Model-free analysis of fMRI

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Possible issues of model-based analyses

- Require hypotheses
  - What do we now and expect to happen in the brain?
- Estimation of haemodynamic response function
  - What does the brain response look like?
  - Unlikely similar in all brain areas
- Interpretational difficulties with complex models
  - Did we answer to this question with this model?
- A ton of researcher degrees of freedom
  - Replicatibility of the findings?

Model-free analysis techniques

Blind signal separation

- Independent component analysis (ICA) & principal component analysis (PCA)

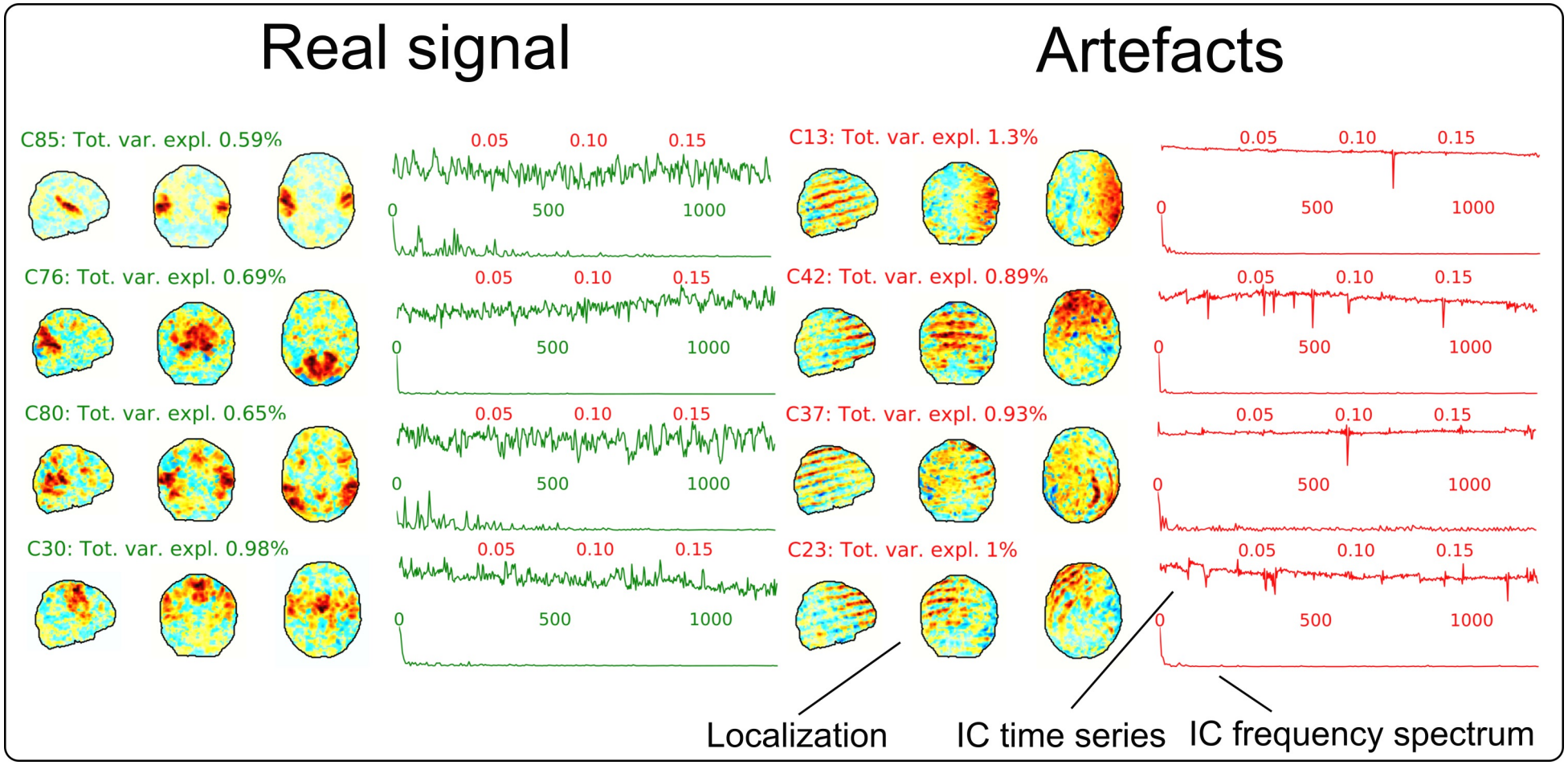
Syncronization analyses

- Intersubject correlation analysis (ISC)
- Time-window ISC analysis
- Intersubject phase synchorisation analysis (ISPS)
- Intersubject functional connectivity analysis (ISFC)

Blind signal separation

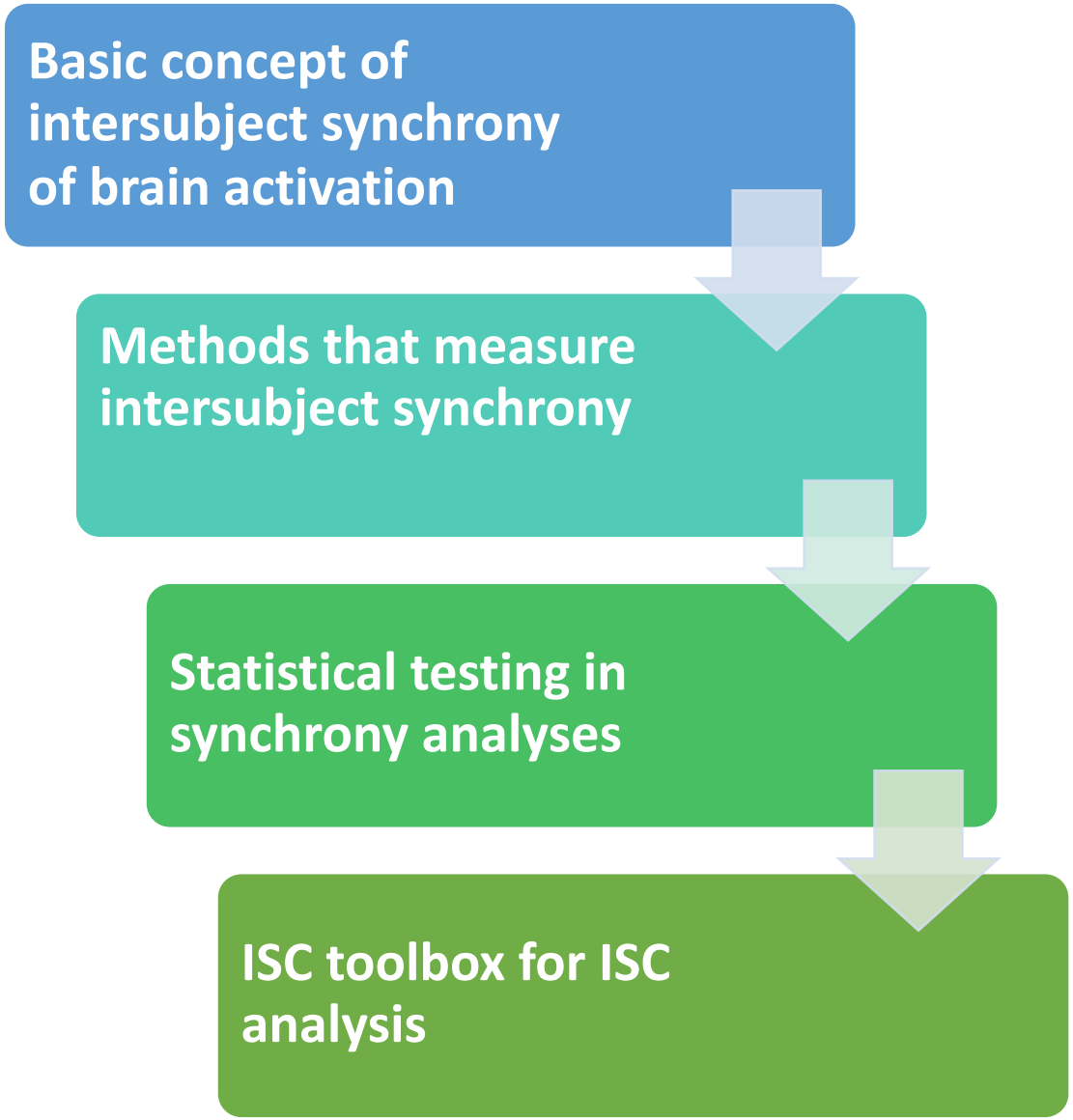
- **Motivation:** To extract different or mutual sources of information from a set of variables wirthout prior knowledge
- **Input data**
  - Audio signals from different microphones
  - fMRI signals from different voxels / brain areas
- **Independent component analysis (ICA)**
  - Finds independent sources of information
  - Separate two different speakers from mixed audio signals
- **Principal component analysis (PCA)**
  - Finds uncorrelated components that explain the mutual variance of the source signals
  - Shared component between two speakers, audio intensity?

Independent component analysis (ICA)



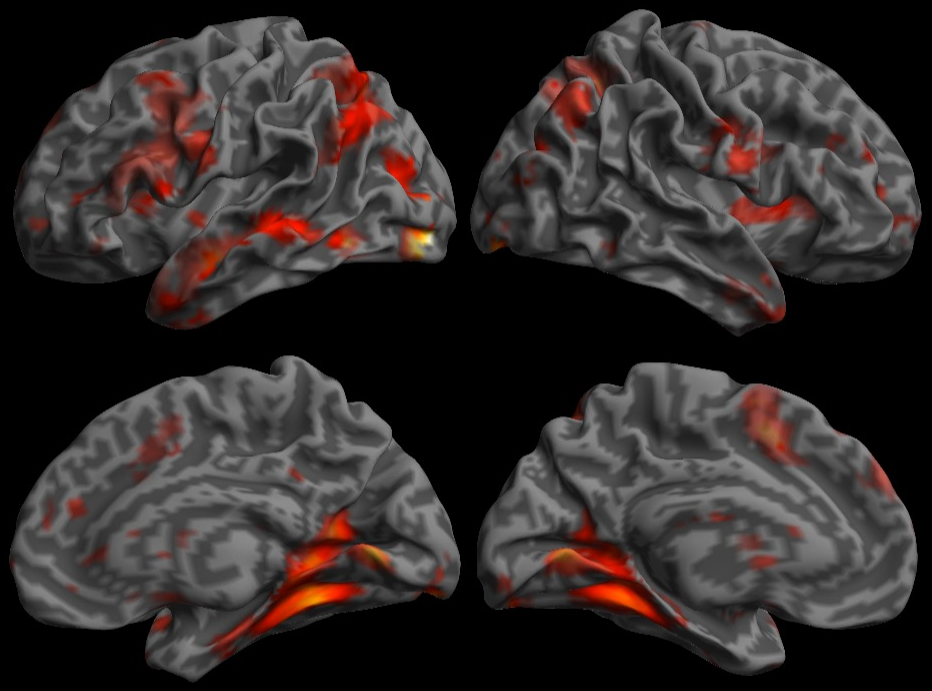
(Pruim, 2015)

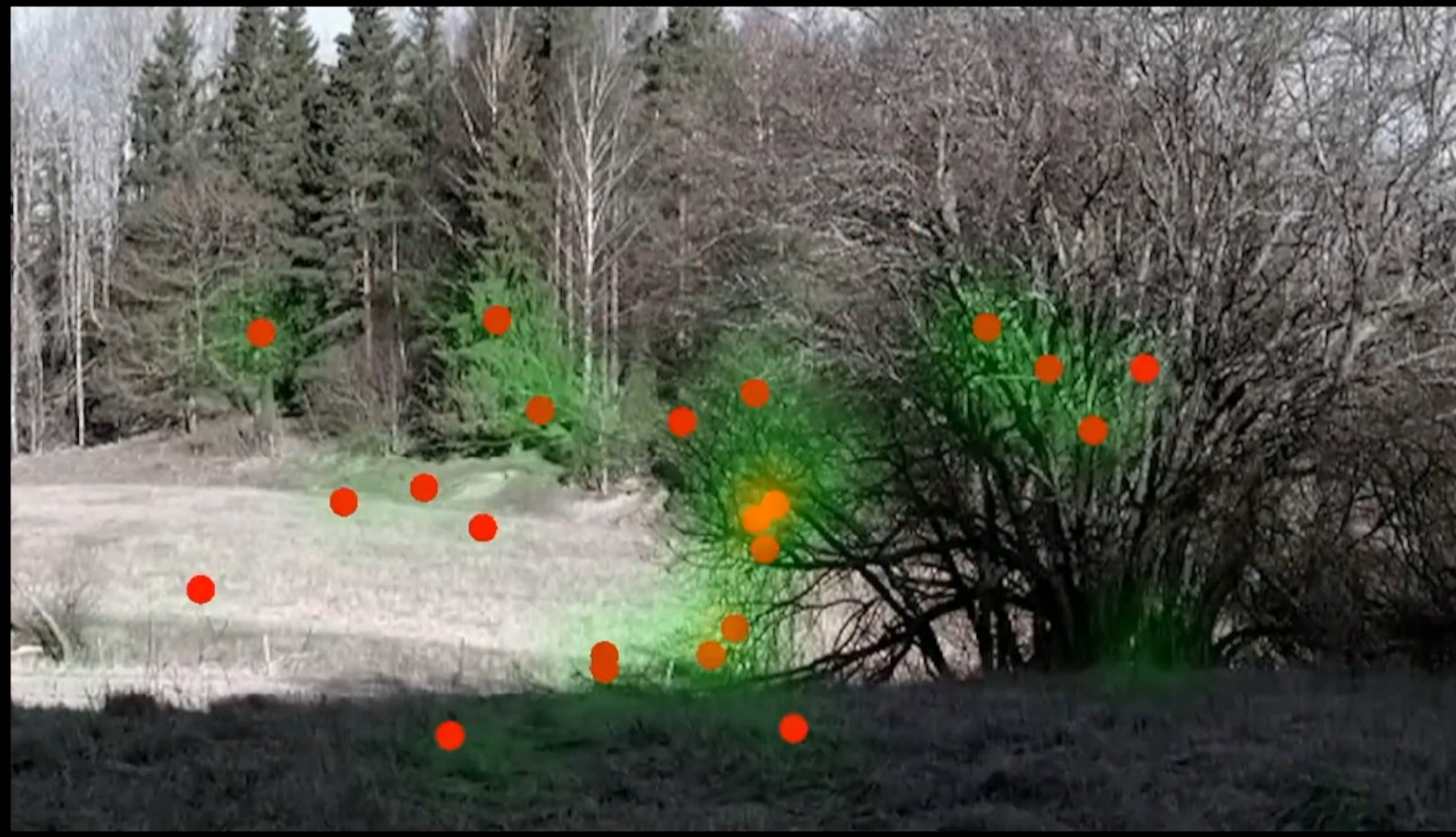
Topics

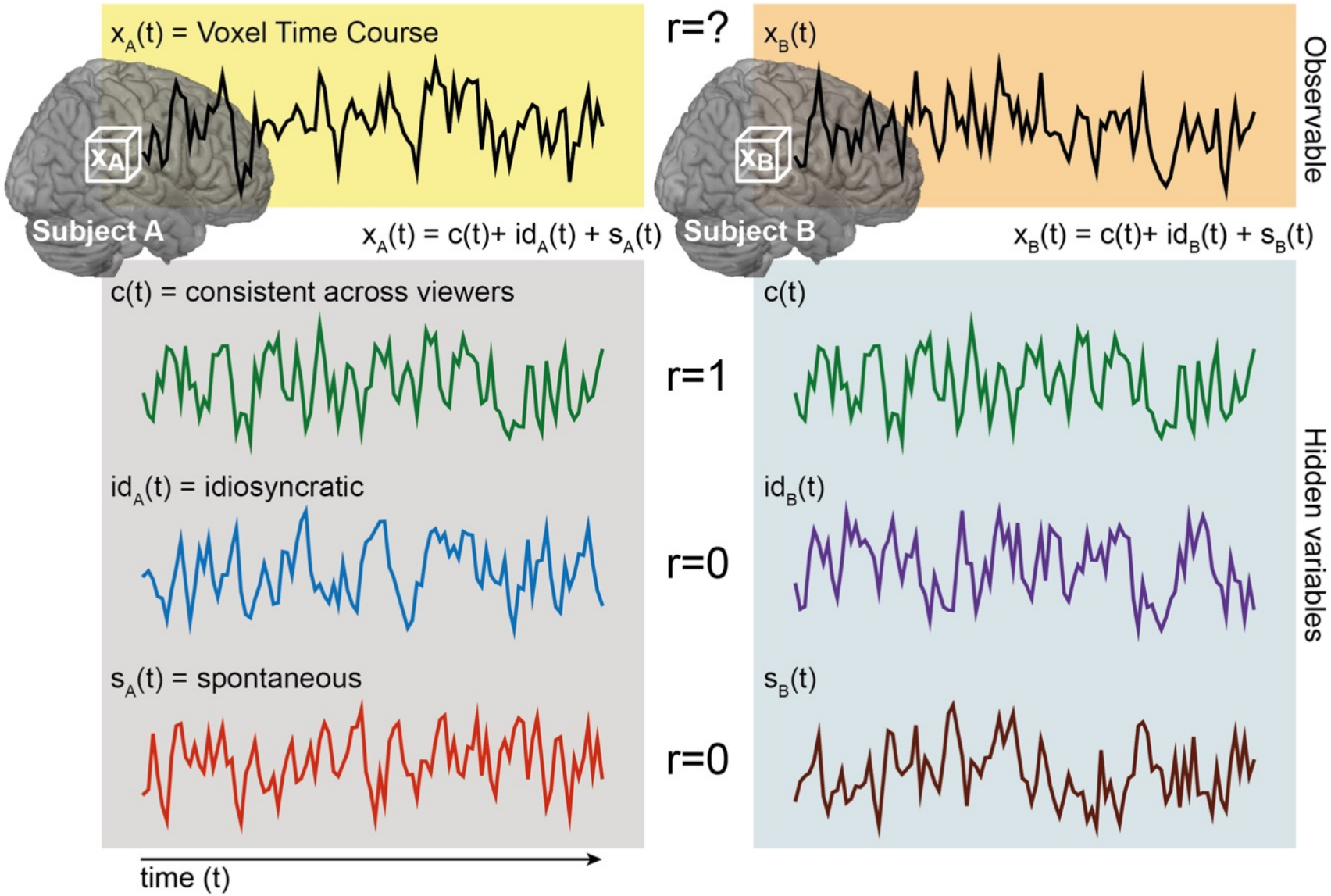

Basic concept of intersubject synchrony of brain activation
Methods that measure intersubject synchrony
Statistical testing in synchrony analyses
ISC toolbox for ISC analysis

Films induce consistent brain activation across subjects

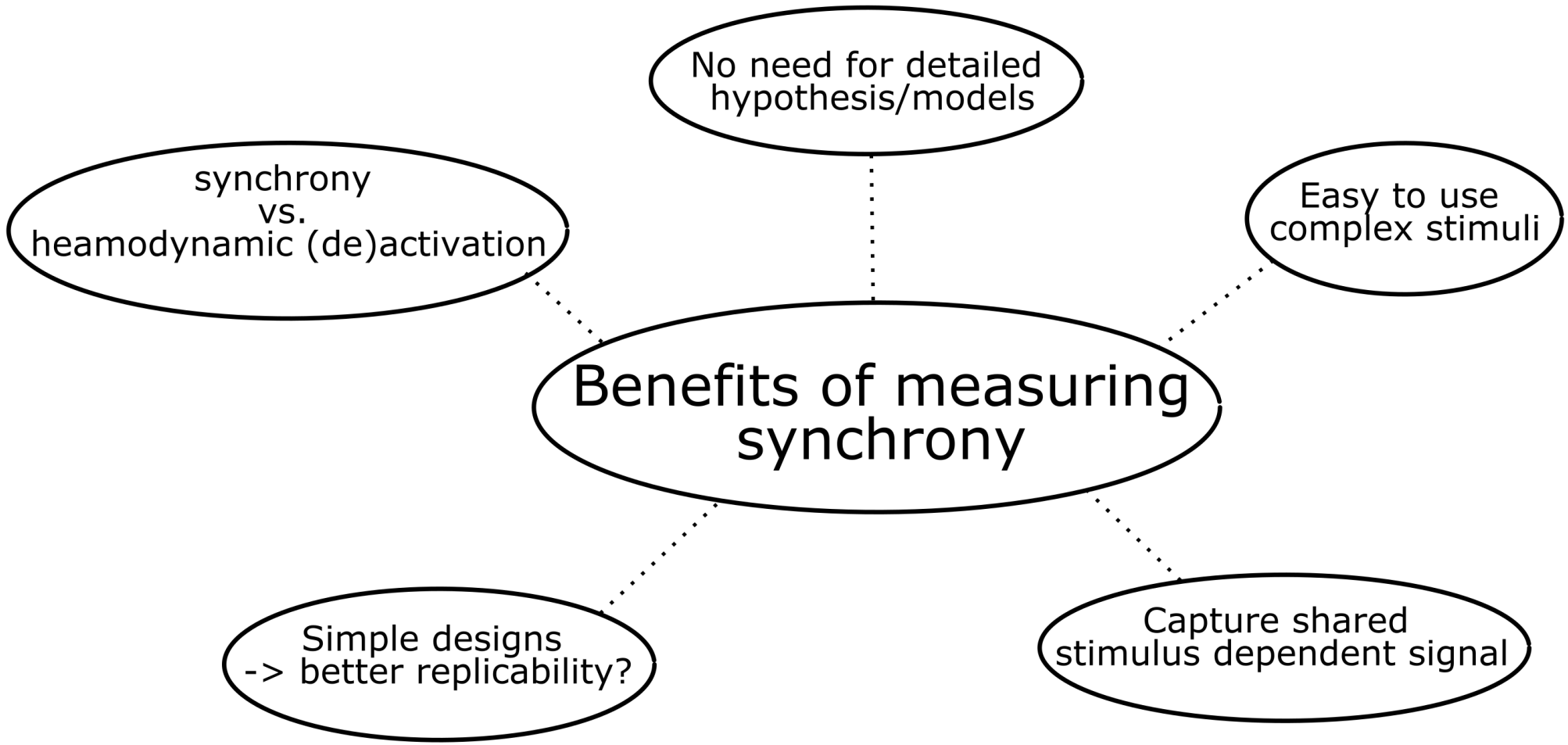
(Hasson, Nir, Levy, Fuhrmann, & Malach, 2004)





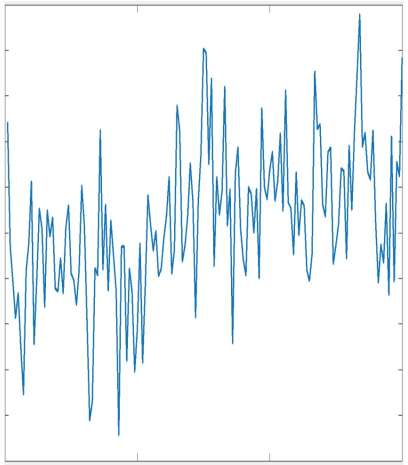


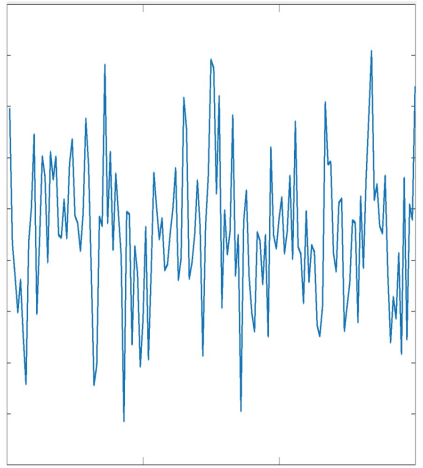
(Nastase, 2019)


No need for detailed hypothesis/models
synchrony vs. heamodynamic (de)activation
Easy to use complex stimuli
Benefits of measuring synchrony
Simple designs -> better replicability?
Capture shared stimulus dependent signal

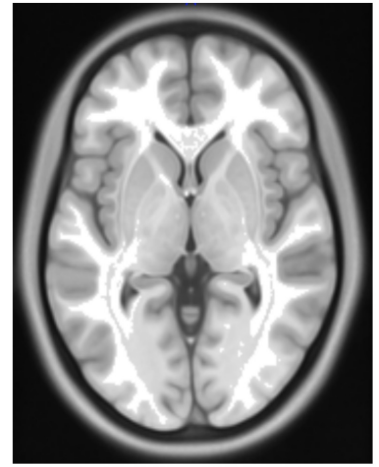
Before synchronization analysis

Shared stimulus





High-pass filtering
(detrending)

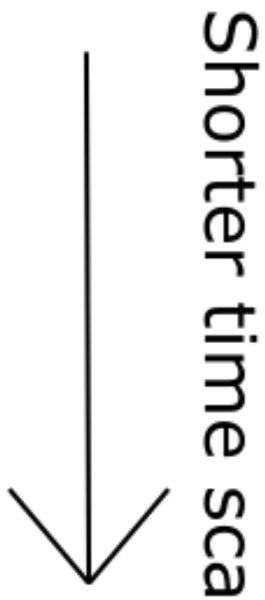


Spatial normalization

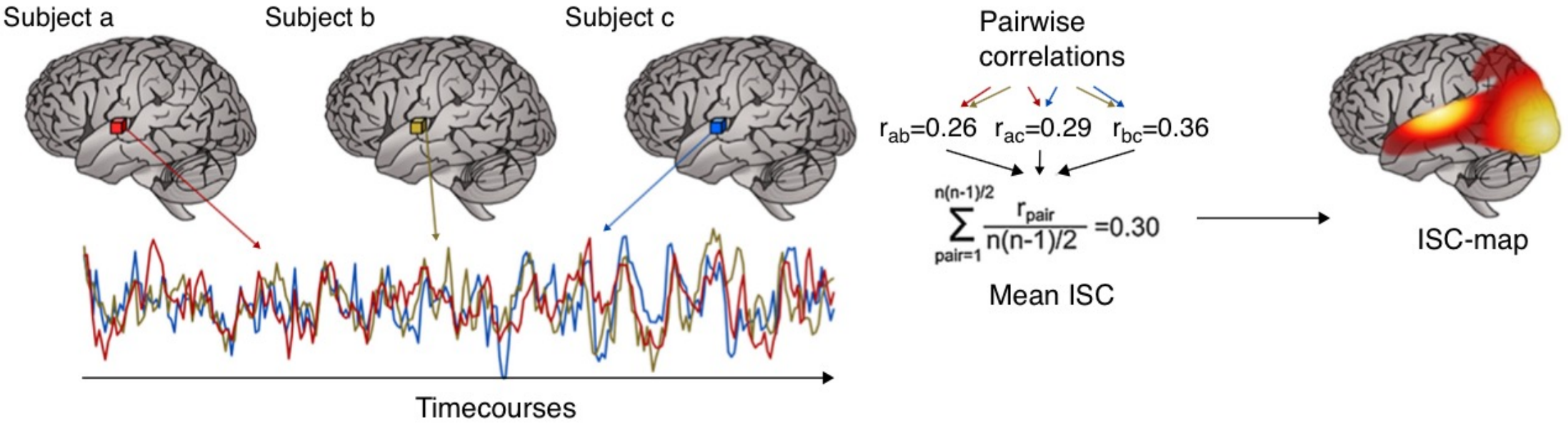
Smoothing

Intersubject correlation analyses

Measure	Time scale of the measured synchrony
ISC	Over the whole experiment (minutes-hours)
Time-window ISC	Specified time-windows (15sec - minutes)
ISPS	Instantaneous (seconds)

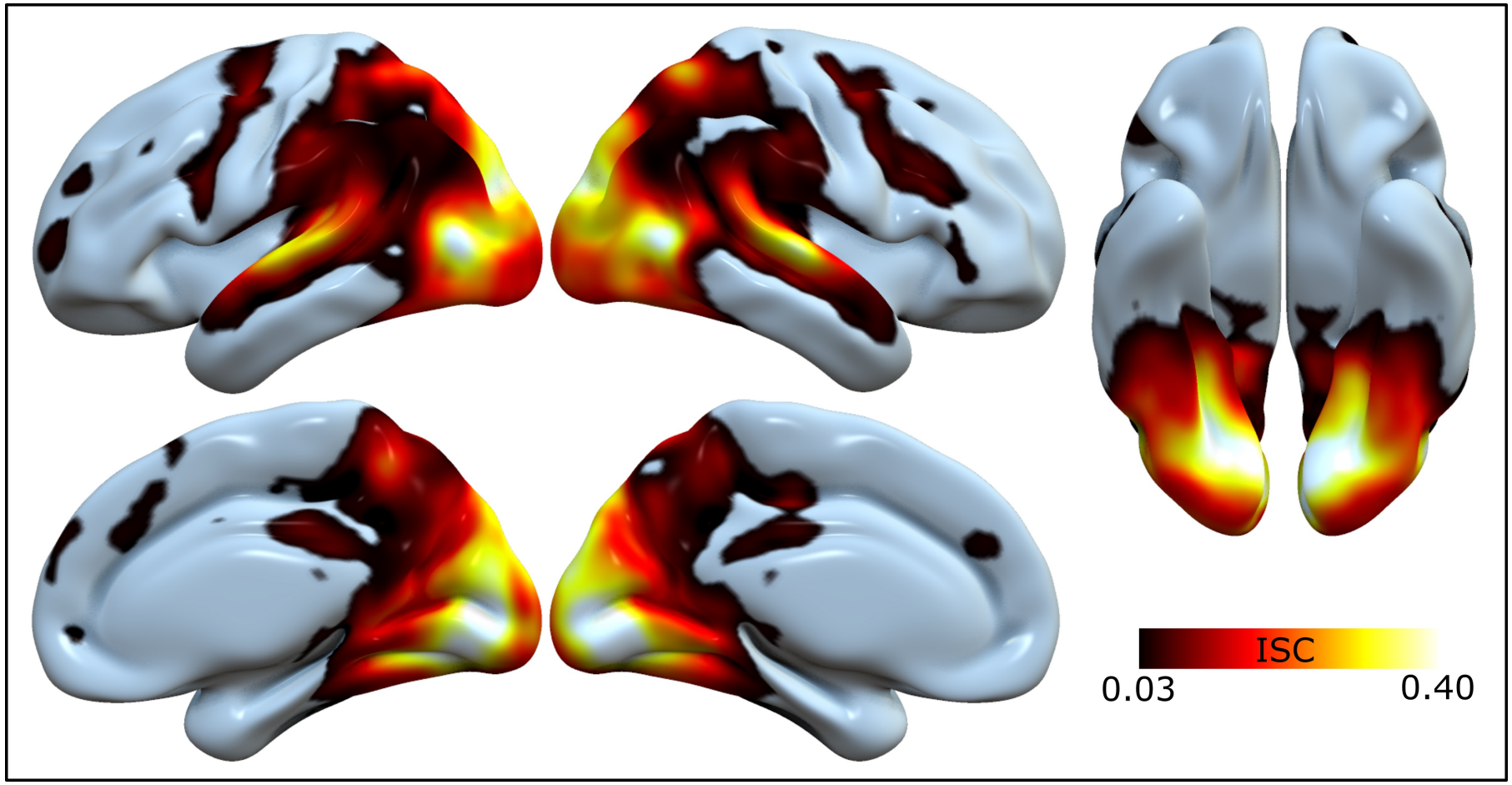


Basic concept of intersubject correlation (ISC)

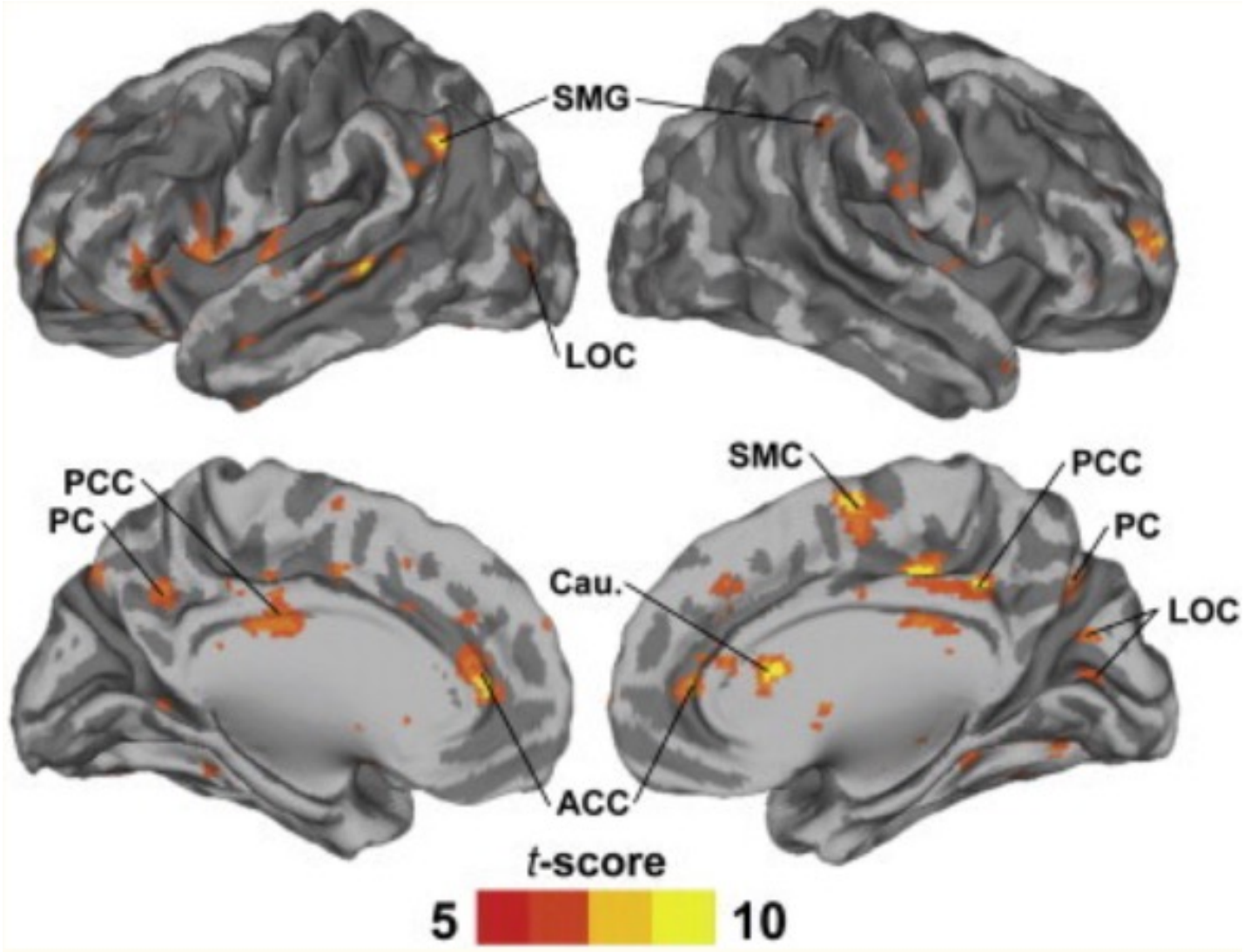


(Nummenmaa, 2018)

Typical ISC when watching films

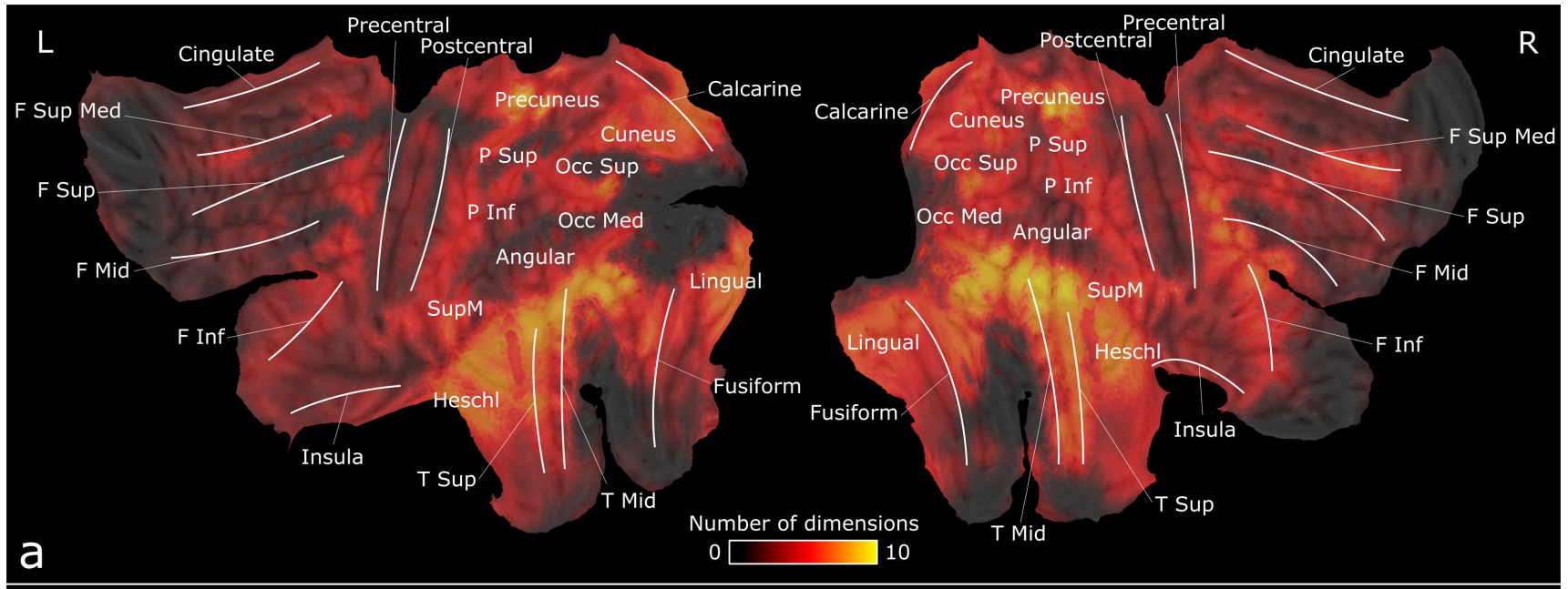


Decreased ISC in autism spectrum disorders

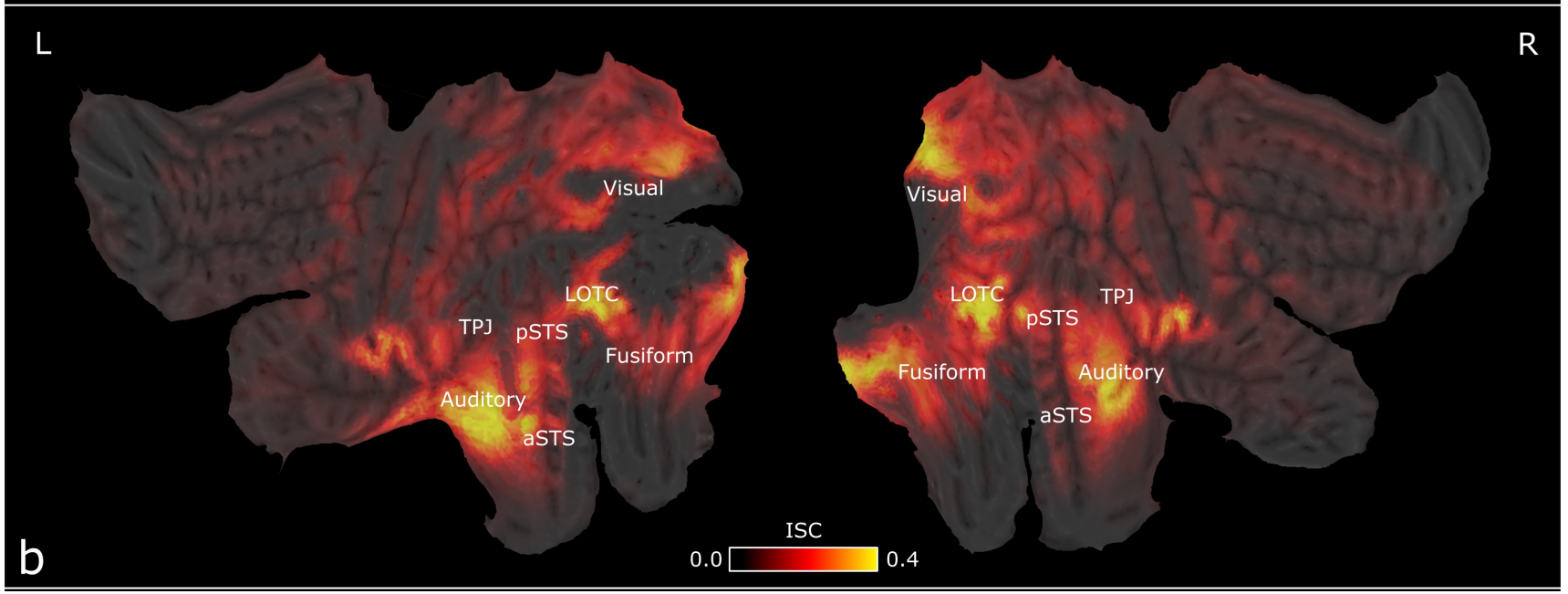


(Salmi, 2013)

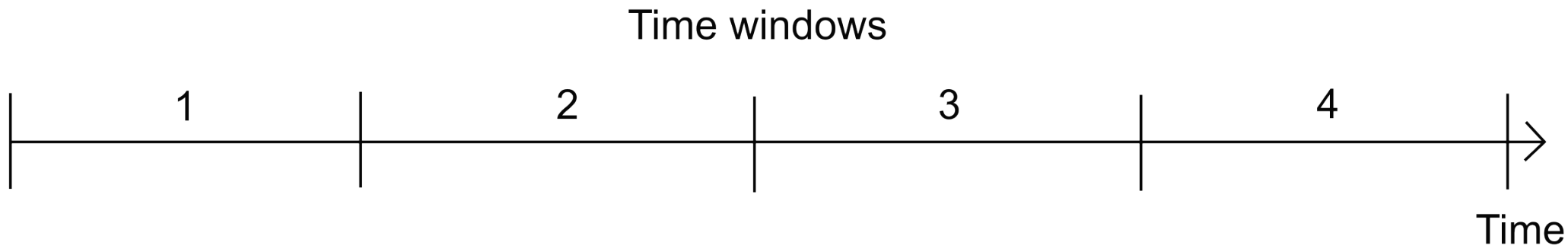
Brain areas activated in social information processing



Avarage ISC of brain activation



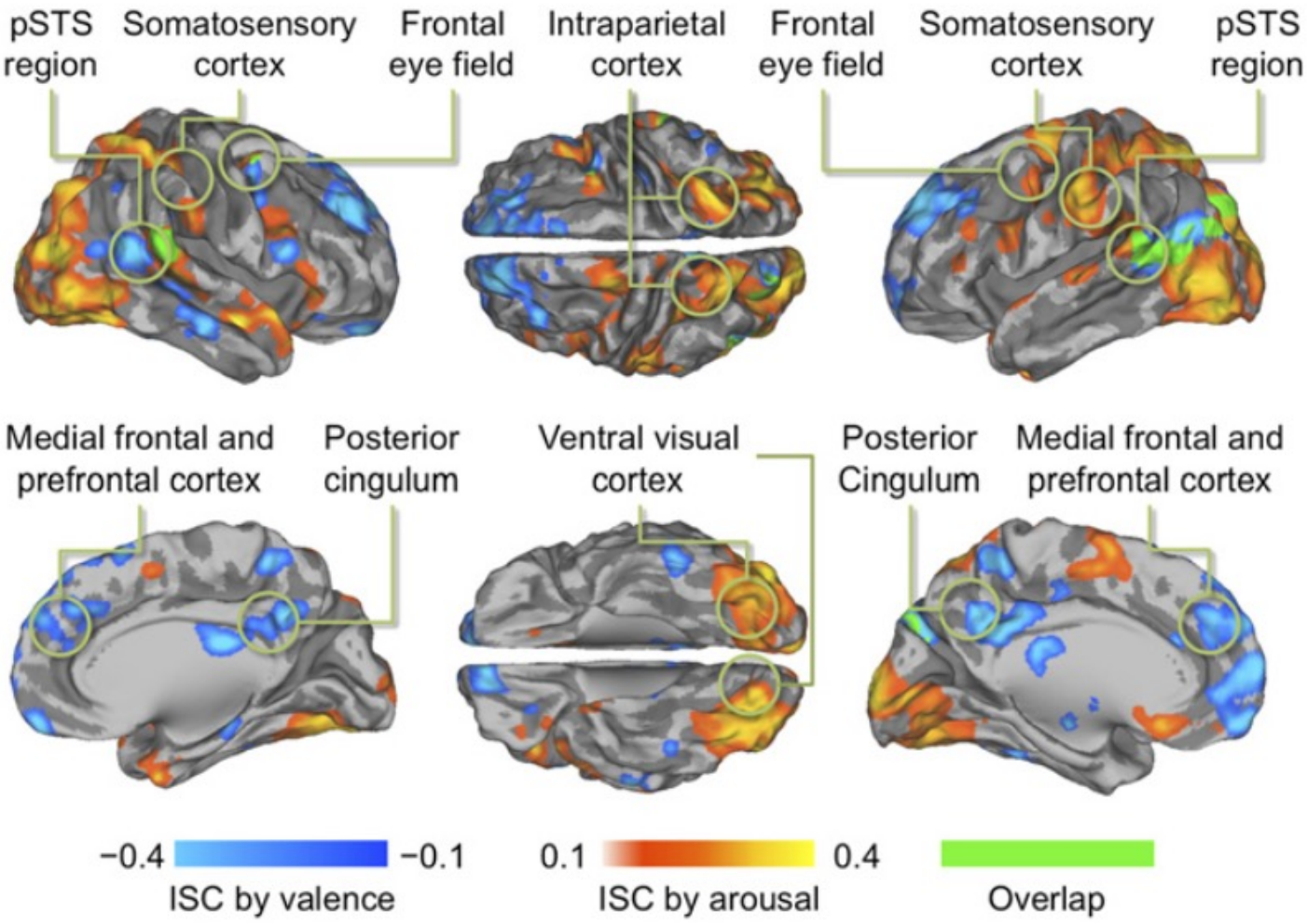
(Santavirta, 2021, *preprint*)



Time window ISC

- Dynamic measure of the intersubject synchrony
- Sliding window approach
  - Reflects the moving average of ISC
- How to choose a proper window length?

Valence and arousal predict time-window ISC



(Nummenmaa, 2012)

Intersubject phase synchronisation (ISPS)

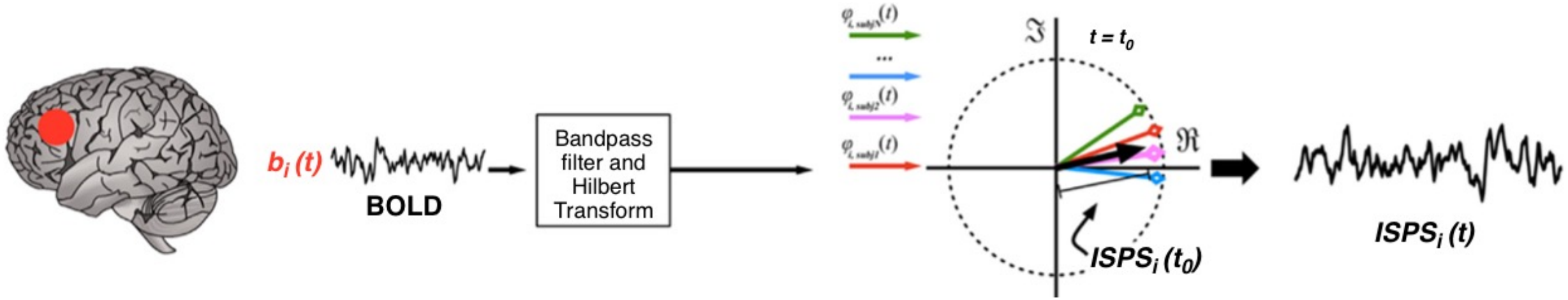
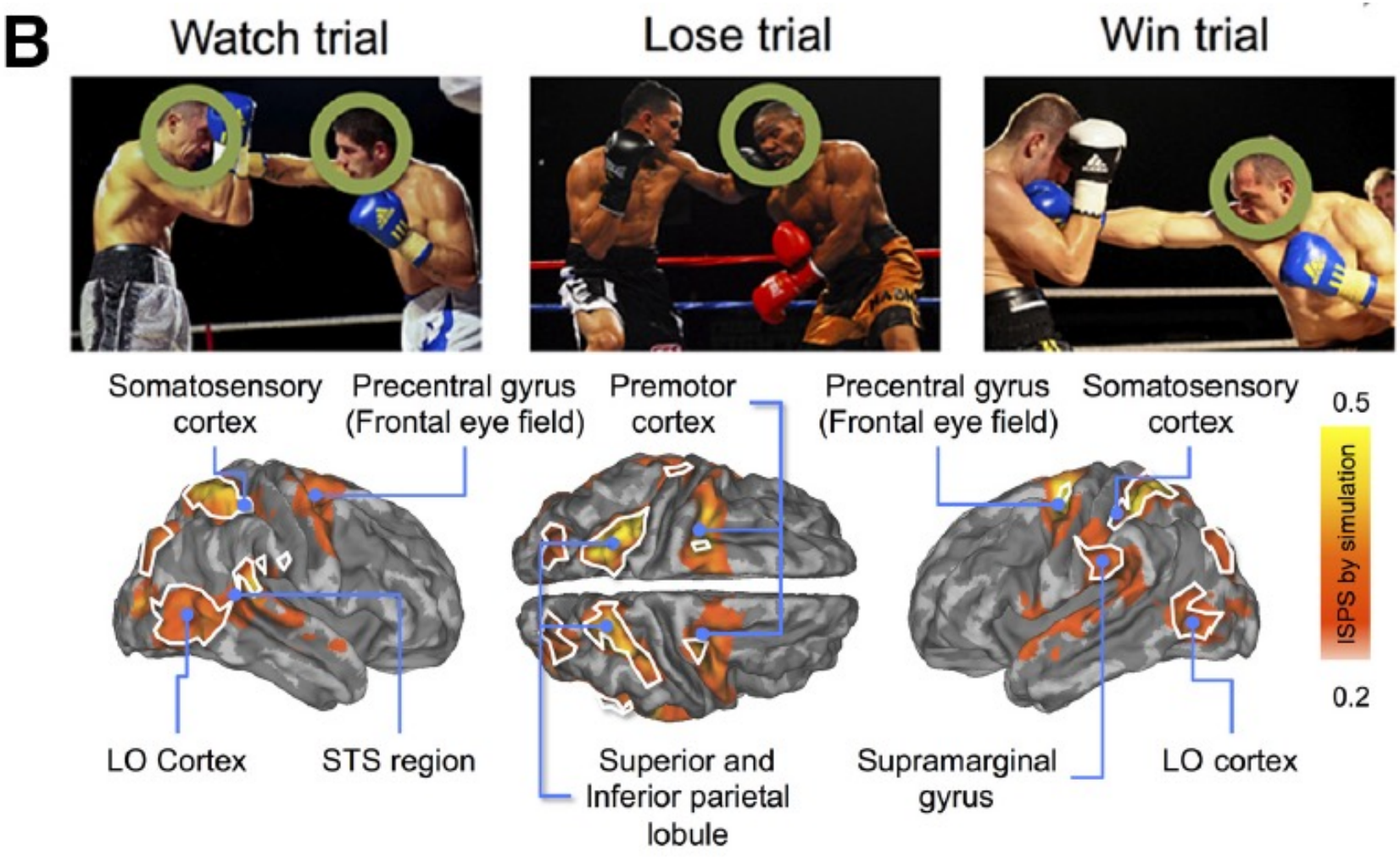


Illustration: (Nummenmaa, 2018)
Theory: (Glerean, 2012)

ISPS in perspective taking vs. passive watching

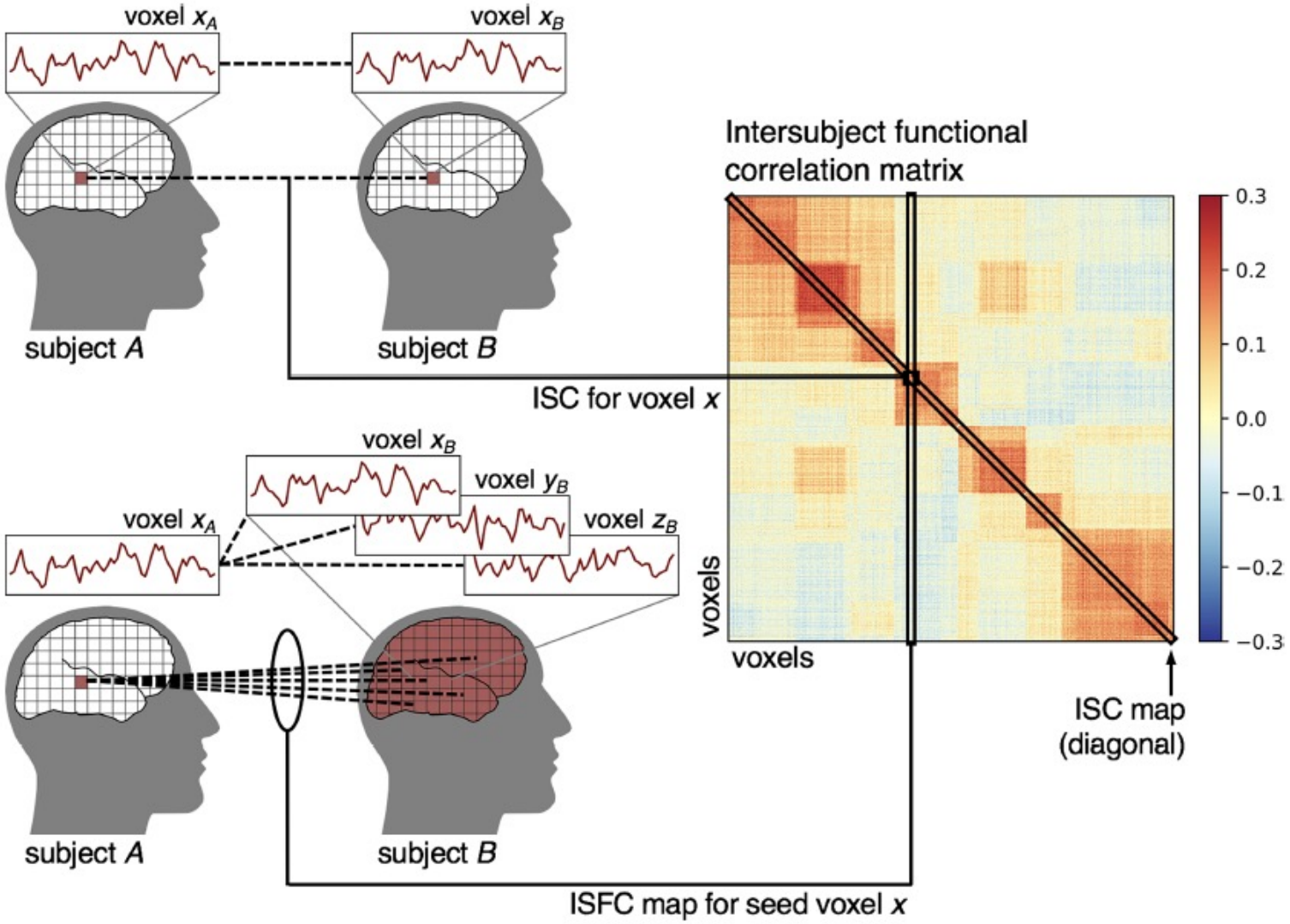


(Nummenmaa, 2014)

Reverse correlation approach

- Tradional analysis:
  - Hypothesis → Model design → GLM → Results
- ”Let’s turn the analysis upside down”
- Find new hypotheses
  1. Measure dynamic brain synchronisation (time-window ISC/ISPS)
  2. Identify time points with high synchrony
  3. Figure out what is happening in the stimulus at the time of high synchrony
  4. Test new hypothesis in future studies.

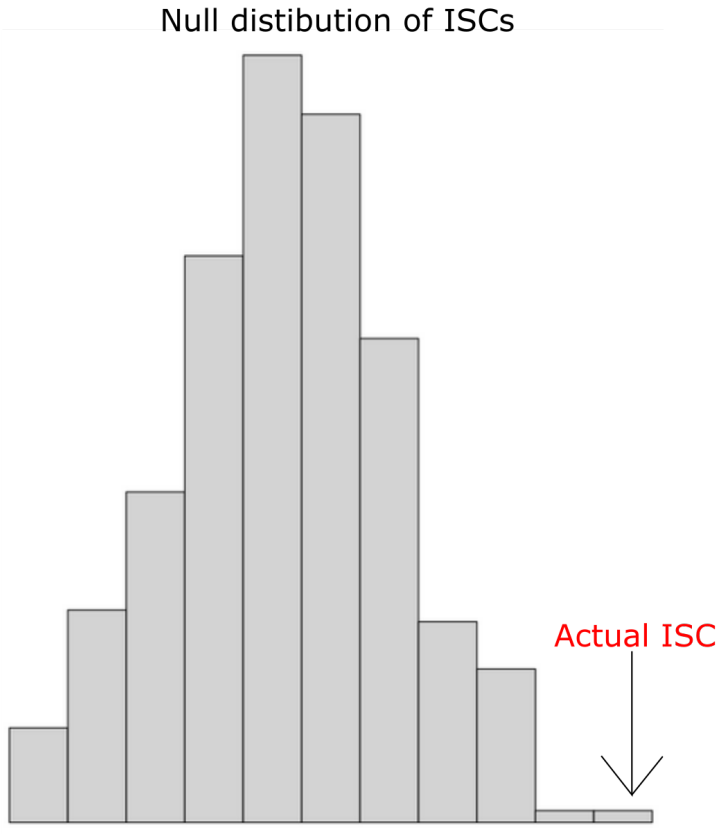
Intersubject functional connectivity (ISFC)



(Nastase, 2019)

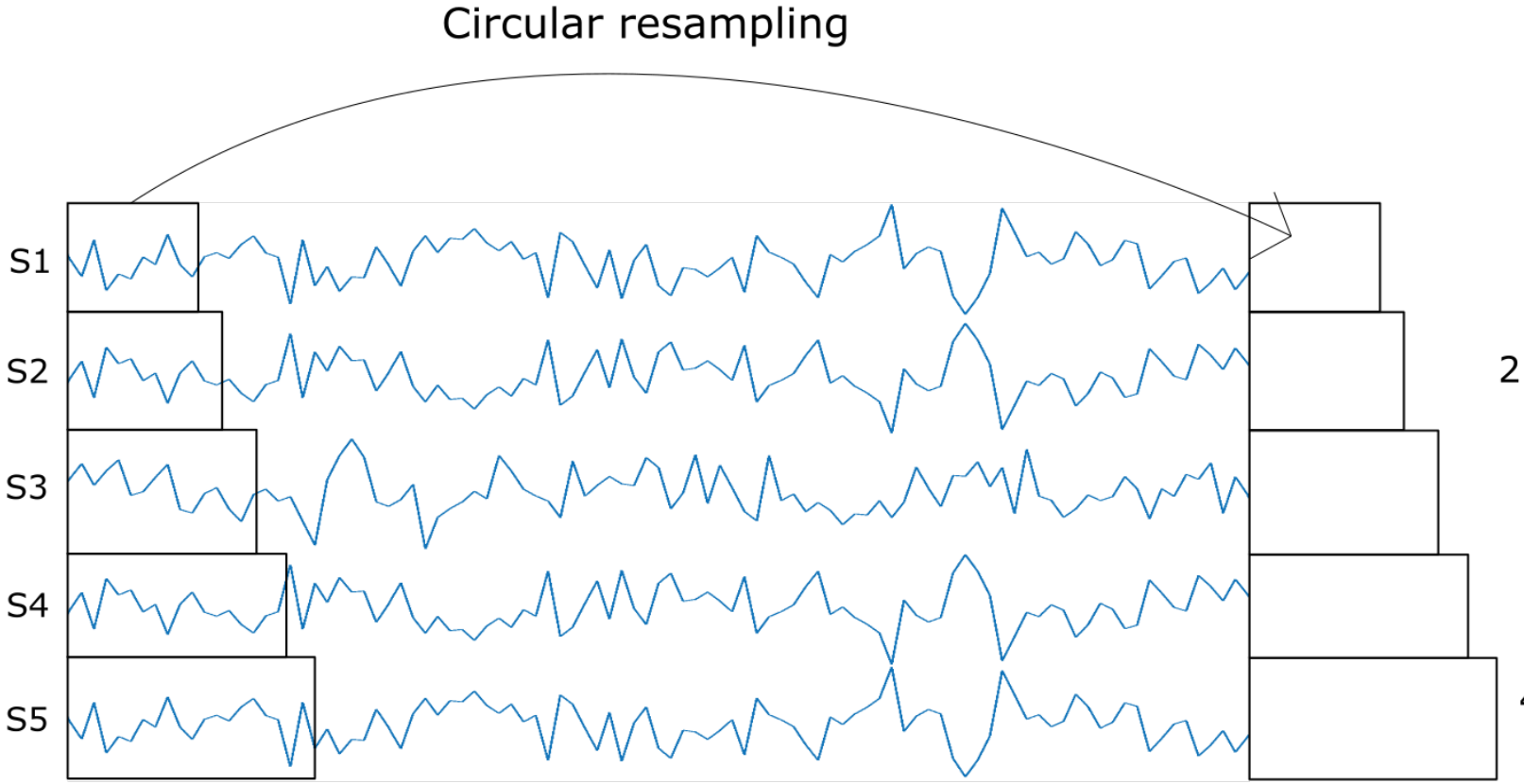
Statistical significance of ISC

- Does ISC differ statistically from zero?
- Pairwise correlation values are **not** independent
  - Parametric tests should not be used
- Non-parametric permutation based test
  - Circular block-resampling
- Multiple comparisons correction



(Kauppi, 2010)

Circular block-resampling method



1. Circular resampling
--> Break the temporal synchrony

2. Calculate group ISC based on resampled data
--> Chance level ISC estimate

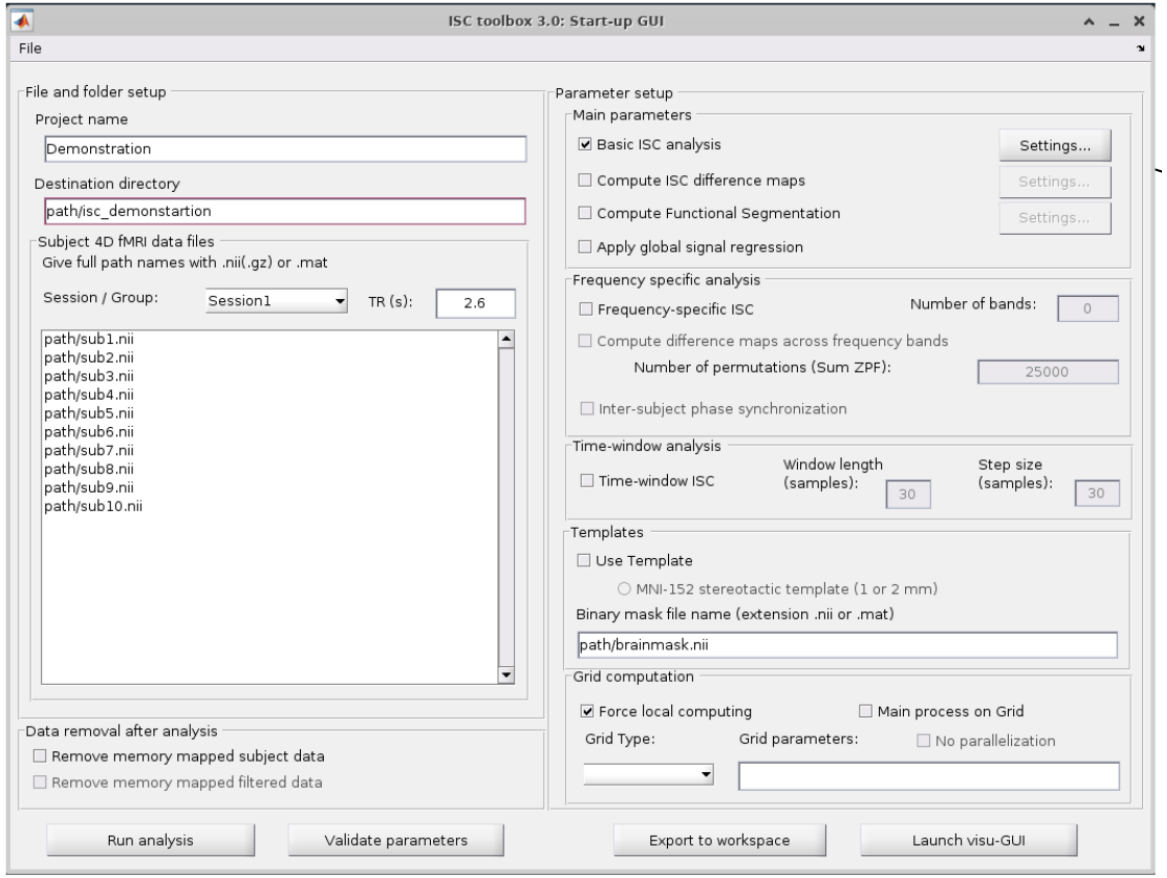
3. Resample many times (millions)
--> Null distribution of ISC values

4. Rank actual ISC value in the null distibution
-->p-value

(Kauppi, 2010)

ISC-toolbox

- Easy to use ISC analysis toolbox for brain fMRI data.
  - https://www.nitrc.org/projects/isc-toolbox/
  - Graphical user interfence
- Runs on MATLAB
- Analyses
  - Basic one group analysis
    - Which brain areas synchronise across subjects?
  - Group comparison analysis
    - In which brain regions the synchronisation is different between two groups (e.g. patiens against healthy controls)?
  - Frequency specific ISC analysis (advanced)
    - Compute ISC analysis separately for different frequency bands in fMRI signal.
    - Time-window ISC / ISPS
  - Multiple comparisons correction



(Kauppi, 2014)

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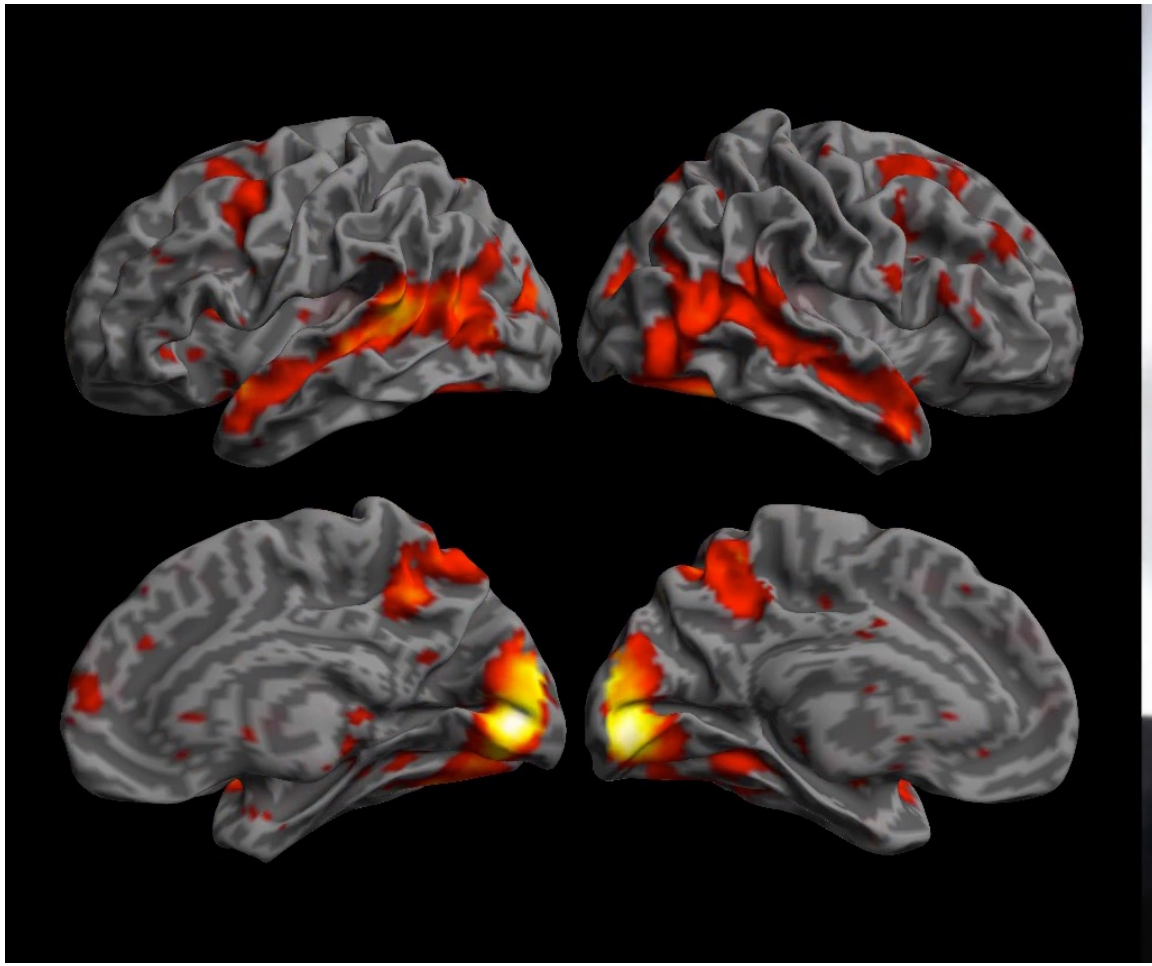
Thank you!