Effective Source Clustering
Largest 30 independent components (single subject)

Makeig, 2007
Why cluster independent components across subjects or sessions?

- ICA transforms the data from a channel basis (activity recorded at each channel)
  - to a component basis (activity computed at each IC).

- Normally, EEG researchers assume that electrode, say channel F7 == F7 == F7 ... in each subject and then ‘cluster’ their data \[”Your Cz = My Cz.”\]

- But this is only \textit{roughly} correct!

Makeig, 2007
Example: First Subject

Electrode
F7

ICs

IC1

IC2

Cortex

Scalp

∑

IC3

IC4
Third Subject

Electrode F7

ICs

IC1

IC2

Cortex

Scalp

IC3

IC4

Makeig, 2005
Fourth Subject
No more than ~30% of any scalp channel variance is produced by any one brain source!

Scalp EEG signals are strong brain source mixtures.

In this sense channel signals are *epiphenomena*,
& source signals are the EEG phenomena of interest.
A FM-theta cluster during working memory

Onton et al., NeuroImage 2005
The same problems hold for clustering independent components

Across Ss, components don’t even have “the same” scalp maps!

→ Are “the same” components found across subjects?

• What should define “the same” (i.e., “component equivalence”)?
  • Similar scalp maps?
  • Similar cortical or 3-D equivalent dipole locations?
  • Similar activity power spectra?
  • Similar ERPs?
  • Similar ERSPs?
  • Similar ITCs?
  • Or similar combinations of the above?? …
EEG IC Source Locations
(135,794 IC equivalent dipoles)
Does the spatial distribution of IC equivalent dipole source locations depend on the task the subject performs?

i.e.

Do “the same” ICs (& IC clusters) appear for every task?
Equivalent dipole density

\texttt{>> dipoledensity()}

Onton et al., 2005

Sternberg letter memory task
Equivalent dipole density

Onton et al., 2005

>> dipoledensity()
Equivalent dipole density

>> dipoledensity()

Onton et al., 2005

Auditory oddball plus novel sounds
Equivalent dipole density

Onton et al., 2005

Emotion imagery task

>> dipoledensity()
Equivalent dipole density Exp I

>> dipoledensity()
Equivalent dipole density Exp II

>> dipoledensity()
Sometime clusters are spatially separate AND have distinct responses.

In other cases, they may have similar responses or may overlap spatially.

Onton & Makeig, 2007
Problems with multi-measure clustering

What are the clusters according to location?
Problems with multi-measure clustering

What are the clusters according to size?
Problems with multi-measure clustering

What are the clusters according to location and size?

Well, it depends on how much weight we give each measure...
Measure Projection: RSVP Example

Project Target ERSPs on Equivalent Dipole Locations

N. Bigdely-Shamlo, 2011
Measure Projection: RSVP Example

(p < .0002)

ERSP

ERP

N. Bigdely-Shamlo, 2011
Effects of skull conductivity mis-estimation

Simulate 25
↑ RLS_{25-4}
↓ RLS_{80-4}

Assume 80

Simulate 25
↑ RLS_{25-4}
↓ RLS_{15-4}

Assume 15
Electromagnetic source localization using realistic head models

Solve the forward problem using realistic head models (BEM) and mesh generation.

Source estimation and signal processing:

- Simple Map
- MRI
- EEG/MEG

Segmentation

Zeynep Akalin Acar & Scott Makeig ‘06
Simultaneous Conductivity And Location Estimation
Figure 7: Estimated source distributions for independent component (IC) 5 of subject S1 using forward models incorporating BSCR values at various SCALE iterations when iterations start from BSCR = 80 (red plot) and from BSCR = 25 (blue plot). Color bar: normalized signal source density.

The SCALE Approach

A. Akalin Acar, C. Acar & S. Makeig, 2015
High-resolution source localization

Figure 7: Estimated BSCR, source compactness, and visualized source distributions for independent component (IC) 5 for subject S1 using SCALE-generated S1 forward head model sequences for two BSCR initial values, BSCR = 80 (red trace) and BSCR = 25 (blue trace). Semi-inflated cortical surface plots show the estimated (central medial) source distribution at several SCALE iterations. The color bar (lower right) shows estimated voxel source signal density relative to its maximum absolute value. The grey—color threshold value in these plots (±30% of the maximum voxel density value) was selected as the elbow in the cumulative histogram of squared voxel values in the ultimate source estimate (box, upper right).
Topological source clustering

Arthur Tsai et al., *NeuroImage*, 2014
Questions?