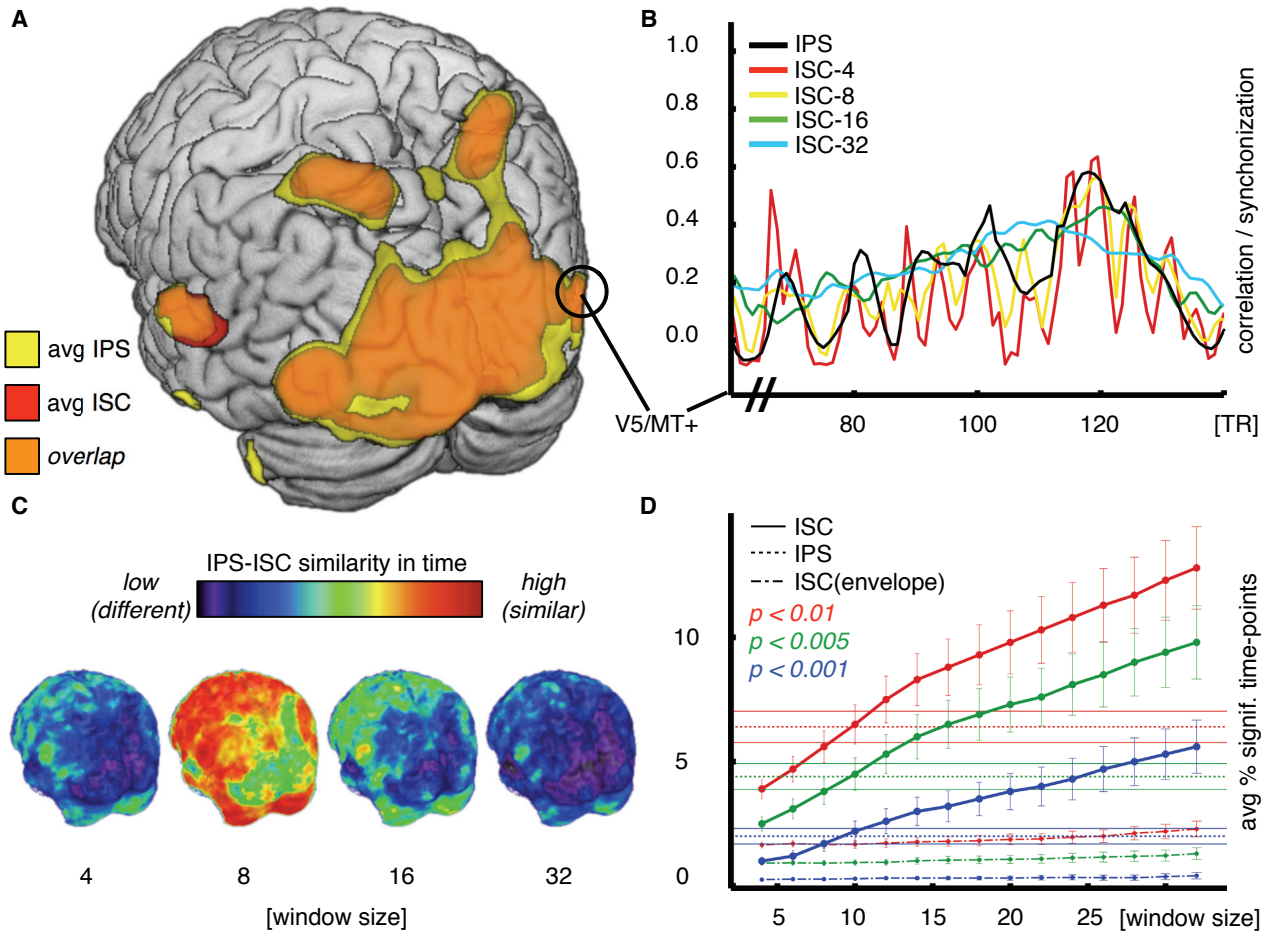


Sliding window intersubject correlation produces time-series of group-level brain activity similarity.

Complex stimuli are constantly changing 2

3) intersubject phase synchronisation

Intersubject phase synchronisation



Average ISC matches temporal average of IPS

Short ISC windows provide noisy ISC time series.

Longer ISC windows are missing the fast changes

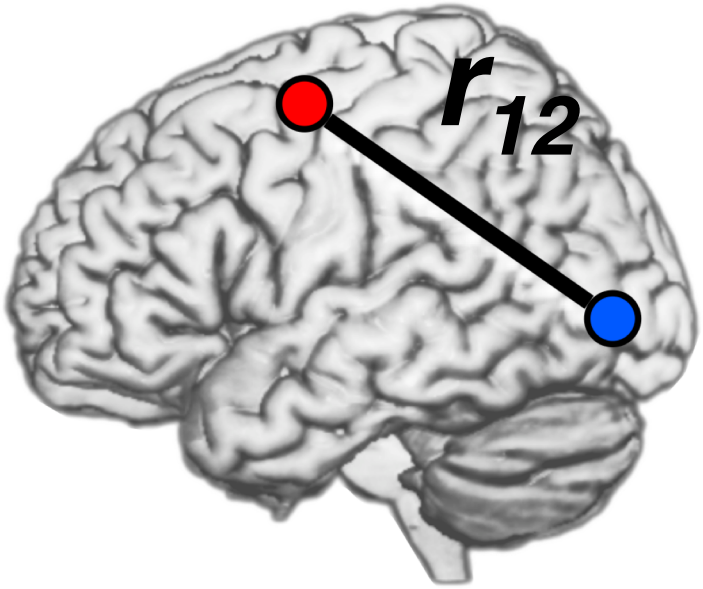
IPS and sliding window ISC seem to match at windows of size 10

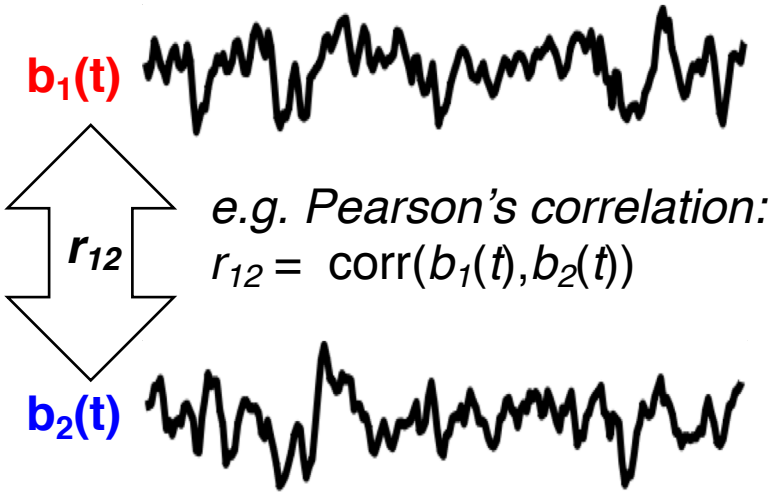
Glerean et al (2012) **Functional Magnetic Resonance Imaging Phase Synchronization as a Measure of Dynamic Functional Connectivity**

Functional connectivity with naturalistic imaging

4) functional networks

Functional connectivity and graph theory (network science)





e.g. Pearson's correlation:

$r_{12} = \text{corr}(b_1(t), b_2(t))$

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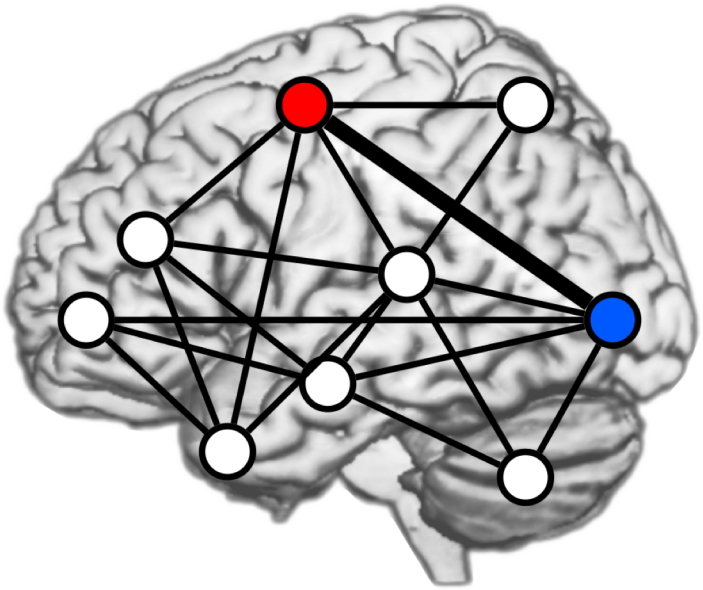
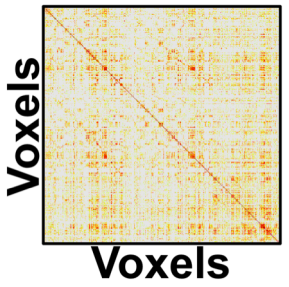
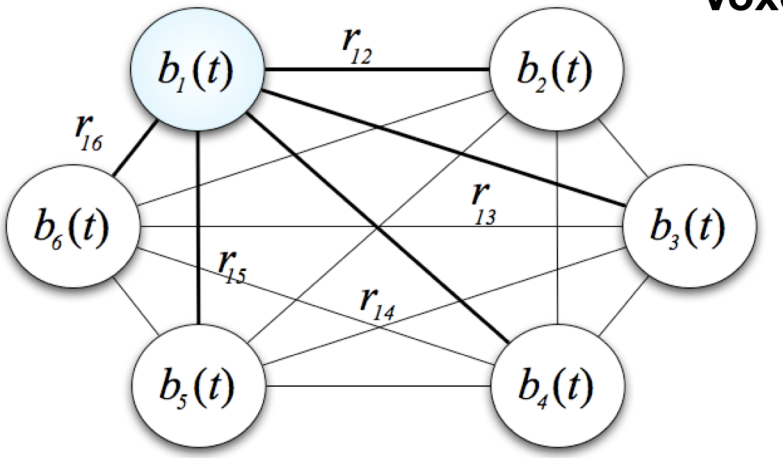
Building a functional network

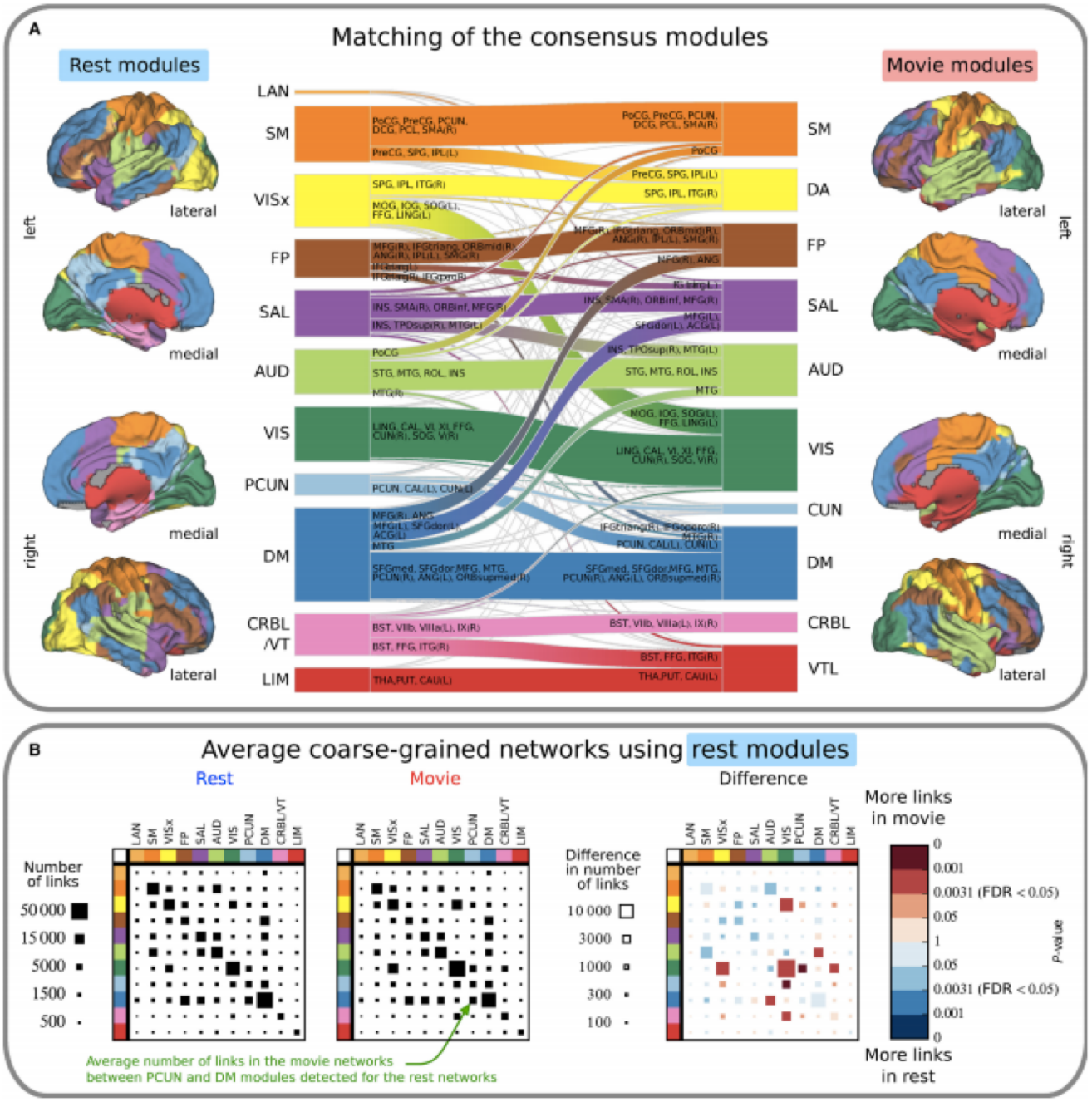
Repeat for all pairs of nodes and we get the full functional network







Eric Glen
www.glenserver.net

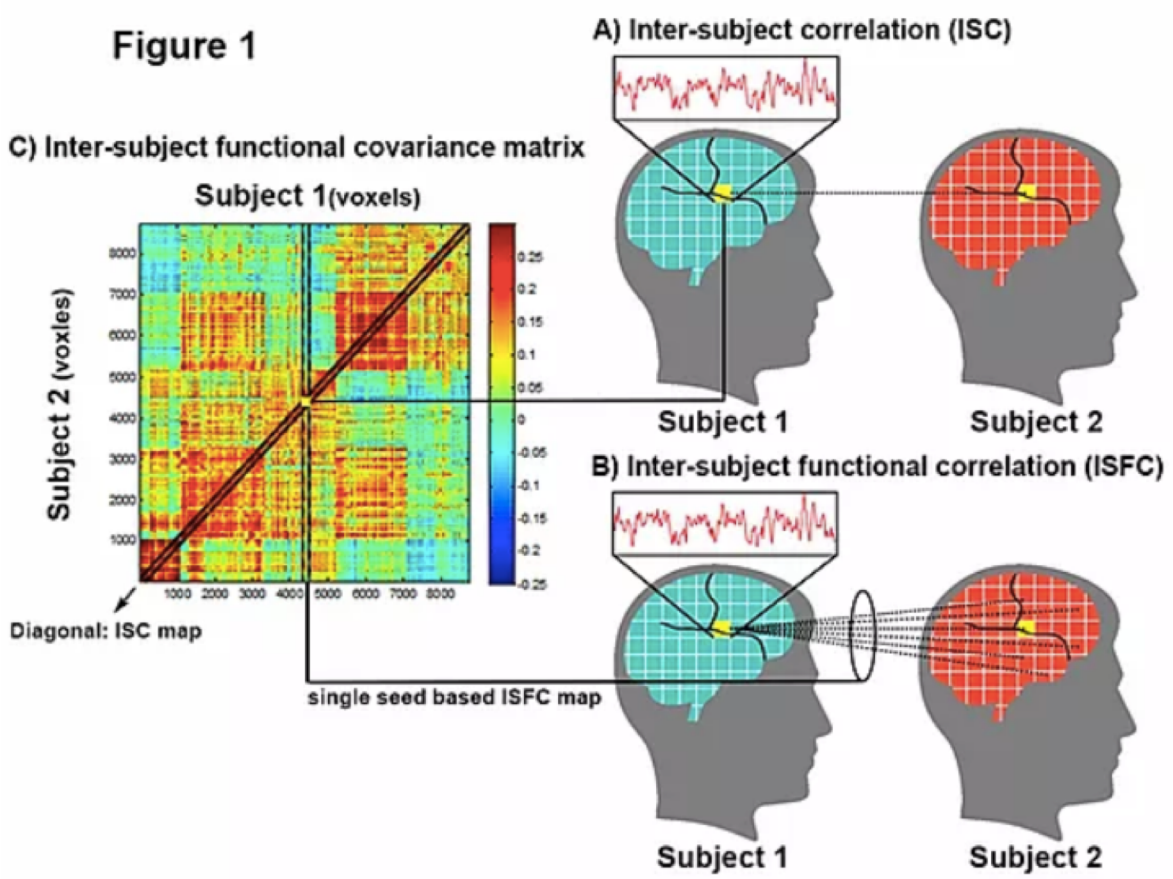


Kujala, Glerean, E. et al. (2016). European Journal of Neuroscience

Functional connectivity with naturalistic imaging 2

5) intersubject functional connectivity

Separating the functional network that is extrinsic (stimulus dependent) from the intrinsic one



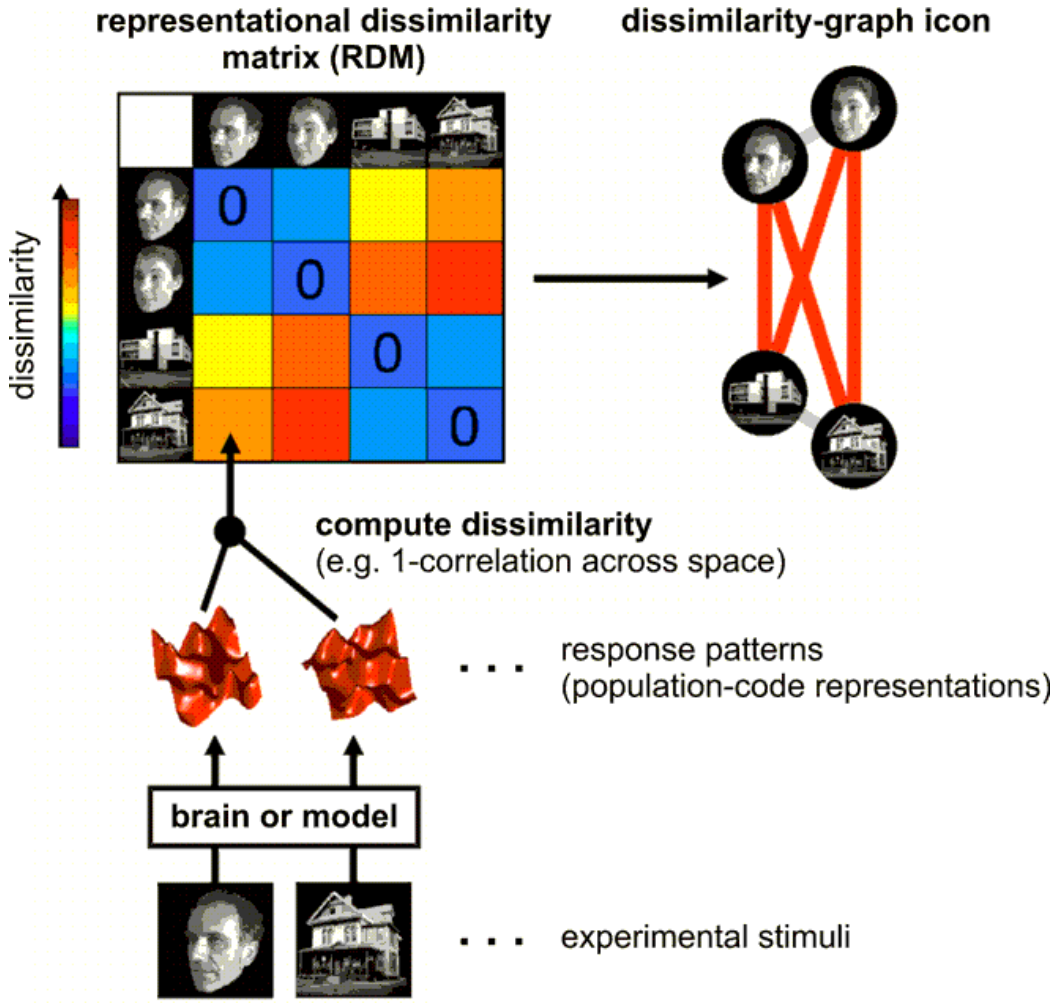
Simony E, Honey CJ, Chen J, Lositsky O, Yeshurun Y, Wiesel A, Hasson U (2016) Dynamic reconfiguration of the default mode network during narrative comprehension. Nat Commun 7.

Inter-individual differences

6) intersubject representational similarity analysis

Representational similarity analysis

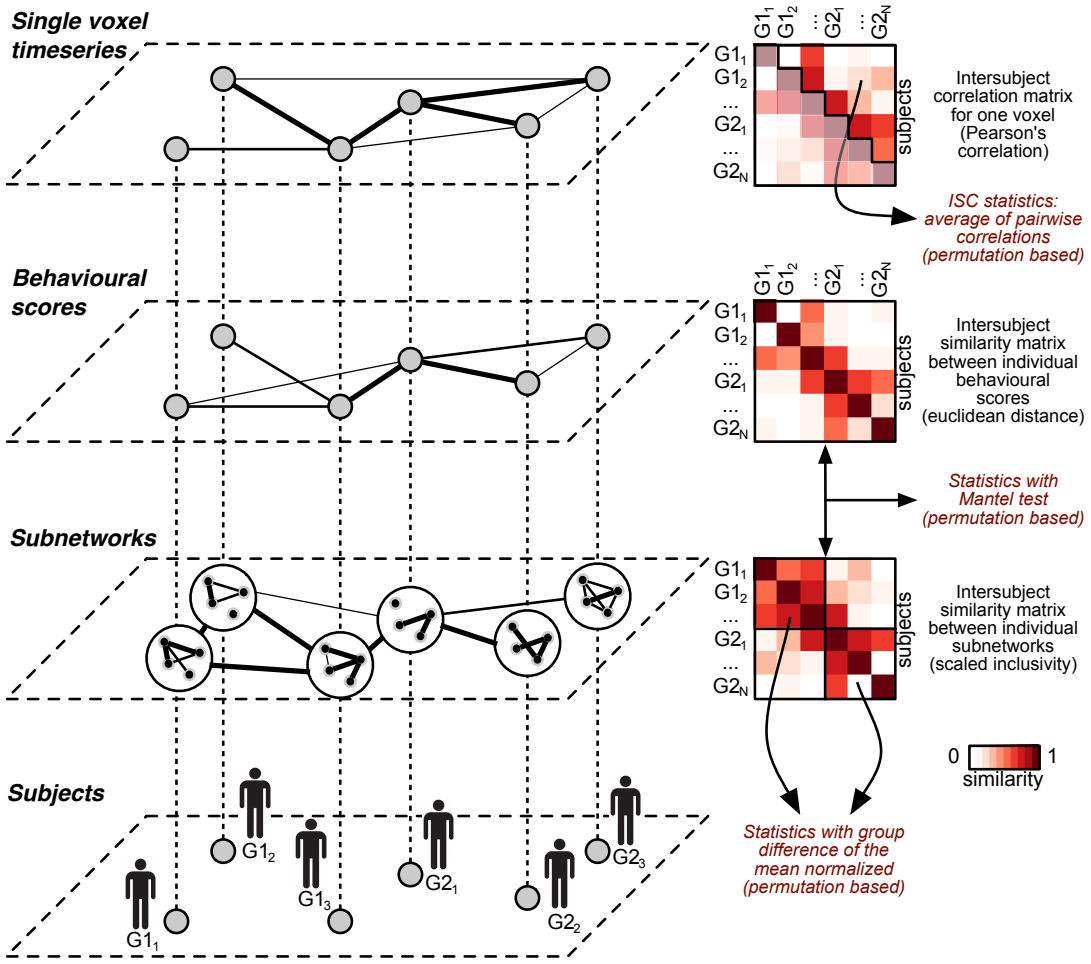
Instead of testing a one-to-one relationship between a stimulus model and brain response (GLM), **RSA** tests that the **similarity of brain responses** is related to the **similarity of the stimuli presented (Mantel test)**



Kriegeskorte et al. 2008

Intersubject analysis framework

- **RSA** can be re-used for similarities across subjects
- **Mantel test** (comparison between similarity matrices)
- **Comparing within groups/conditions similarities**



Glerean et al. 2016
Finn, Glerean, et al. 2020

…and statistics?

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Naturalistic paradigms – statistical considerations

Embrace permutations!

Due to the nature of ISC, **there is no data independence**. The only way to deal with statistical inference is to **adopt permutation based approaches for all statistical analysis**.

Some papers:

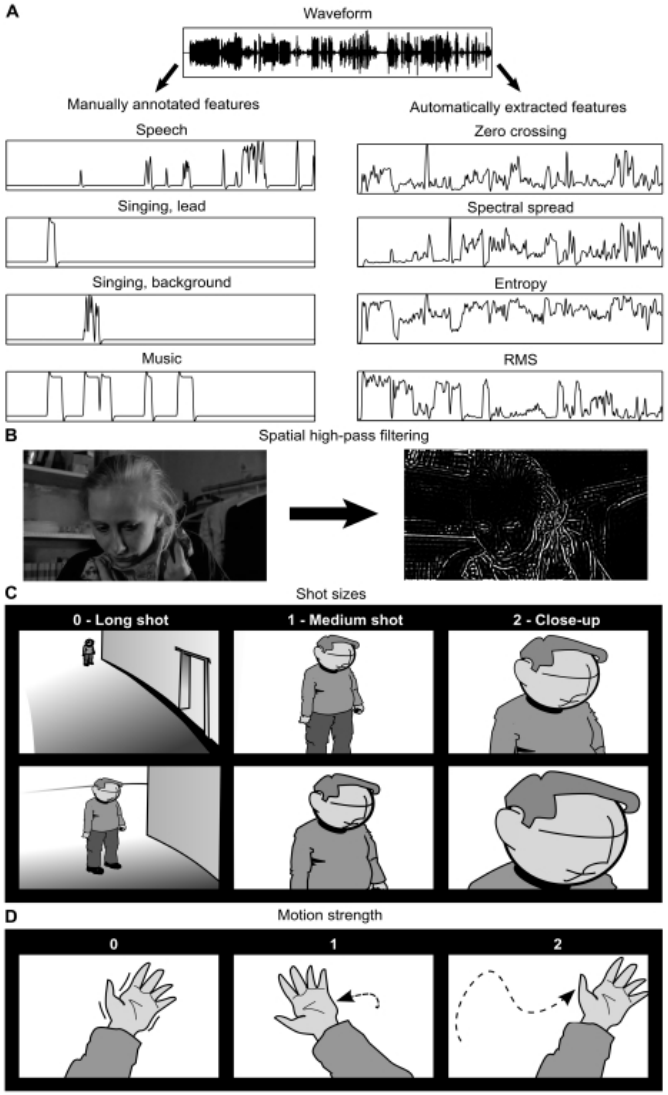
https://pubmed.ncbi.nlm.nih.gov/27195792/

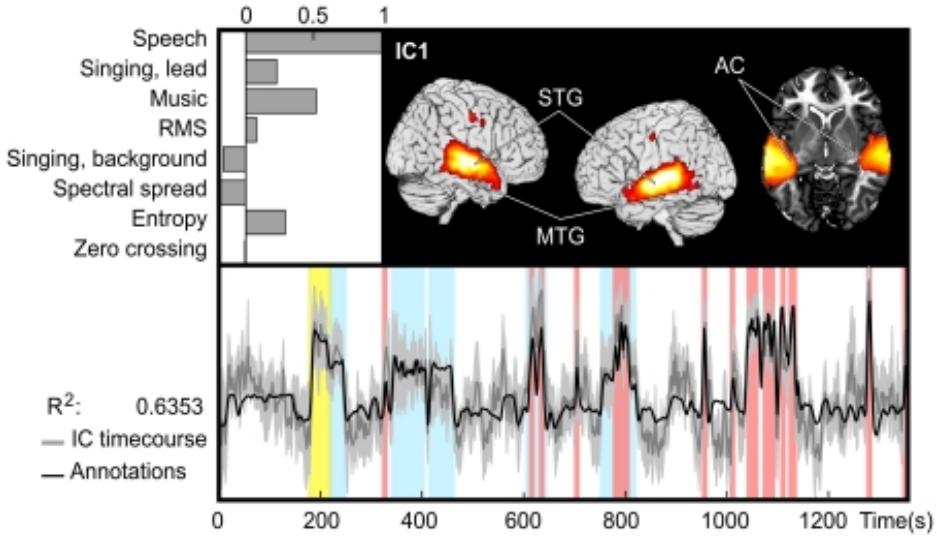
https://pubmed.ncbi.nlm.nih.gov/27751943/

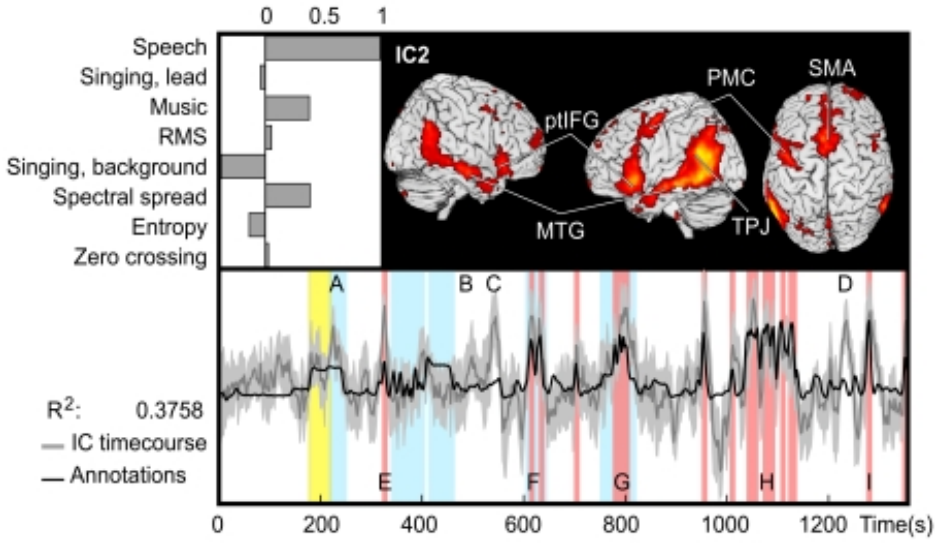
…and behaviour?

Model based analysis with automated feature extraction

Modelling of naturalistic stimuli and then using GLM







Lahnakoski et al. (2012)

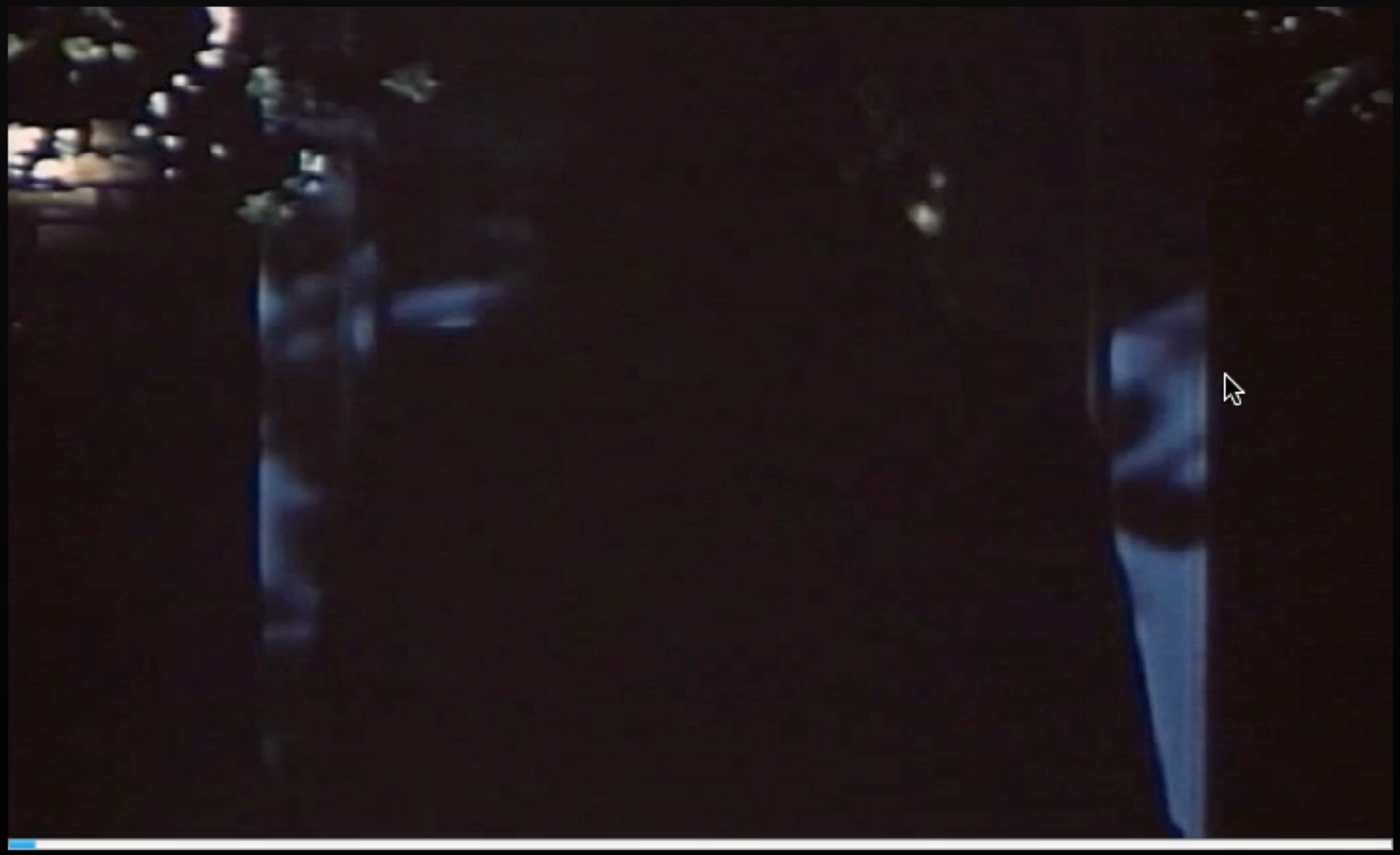
Model based analysis with behavioural annotations

Please annotate the amount of Valence in time by using the mouse

+ positive valence

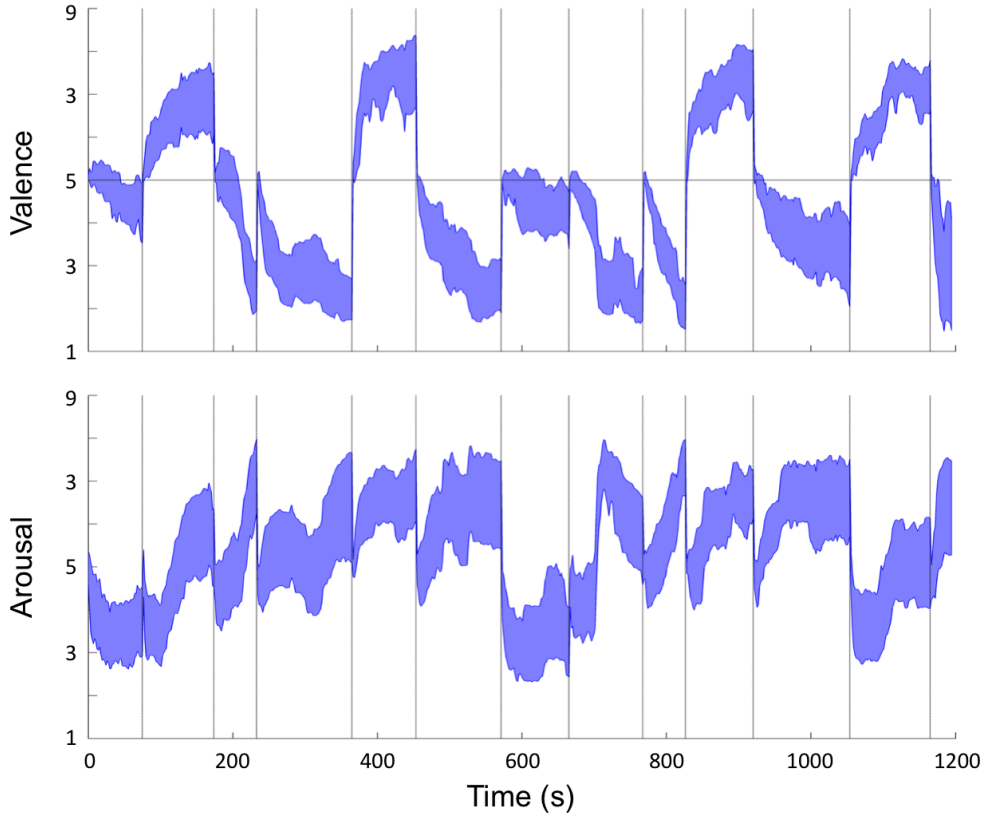
- negative valence

1.9 of 91.5 seconds



Participants' annotations used to model brain activity

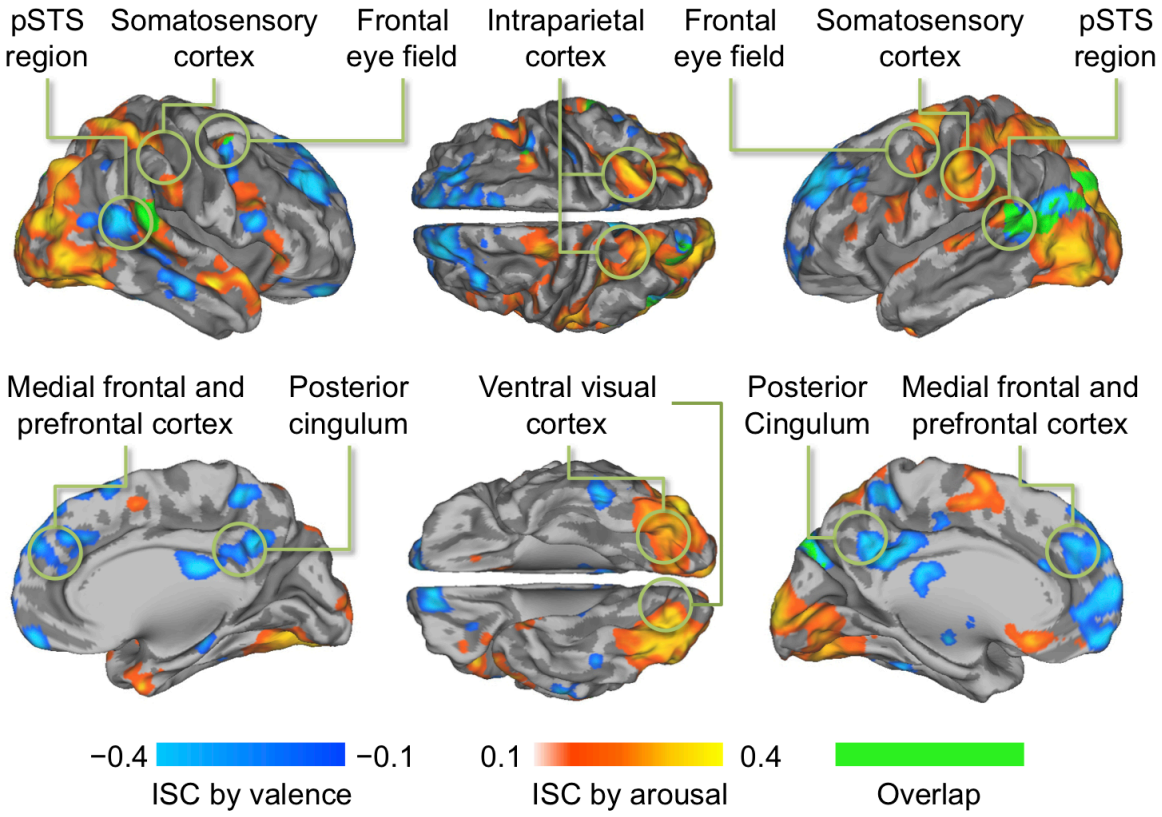
- **Average valence/arousal**



Nummenmaa, L., Glerean, E. et al. (2012). **Emotions promote social interaction by synchronizing brain activity across individuals.** PNAS 109(24), 9599–604.

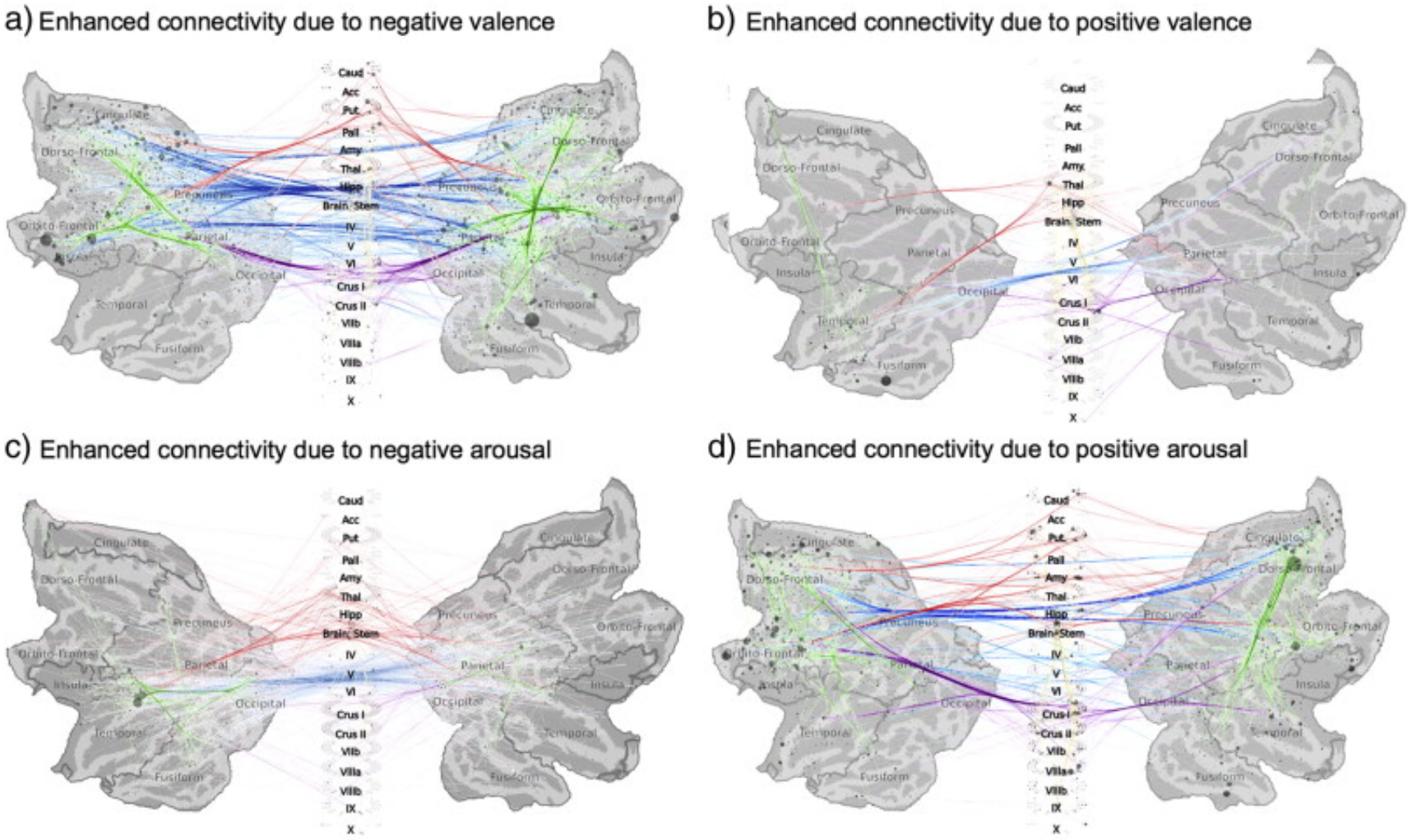
Participants' annotations used to model brain activity

- **Intersubject correlation modulated by valence/arousal**



Nummenmaa, L., Glerean, E. et al. (2012). **Emotions promote social interaction by synchronizing brain activity across individuals.** PNAS 109(24), 9599–604.

Brain networks in emotions



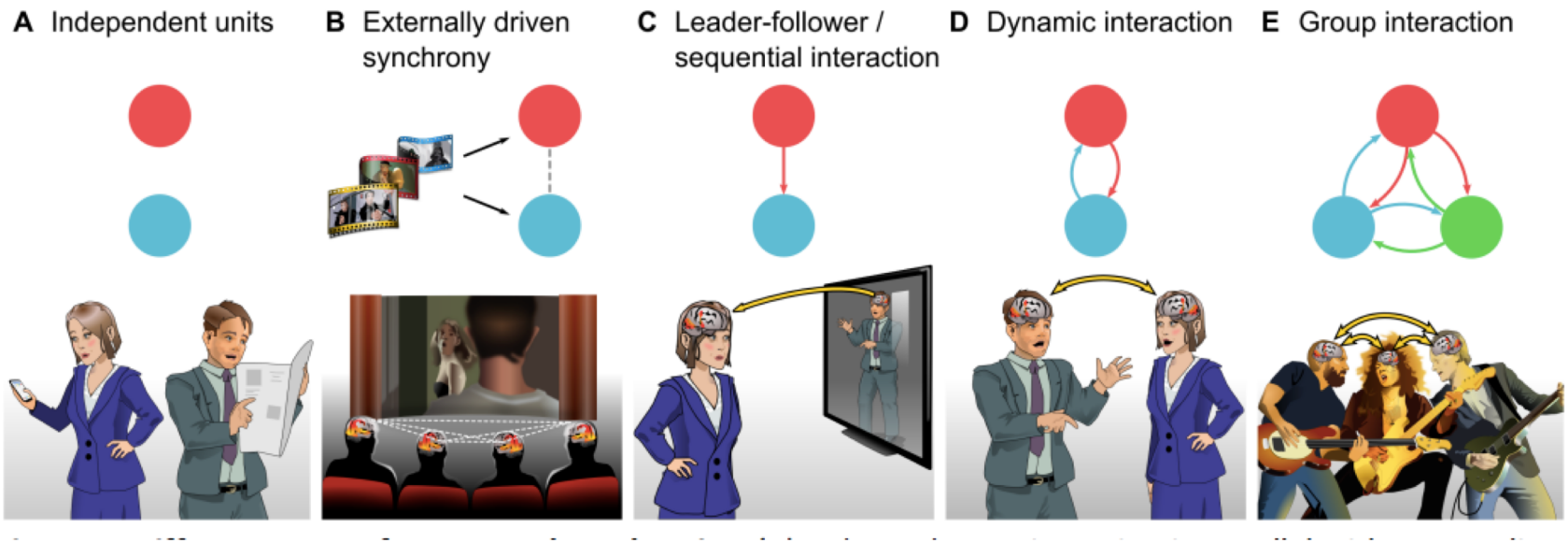
Nummenmaa, Saarimäki et al. (2014) Neuroimage

Reflections and future directions

Reflections and future directions

More complex paradigms are being explored

*Nummenmaa, Lahnakoski, **Glerean** 2018*



More work when it comes to transparent and open methods https://figshare.com/articles/Community-driven_methods_development_in_naturalistic_neuroscience/12366944/1