Statistical analysis of volume and surface-based data

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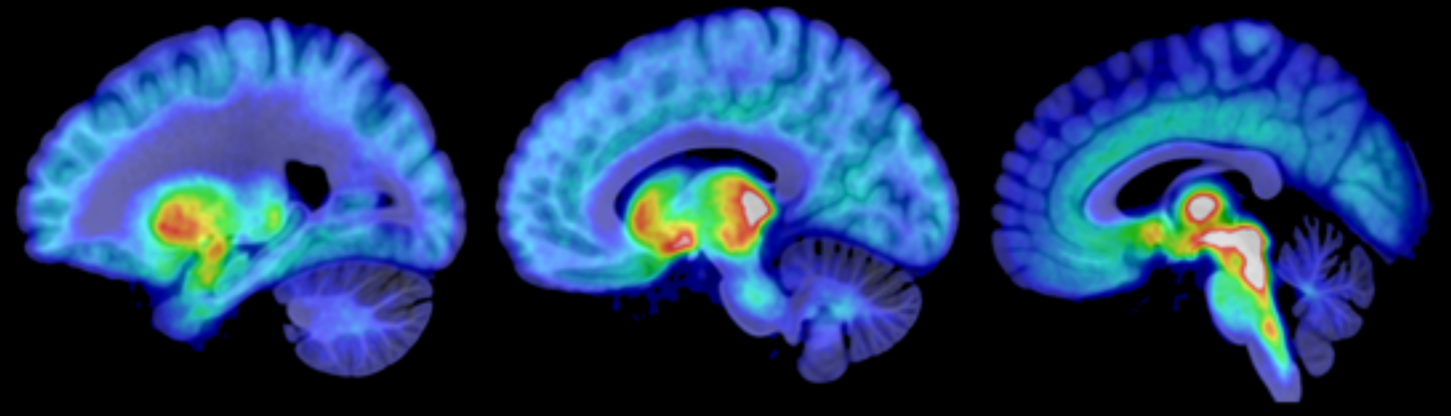
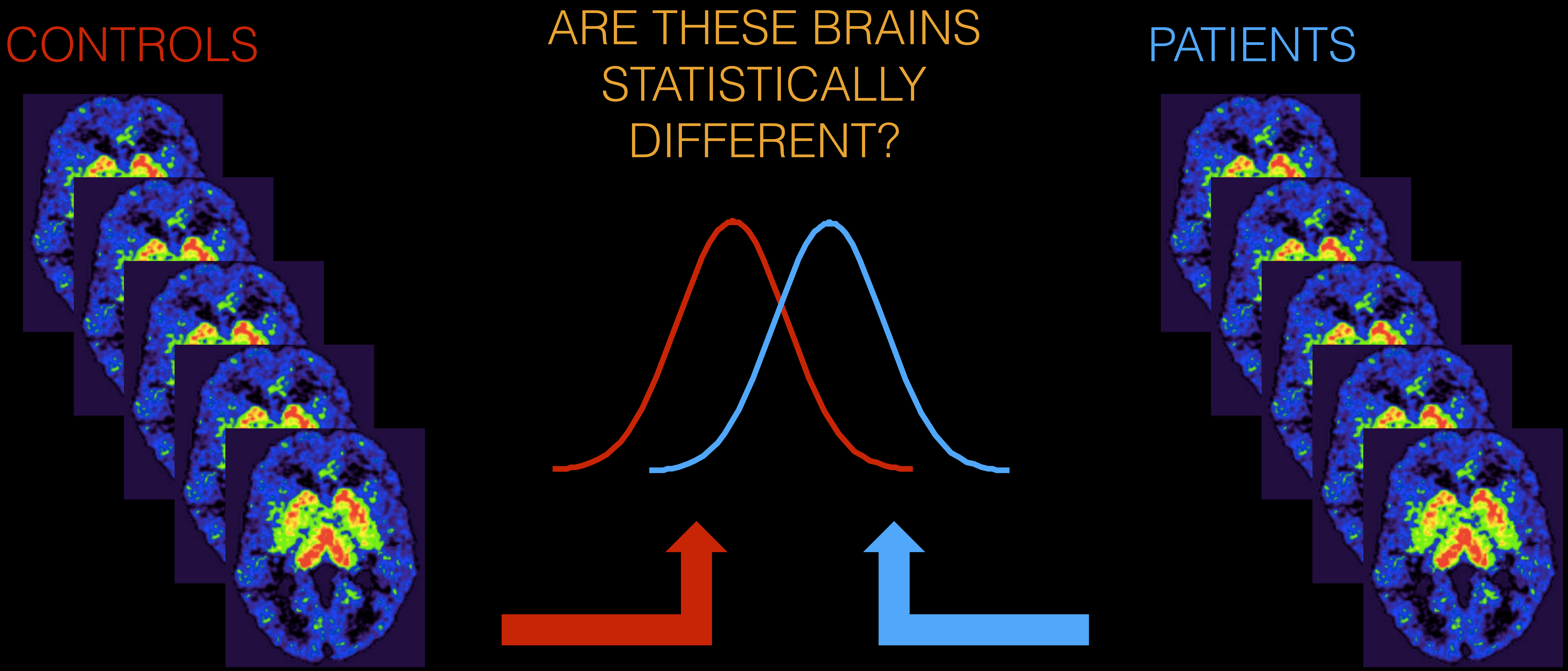


Contents

- Basic statistical inference in neuroimaging (and elsewhere)
- ROI-based statistics versus full-volume comparisons
- The basic recipe for SPM analyses
    1. Spatial normalization
    2. Smoothing
    3. Statistical parametric mapping
- Concluding remarks

The goal of statistical analysis of brain images



Basic problems associated with scientific measurement

ERRORS PRESENT AT ALL LEVELS; THEY ALSO ACCUMULATE FROM LEVEL TO LEVEL

TARGET
(e.g. specific neuro-receptor)

TRUE SCORE (T)
How target is defined
(e.g. number of receptors)

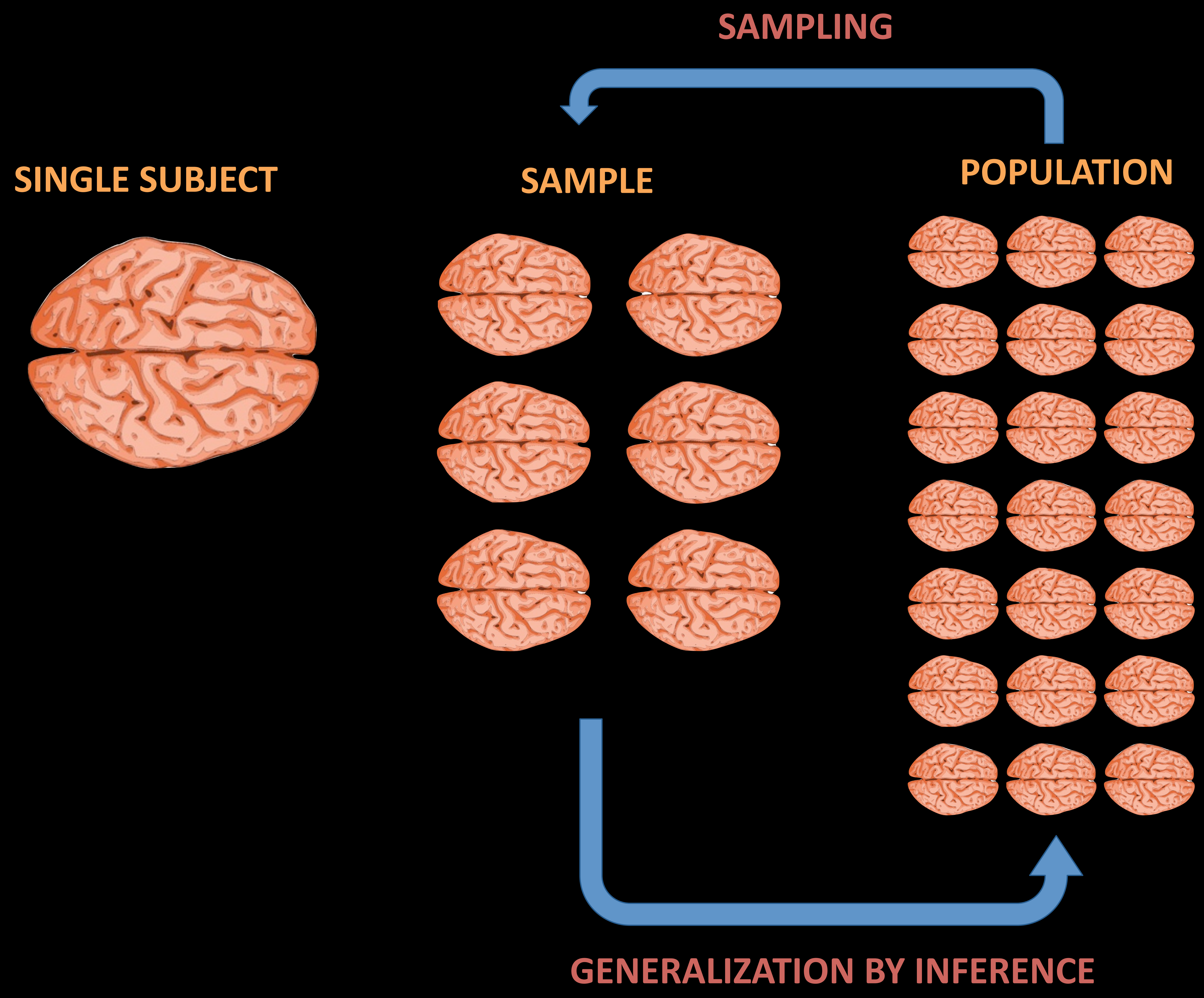
MEASUREMENT

OBSERVED SCORE
(Outcome measure such as BPND)

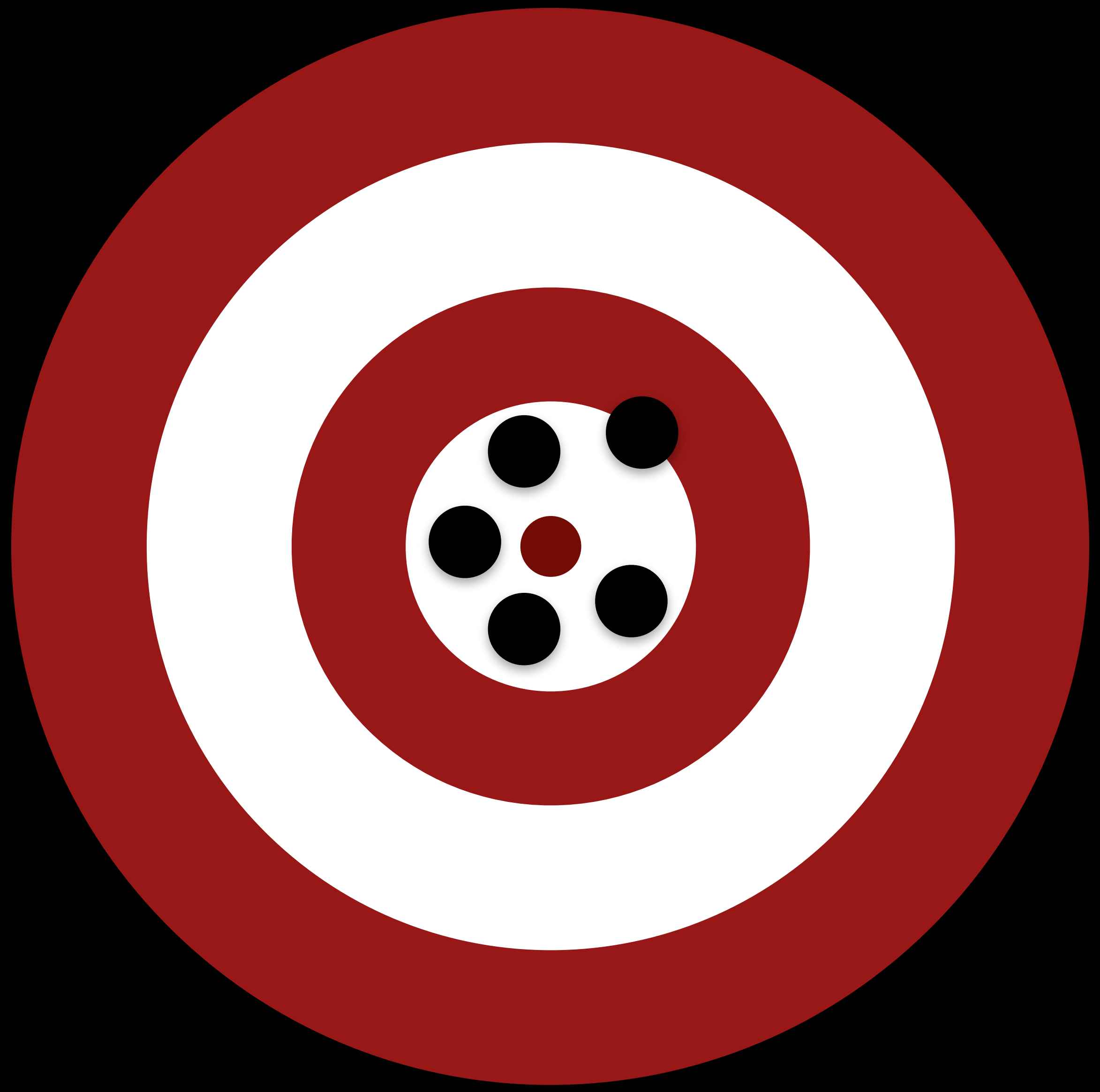
PREDICTION OF BEHAVIOR
(e.g. anxiety-like behaviour)

- How well is target variable reflected in true scroe (construct validity)
- How well true score is reflected in observed score? (reliability)
- How well does observed score predict behaviour? (criterion-based validity)

Making inferences about the population

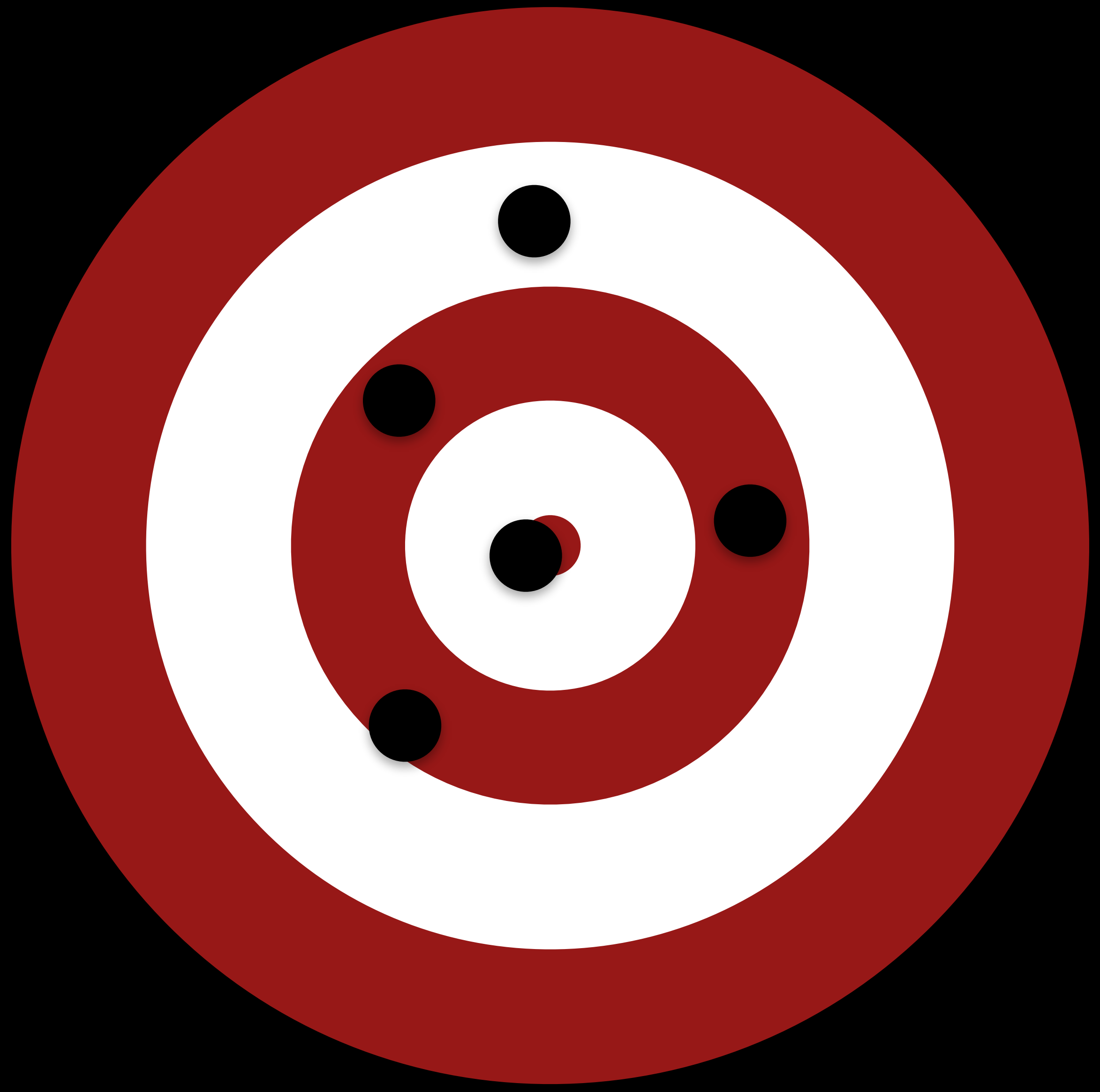


Reliable and valid



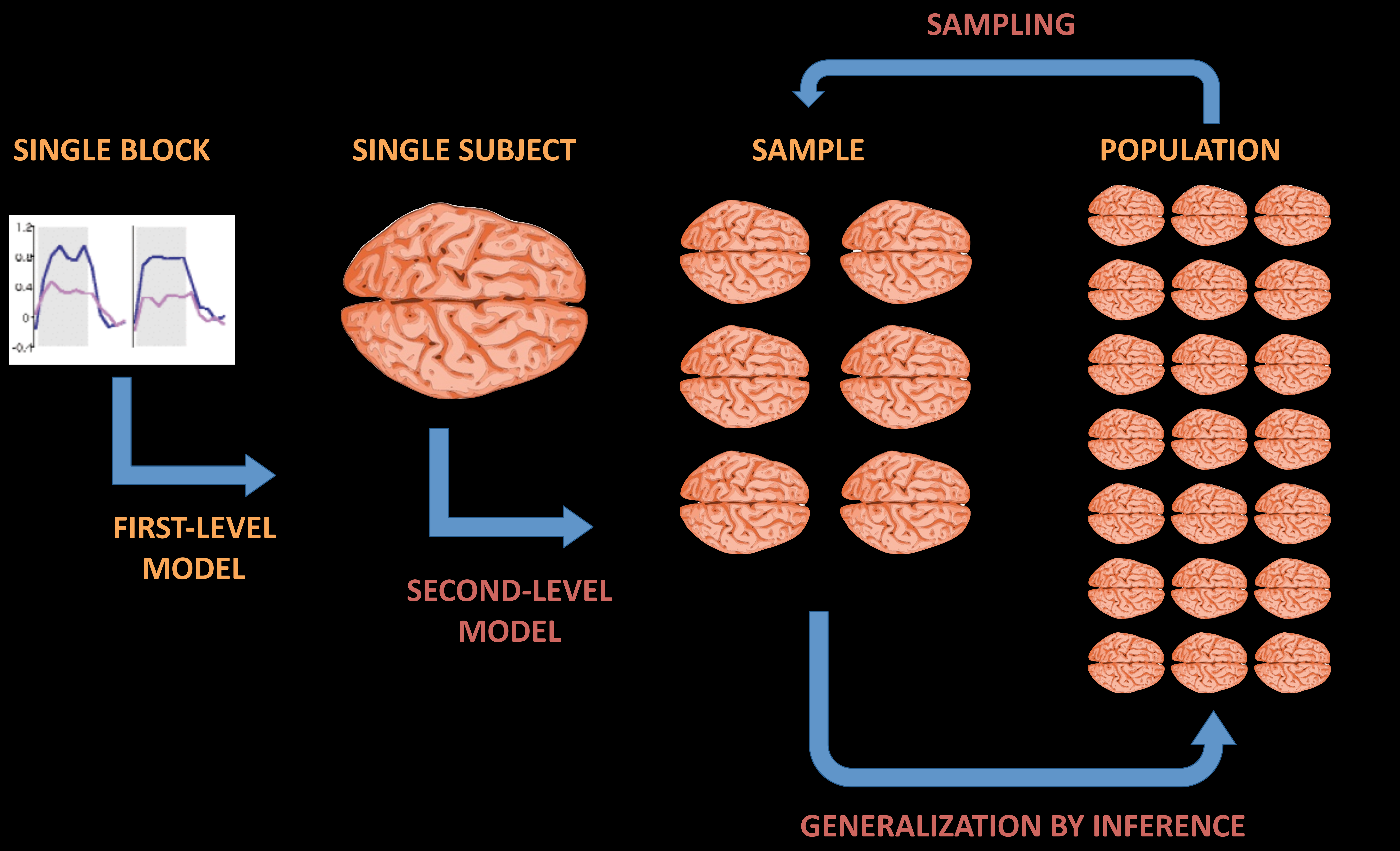
Reliable but invalid

Unreliable but valid



Unreliable and invalid

Making inferences about the population



Univariate data

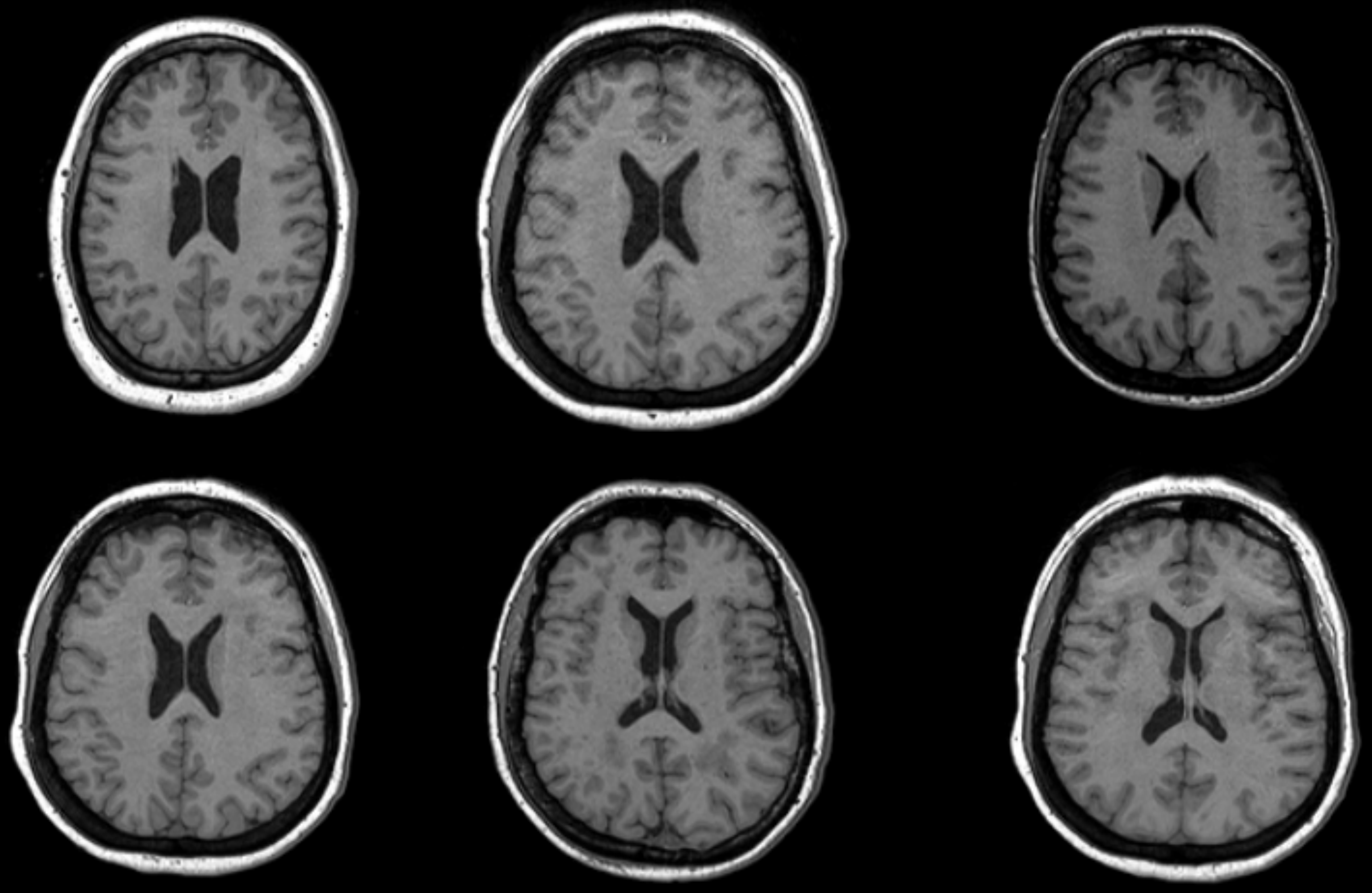
Regularly shaped, low-dimensional

Controls	Patients
3	5
4	4
5	6
6	7
3	6
2	5
3	2
5	6
2	8

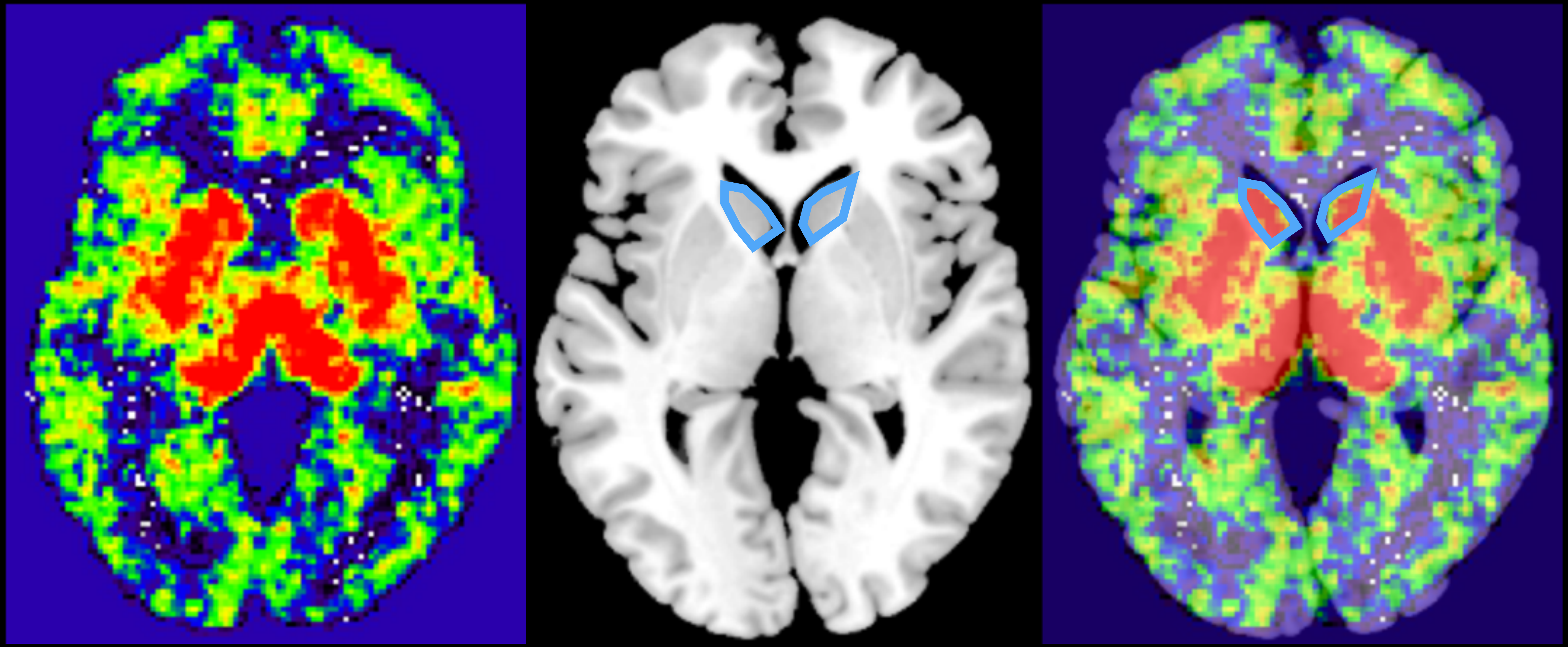
T-test

3D neuroimaging data

Irregularly shaped,
high-dimensional



ROI-based analyses



Extract outcome measure in ROI

Controls	Patients
3	5
4	4
5	6
6	7
3	6
2	5
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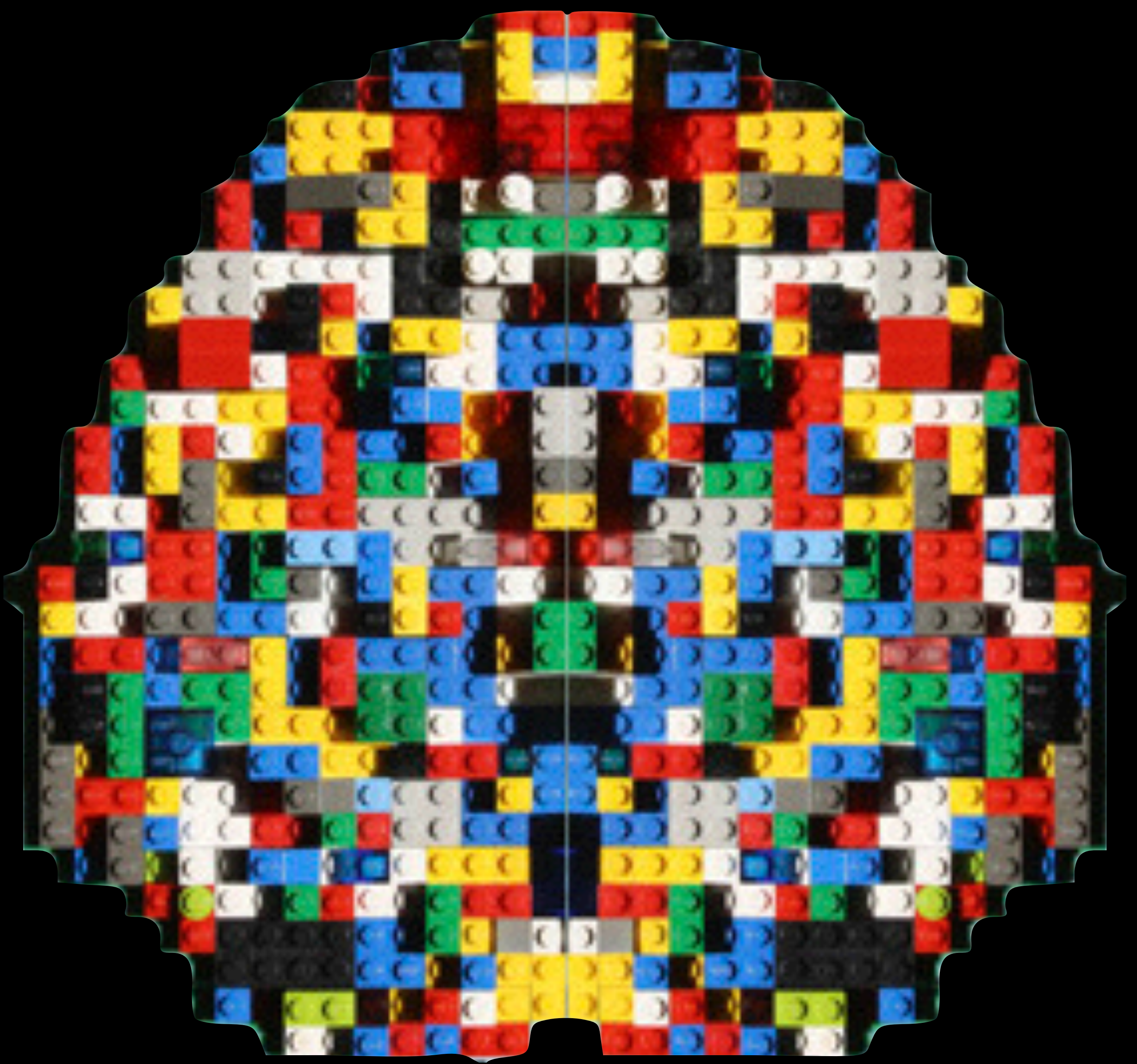
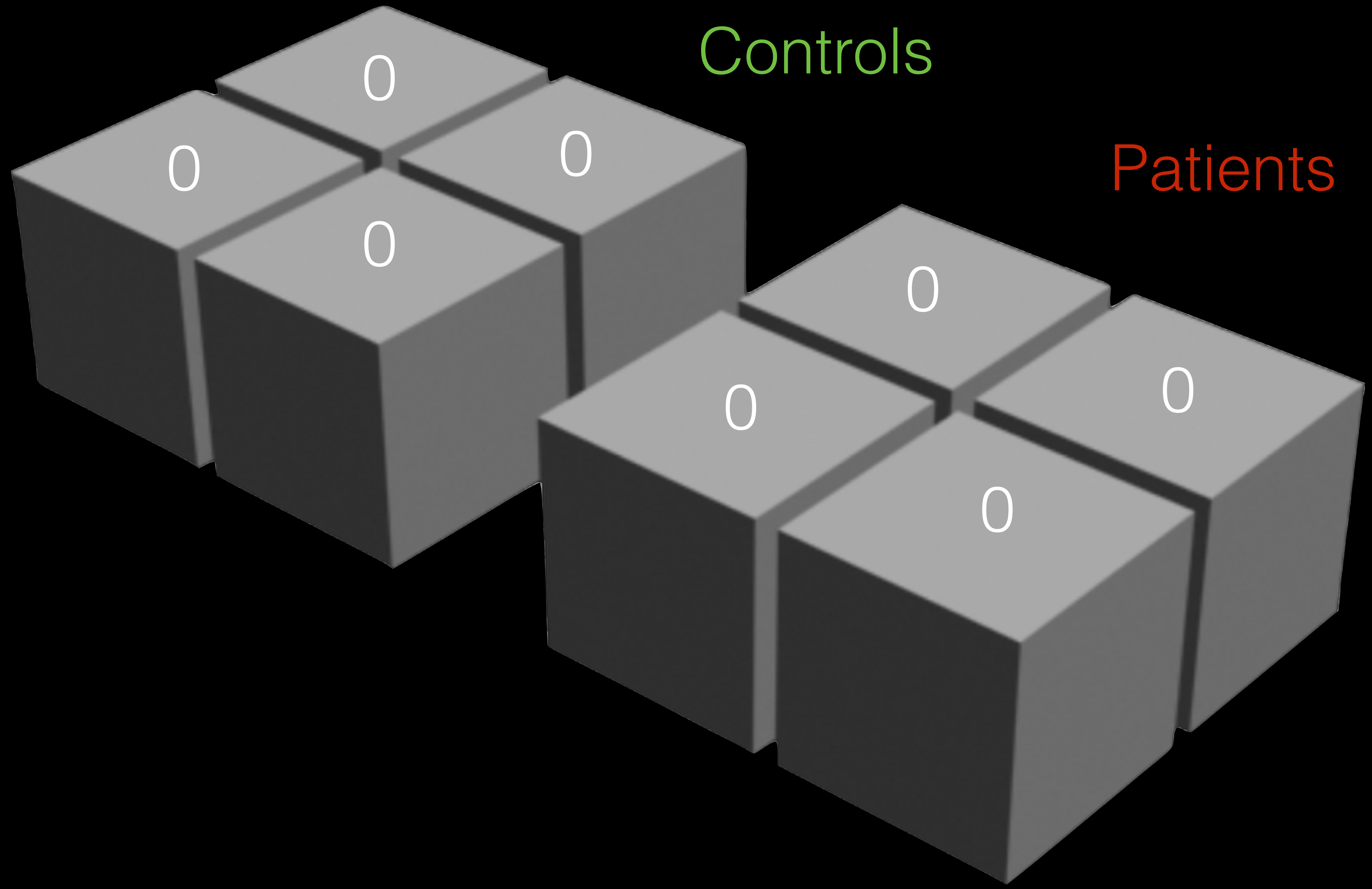
- **Pros**: Anatomically accurate if ROIs well definied, data can be analyzed with simple univariate statistical tests
- **Cons:** extremely laborious, using many ROIs not feasible, averaging within ROI not always appropriate

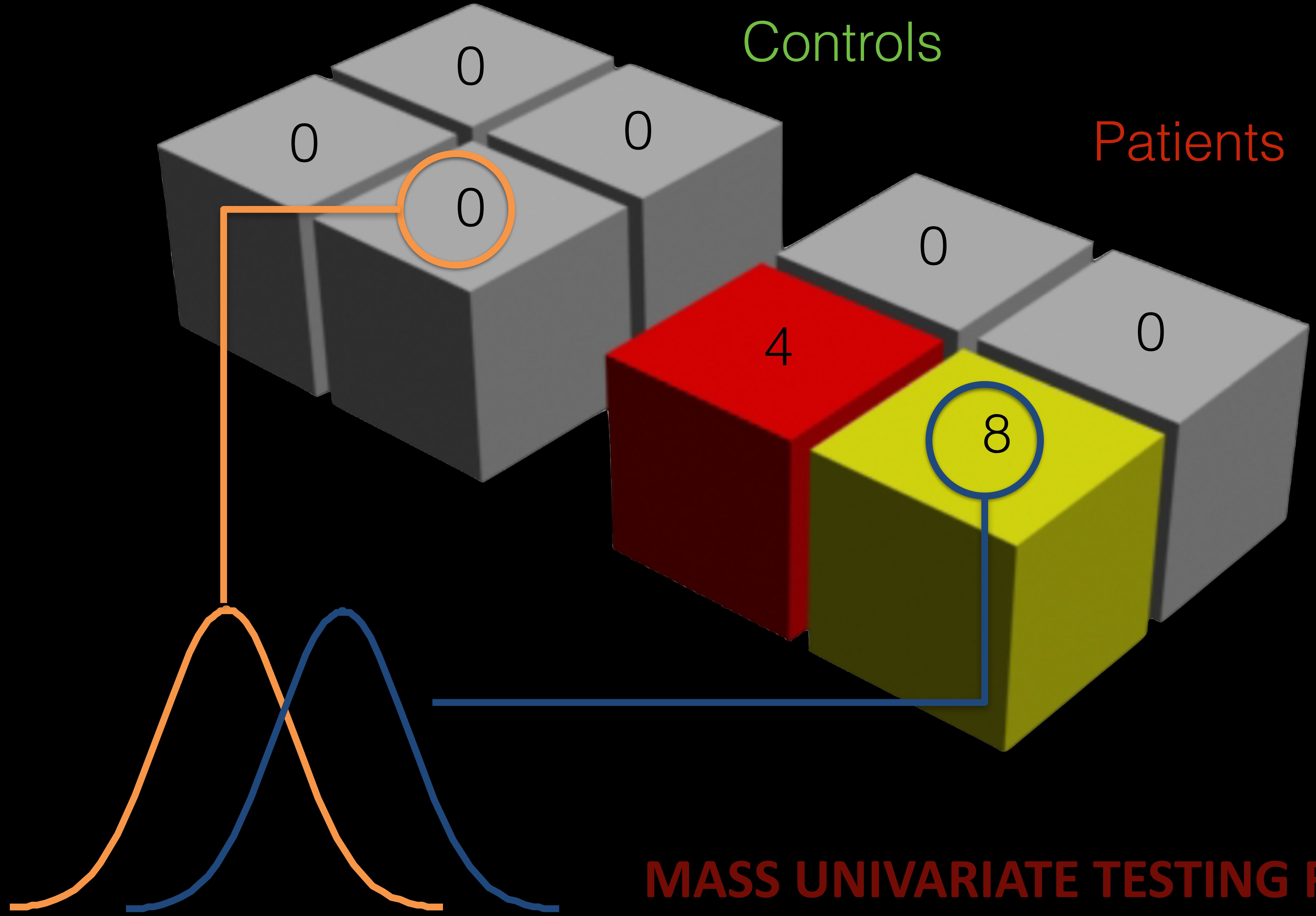




Full-volume analyses with LEGO brains



Full-volume analyses with LEGO brains



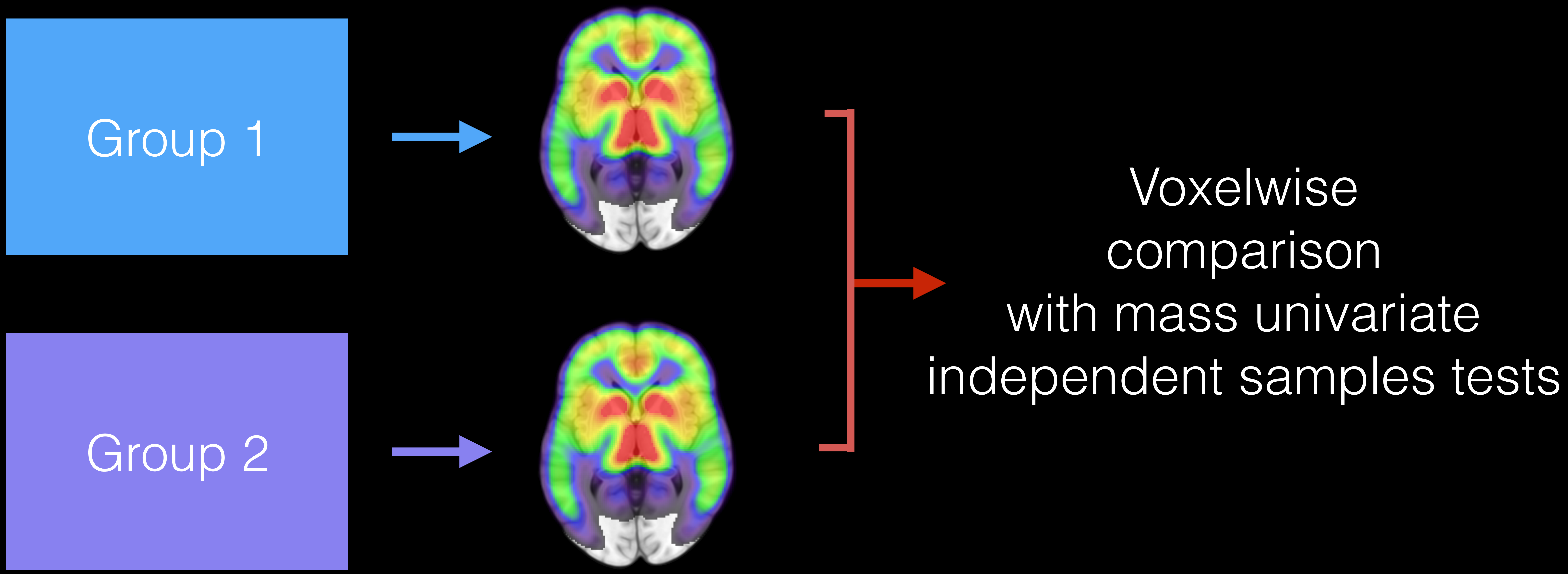
MASS UNIVARIATE TESTING FOR ALL VOXELS

Full-volume analyses with real brains

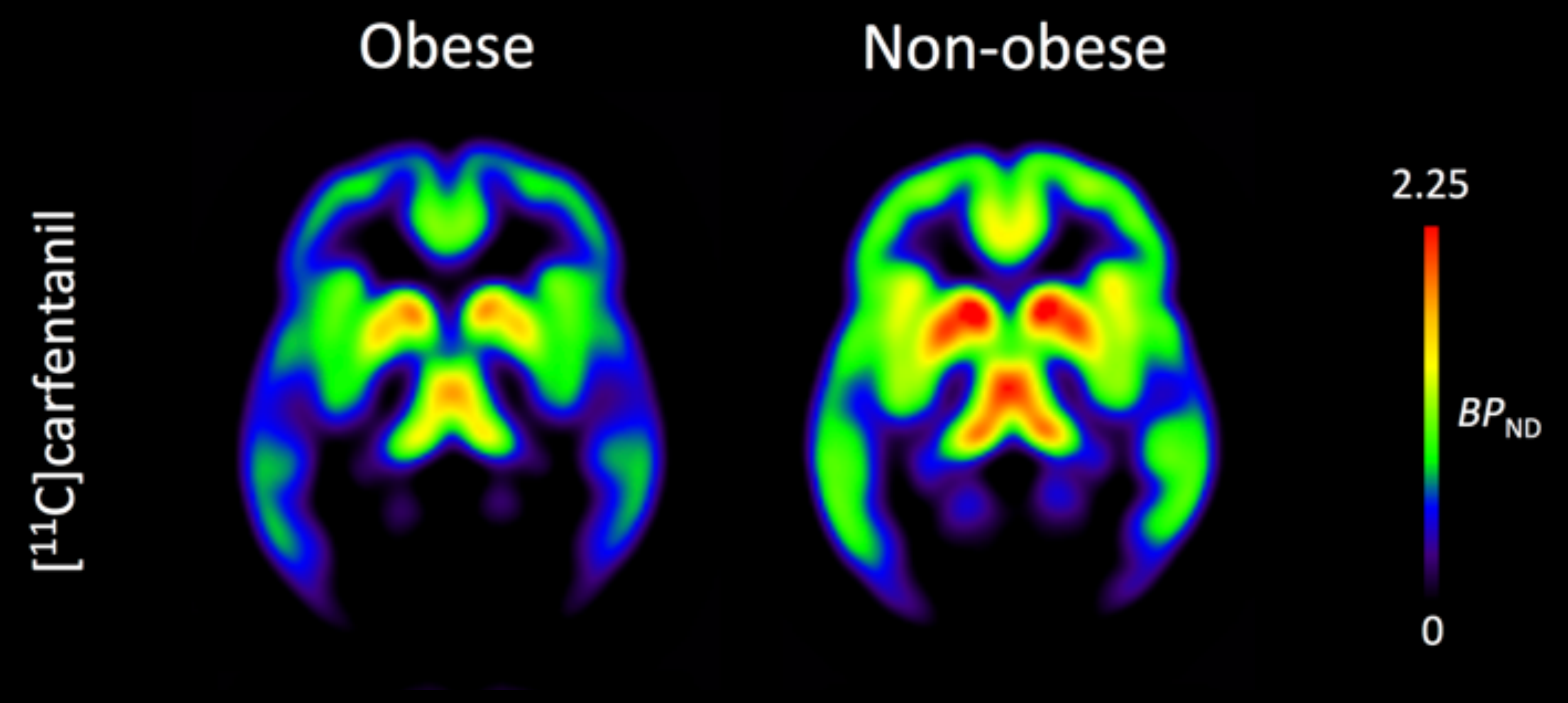
- Basic problem: Individual brains differ in size and shape
- Solution to the problem: Make brains similar by warping them
- But not without problems
  - Warps distort anatomy
  - Anatomical information is not the precise anyway
  - How should we warp the brains?


THE BASIC RECIPE
Voxel intensity = outcome measure
(BPND, contrast estimate, tissue probability)
SUBJECT 1
SUBJECT 2
SUBJECT 3
NORMALI-
ZATION
TEMPLATE
GLM
STATISTICAL
PARAMETRIC MAP
SMOOTH

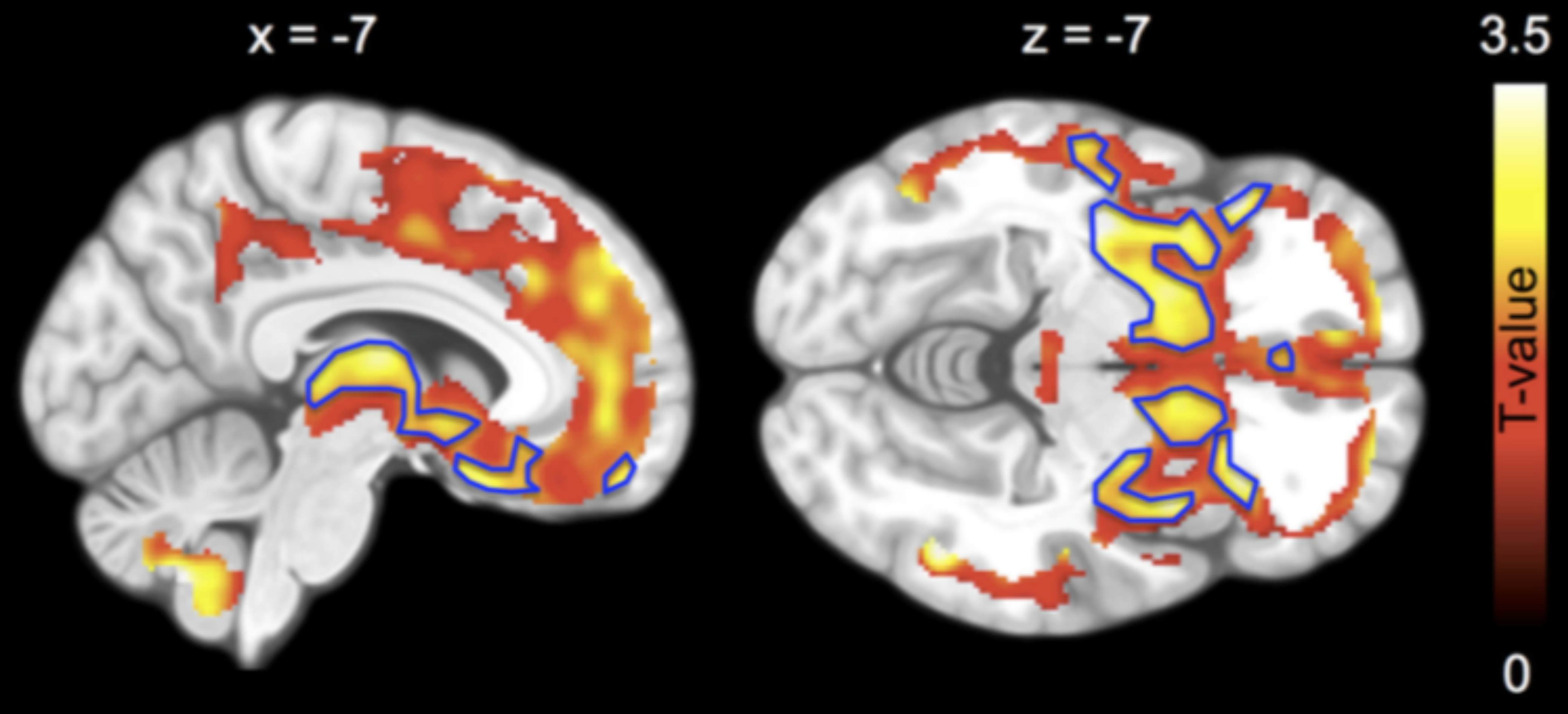
Between-groups design



1) Mean images for each group



2) Statistical differences (t-map)



Karlsson et al (2015 J Neurosci)

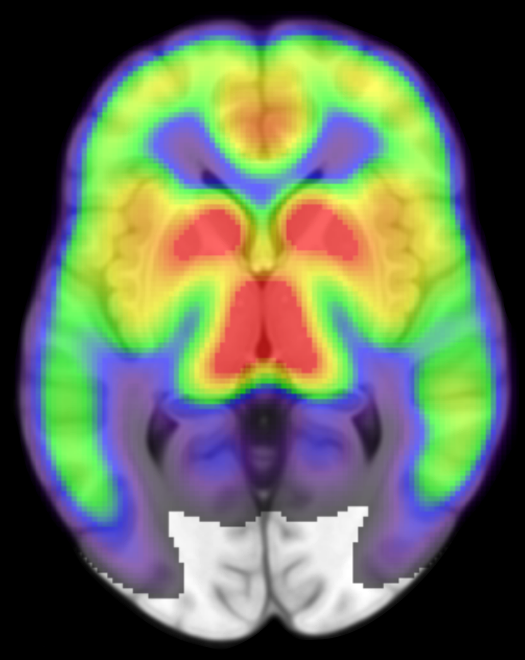
Challenge / longitudinal design

Lag hours or days

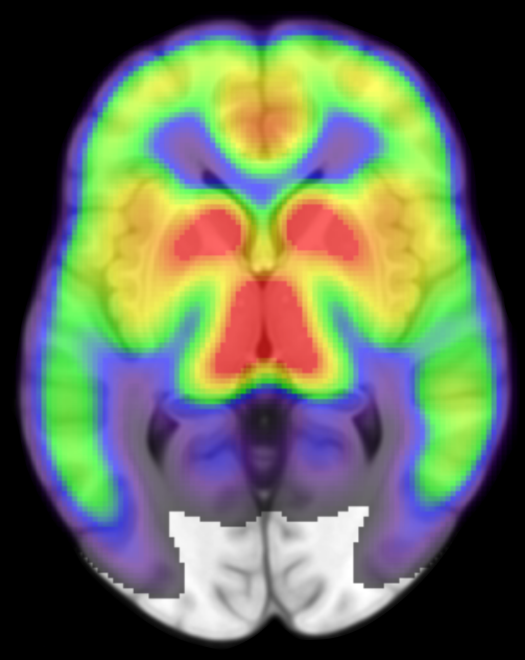
Scan 1

Challenge:
Task, drug, etc.

Scan 2

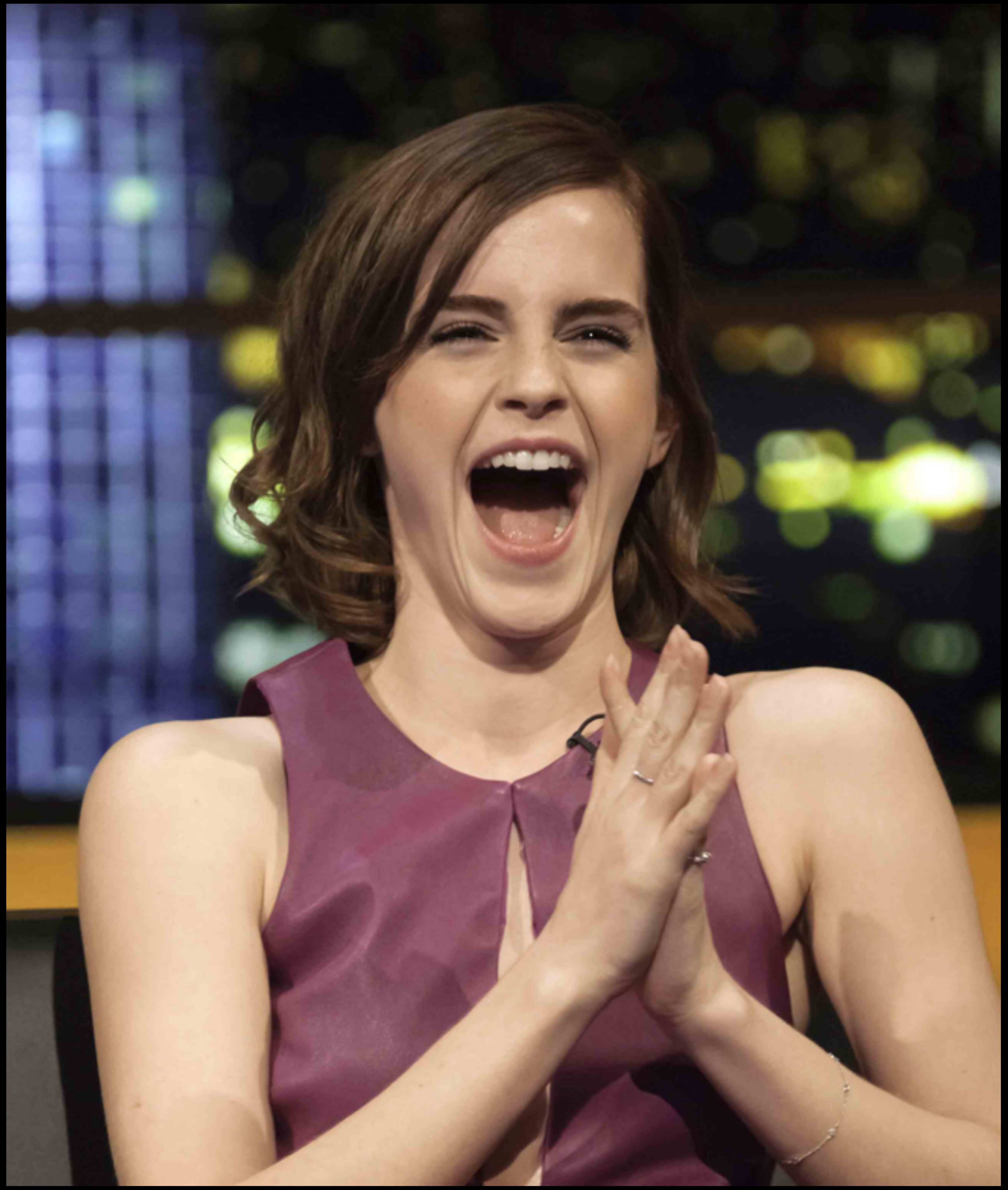


Voxelwise comparison with mass univariate repeated measures tests

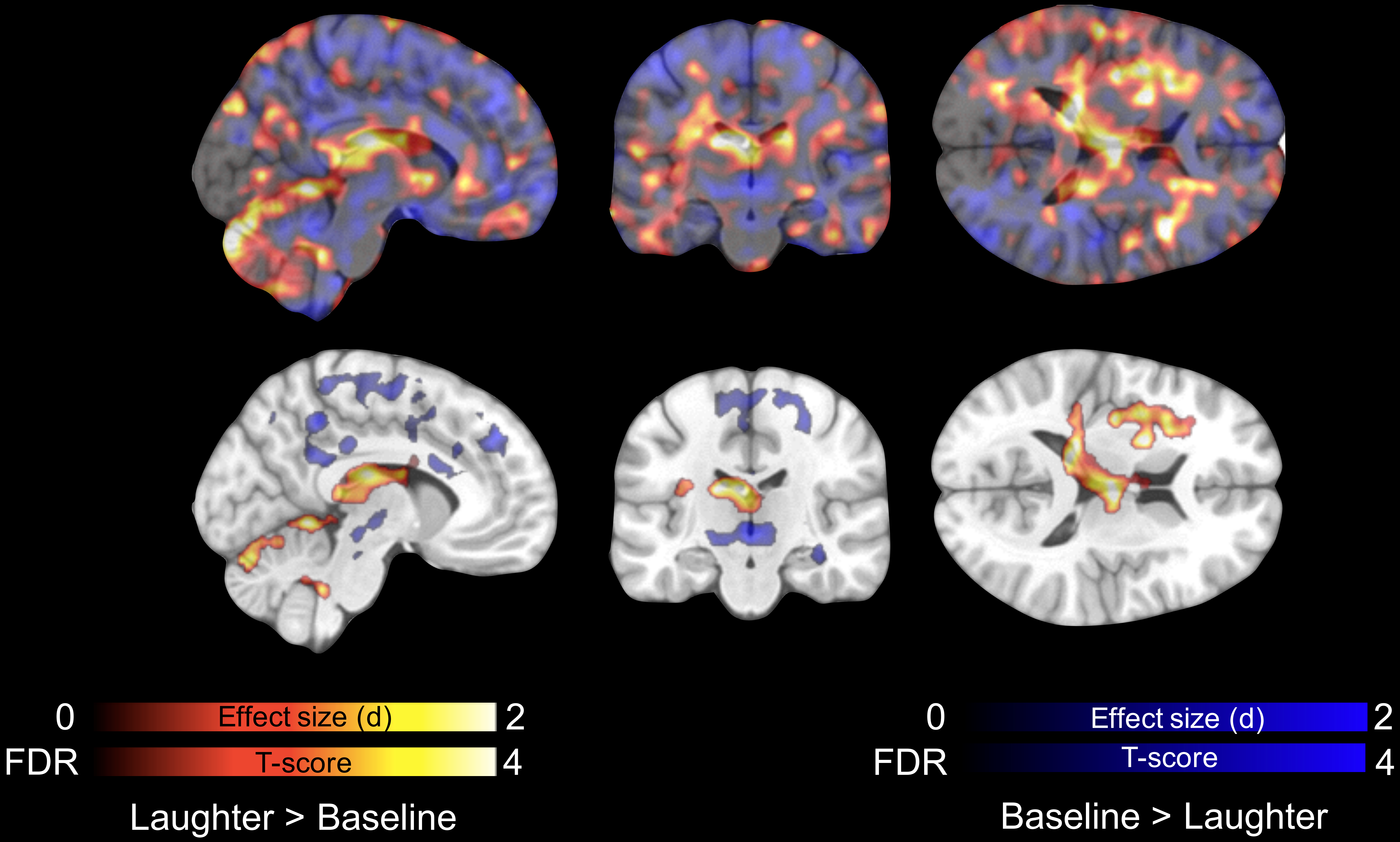


Baseline

Social Laughter



Manninen et al (2017 J Neurosci)

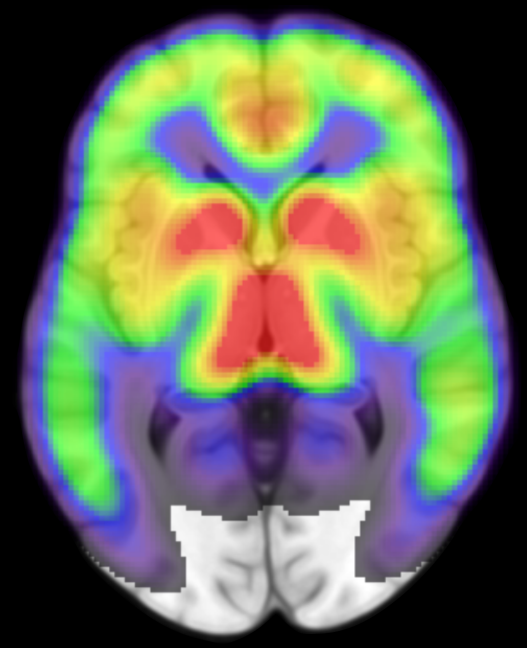


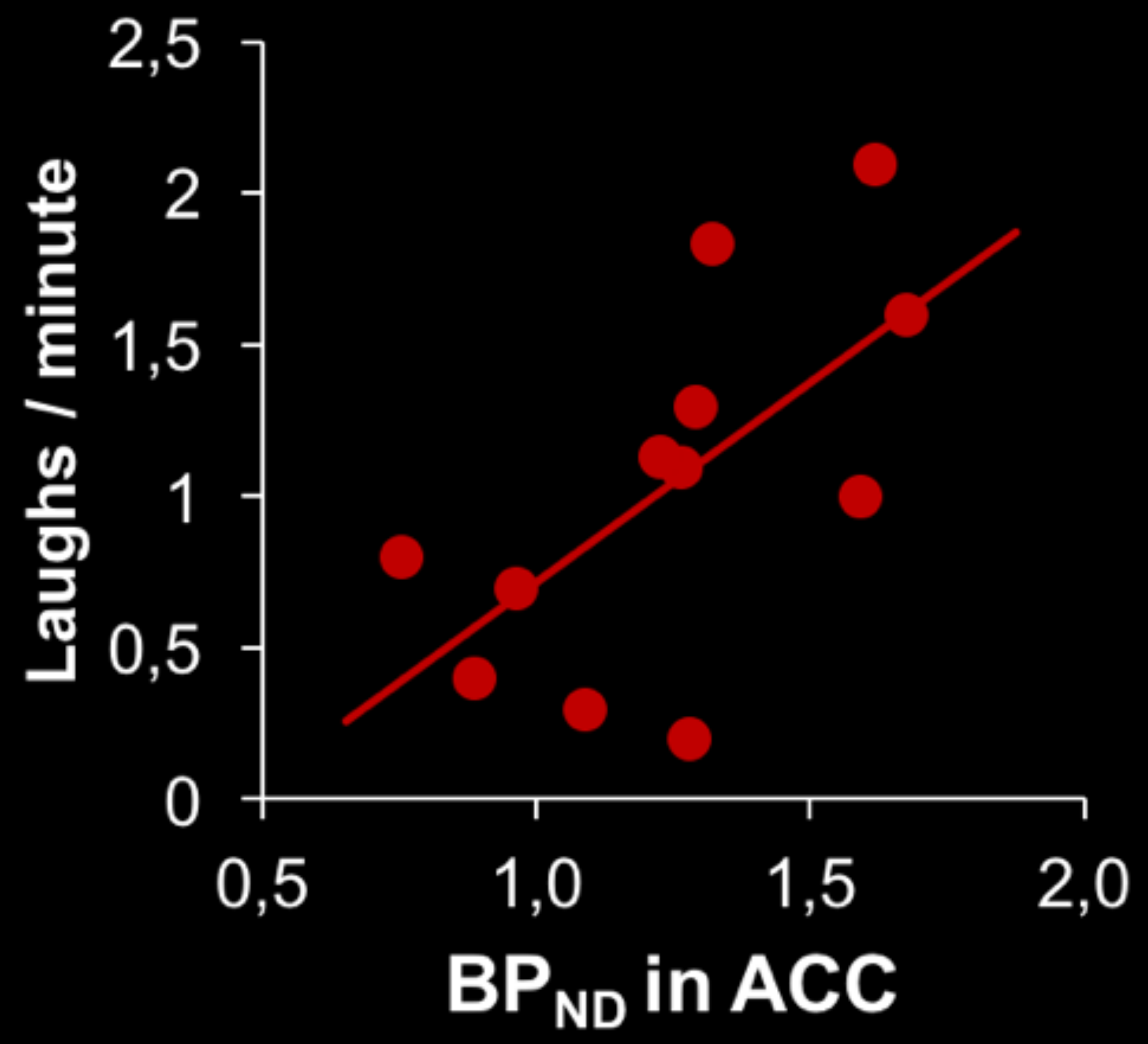
Manninen et al (2017 J Neurosci)

Correlational design

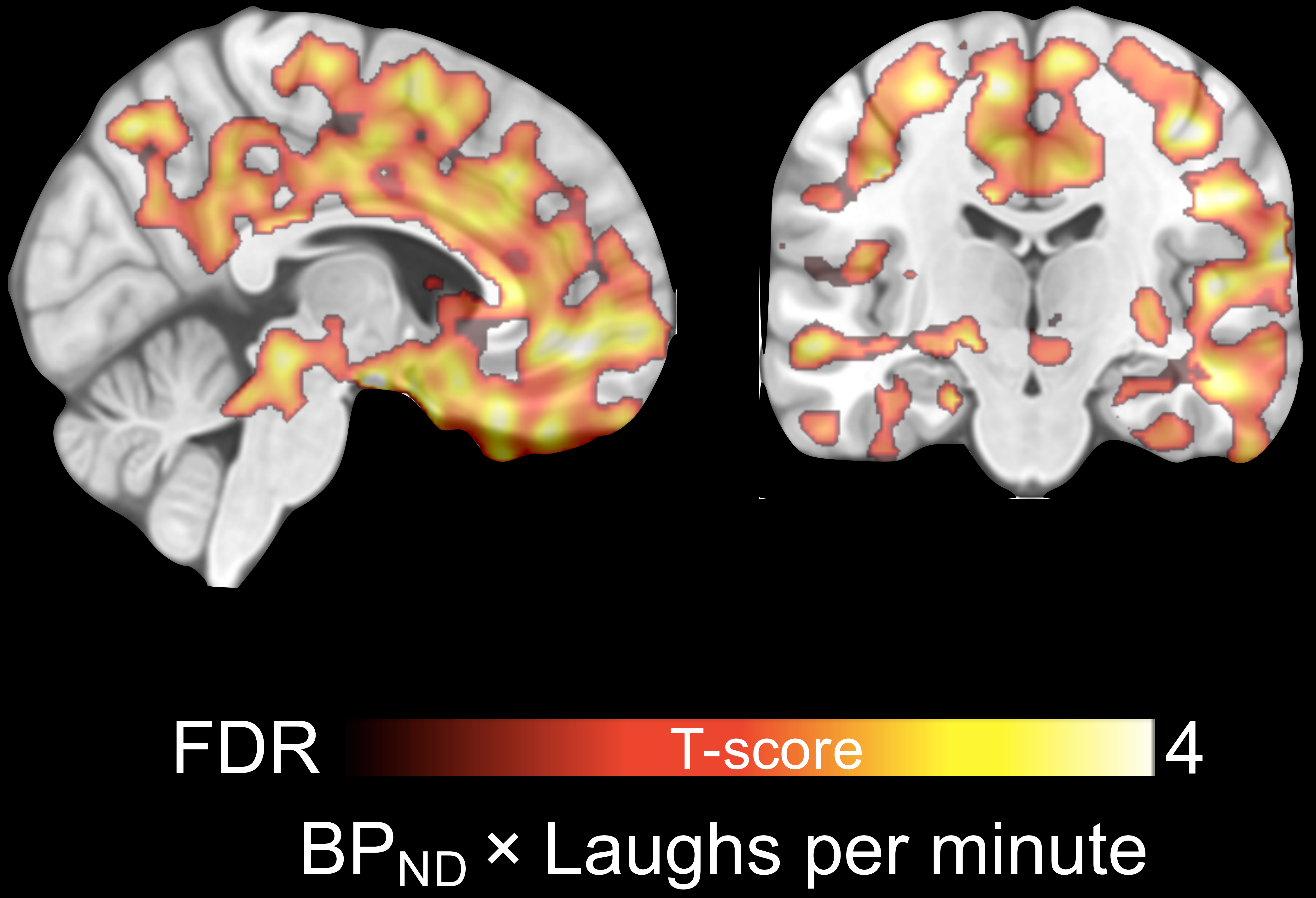
Baseline scan

Univariate biological variable

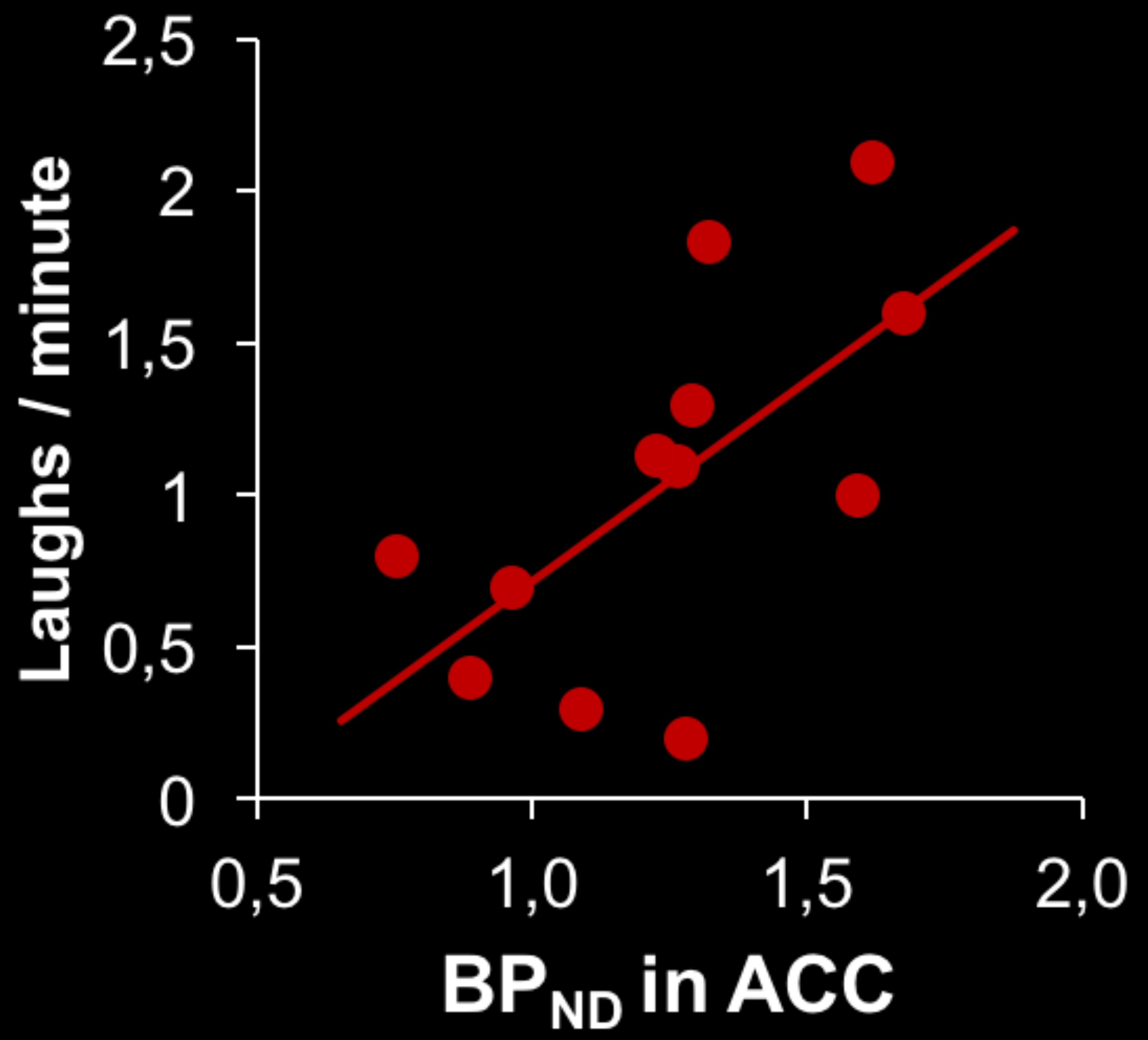




1) Voxelwise correlations between MOR availability and laughter rate



2) Correlation for ROI in orbitofrontal cortex



Manninen et al (2017 J Neurosci)

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SUBJECT 2
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NORMALI-
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TEMPLATE
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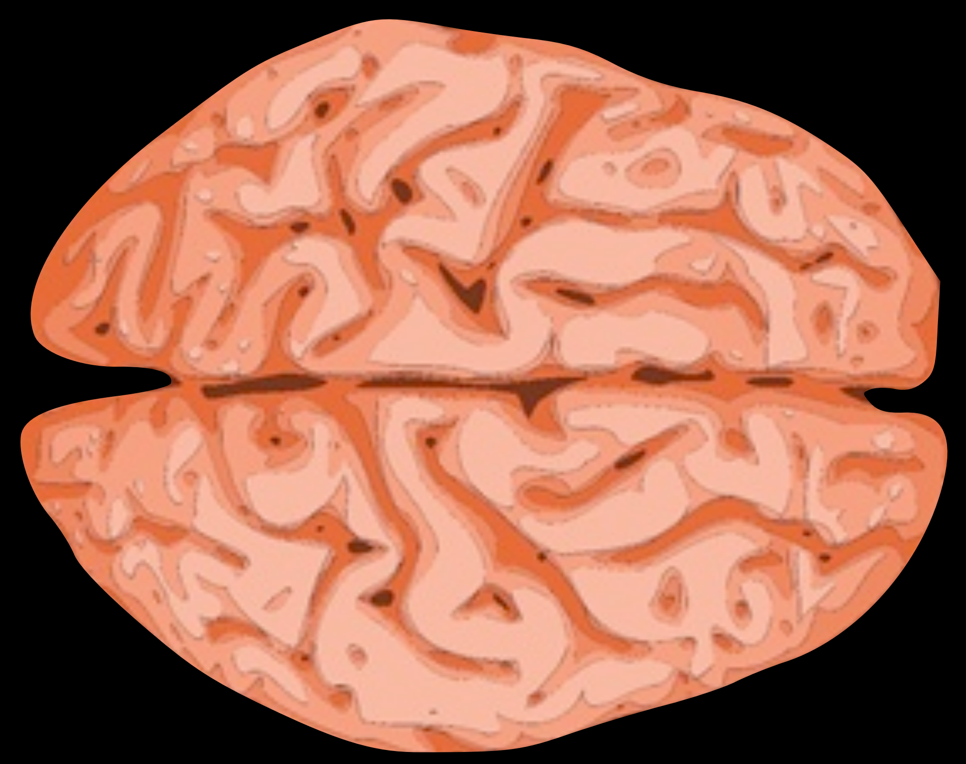
STATISTICAL
PARAMETRIC MAP
SMOOTH

Remember: your results are only as good as your theory!



High reliability and good SNR do not safeguard against stupid research questions and Bad Science™