Effective Source Clustering
Largest 30 ICs (single subject)
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 *roughly* correct!
Example: First Subject

Electrode F7

ICs

IC1

IC2

IC3

IC4

Cortex

Scalp

Makeig, 2005
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.
An FM-theta cluster
In a working memory task
Why should IC clusters have width?
Equivalent cortical areas
Have different scalp maps
And dipole locations!
EEG IC Source Locations
(135,794 IC equivalent dipoles)

NB: Width of these hotspots gives a lower bound on source localization accuracy!
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

>> dipoledensity()

Sternberg letter memory task

Onton et al., 2005

Onton et al., ‘05
Equivalent dipole density

Letter twoback with feedback

>> dipoledensity()
Equivalent dipole density

Auditory oddball plus novel sounds

>> dipoledensity()
Equivalent dipole density

Emotion imagery task

>> dipoledensity()
Equivalent dipole density Exp I

>> dipoledensity()
Equivalent dipole density Exp II

Onton et al., 2005

Visually cued button press task

>> dipoledensity()
So how to cluster components?

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?? …

Makeig, 2007
Study IC Clustering

Sometime clusters are spatially separate AND have distinct responses.

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

Project Target ERSPs on Equivalent Dipole Locations

N. Bigdely-Shamlo, 2011
Project Target ERSPs on Equivalent Dipole Locations

Measure Projection: RSVP Task Example

(p < .0002)
Questions?
High-Resolution Source Localization
Electromagnetic source localization using realistic head models

Solve the forward problem using realistic head models (BEM)

Mesh generation

Segmentation

Simple Map

Sensor Localization

Signal Processing

Source Estimate

Zeynep Akalin Acar & Scott Makeig ‘06
Effects of skull conductivity mis-estimation

Simulate 25
Assume 80

Simulate 25
Assume 15
Simultaneous Conductivity and Location Estimation (SCALE)
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).

Zeynep Akalin Acar et al., *NeuroImage*, 2016

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