Preprocessing MEG Data for Analysis of Event-Related Fields (ERFs)

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Cambridge, UK

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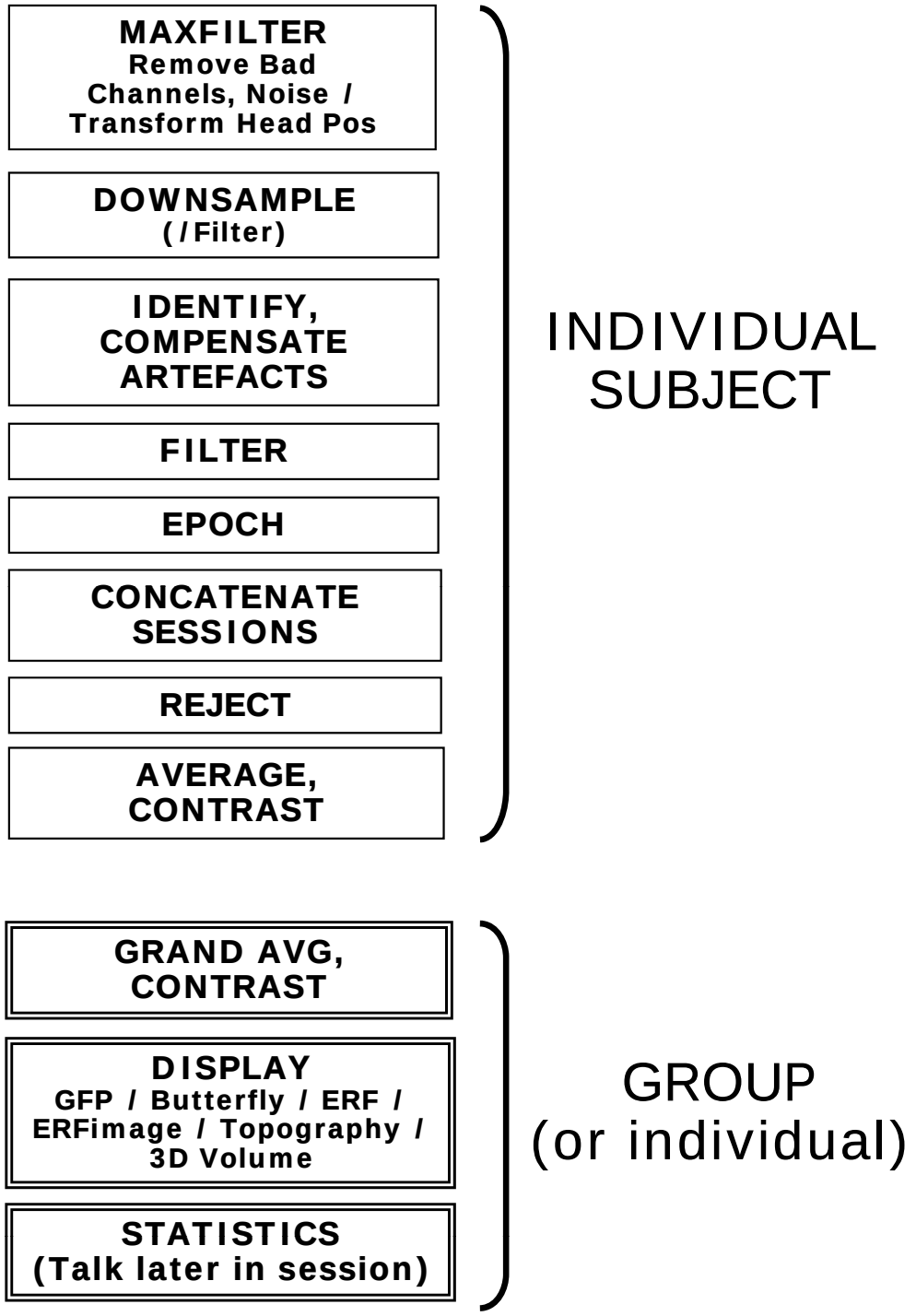
MAXFILTER
Remove Bad Channels, Noise / Transform Head Pos
DOWNSAMPLE
(/Filter)
IDENTIFY, COMPENSATE ARTEFACTS
FILTER
EPOCH
CONCATENATE SESSIONS
REJECT
AVERAGE, CONTRAST
INDIVIDUAL SUBJECT
GRAND AVG, CONTRAST
DISPLAY
GFP / Butterfly / ERF / ERFimage / Topography / 3D Volume
STATISTICS
(Talk later in session)
GROUP
(or individual)

MAXFILTER
Remove Bad Channels, Noise / Transform Head Pos

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STATISTICS
(Talk later in session)

[MaxFilter]

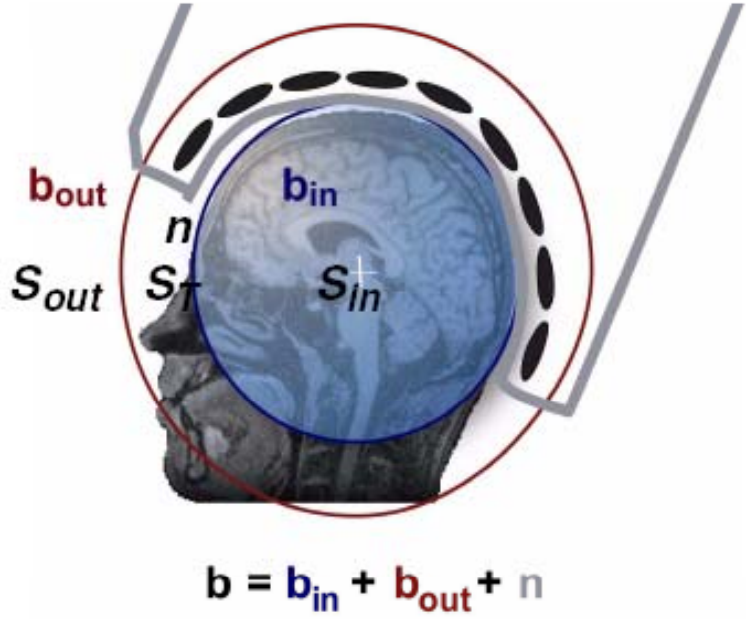
= 'Maxwell' Filtering (Neuromag only)

Remove noise from external sources or from within sensor array (Signal Space Separation, SSS)

Identify and remove (reconstruct) bad sensors
Remove high-frequency HPI signal

Transform head position

- Correct for motion (within a session)
- Align head position across sessions
- Align head position across subjects



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STATISTICS
(Talk later in session)

[Downsample]

= Reduce sampling rate (number of points)

Reduces file size

- Useful if memory-intensive processes planned
- Usually only interested in <50 Hz anyway

NOTE: Low-pass filter should be applied first to prevent aliasing (i.e., high-frequency signal expressed as low-frequency modulation)

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STATISTICS
(Talk later in session)

[Identify Artefacts]

= Identify noise related to physiological signals

Physiological artefacts w/ regular topographies

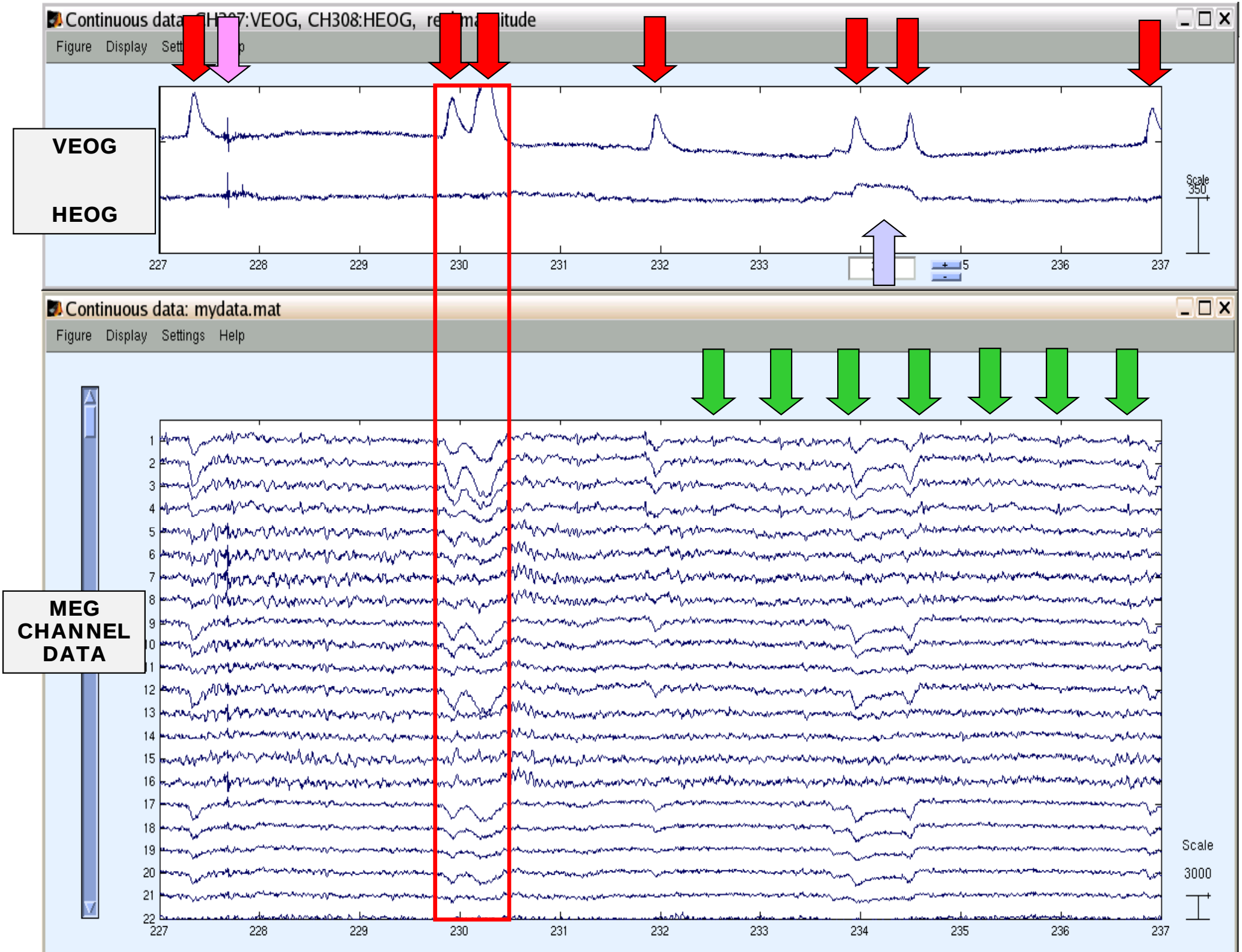
- blink, eye movement, pulse, …

Preempt if possible!

- Ask subjects to be still, fixate, not blink
- Can't do much about the pulse, though!

Record physiological signals

- Compare against MEG channels


Continuous data: CH307:VEOG, CH308:HEOG, re
Figure Display Sett
VEOG
HEOG
Scale 350
227 228 229 230 231 232 233 234 235 236 237
Continuous data: mydata.mat
Figure Display Settings Help
MEG CHANNEL DATA
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
Scale 3000
227 228 229 230 231 232 233 234 235 236 237

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STATISTICS
(Talk later in session)

[Compensate for Artefacts]

= Adjust data to ‘remove’ artefact signal

Why not just reject?

- Difficult to get clean recordings in some populations
- May have limited number of stimuli/trials

Different approaches exist:

- Regression method
  -> MEG(clean) = MEG(dirty) - EOG x propagation factor
- Subtract activity of source dipole @ eyes
- Project out blink-correlated independent component

Issues:

- Brain signal in EOG?
- Brain signal in blink IC?
- Head movement relative to MEG sensors
  ** MUST apply motion correction **
- Variability in blinks, eye movements
- ‘Splitting’ of artefact across components

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STATISTICS
(Talk later in session)

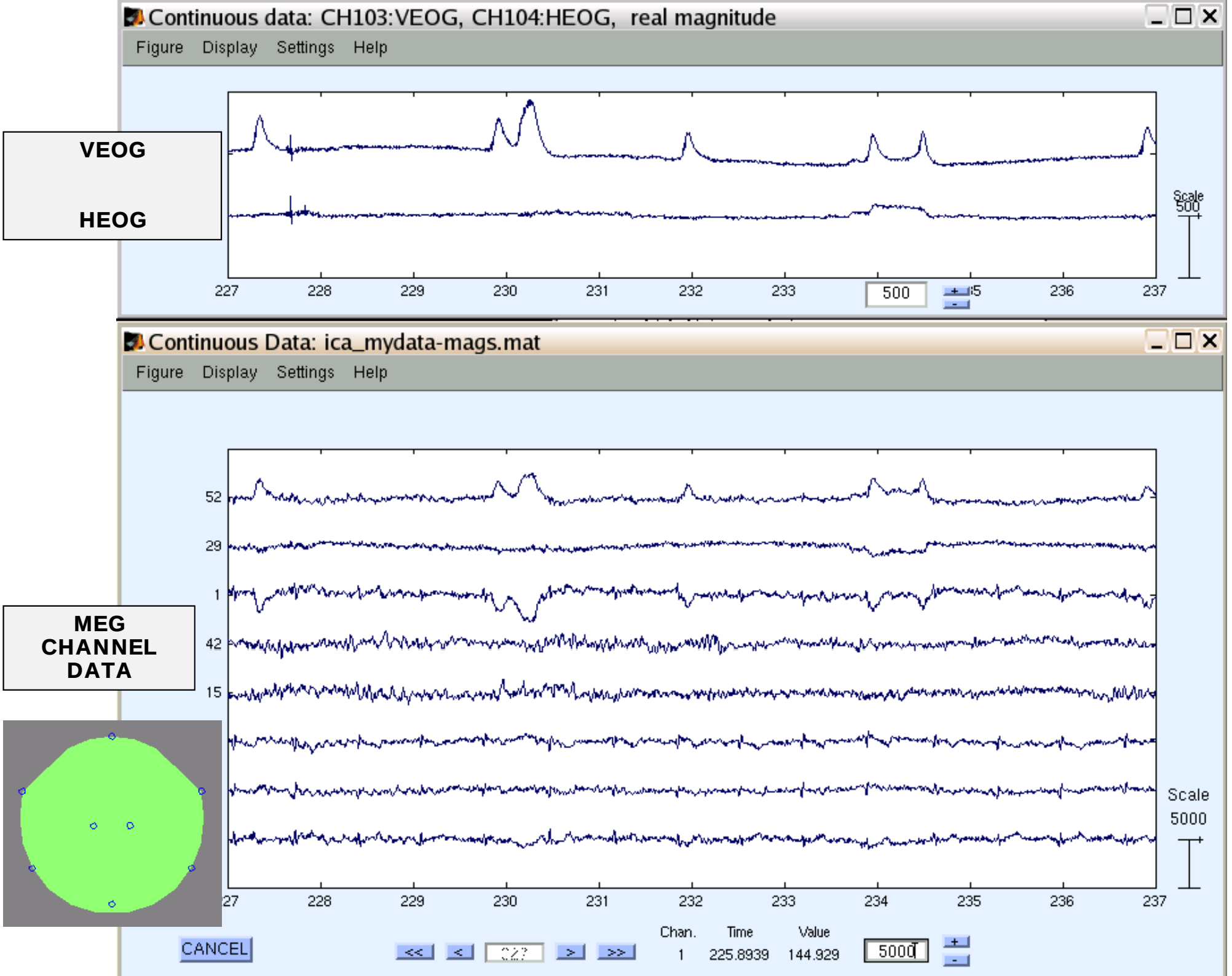
[Artefact Compensation with ICA]

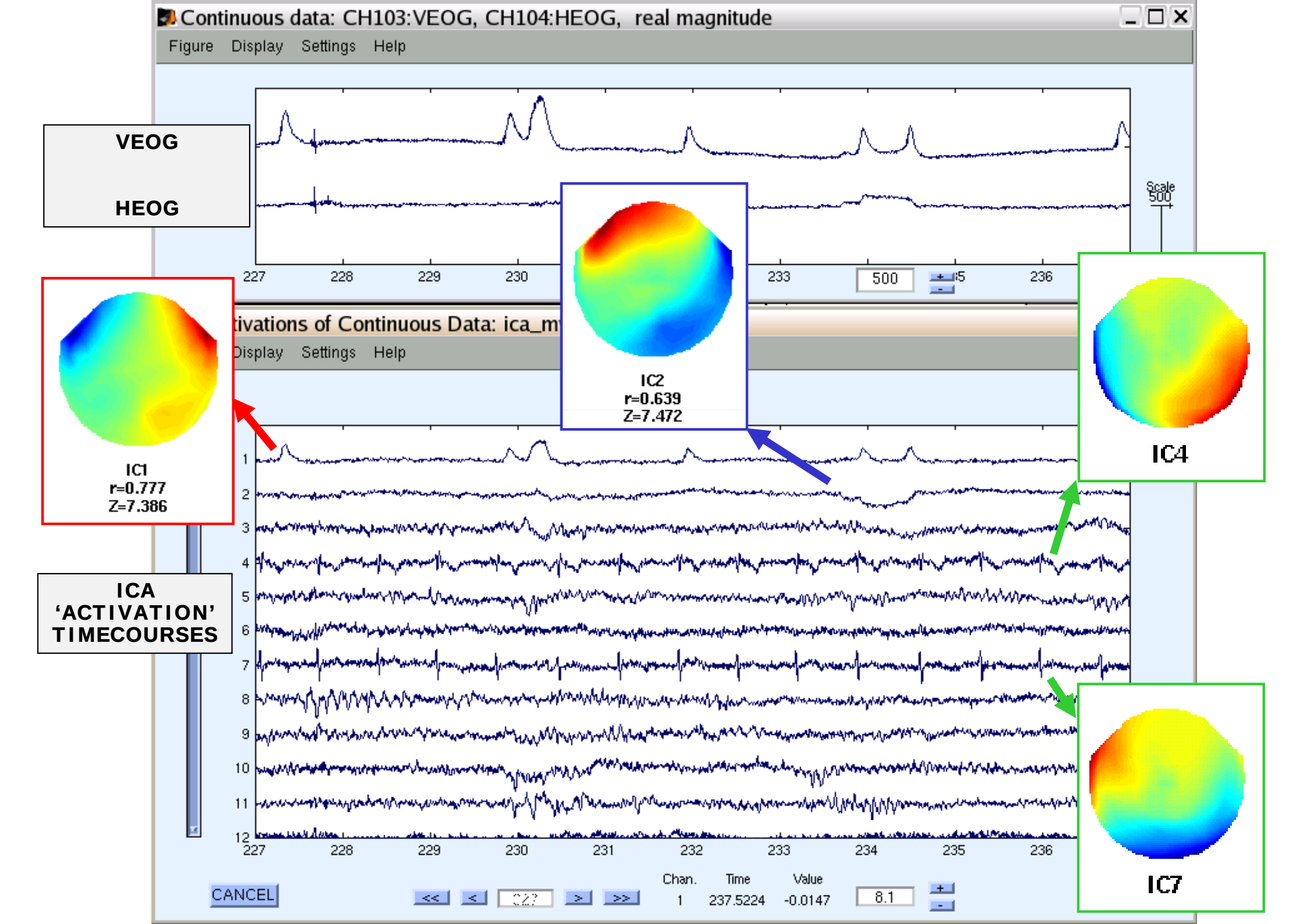
ICA = Independent Component Analysis

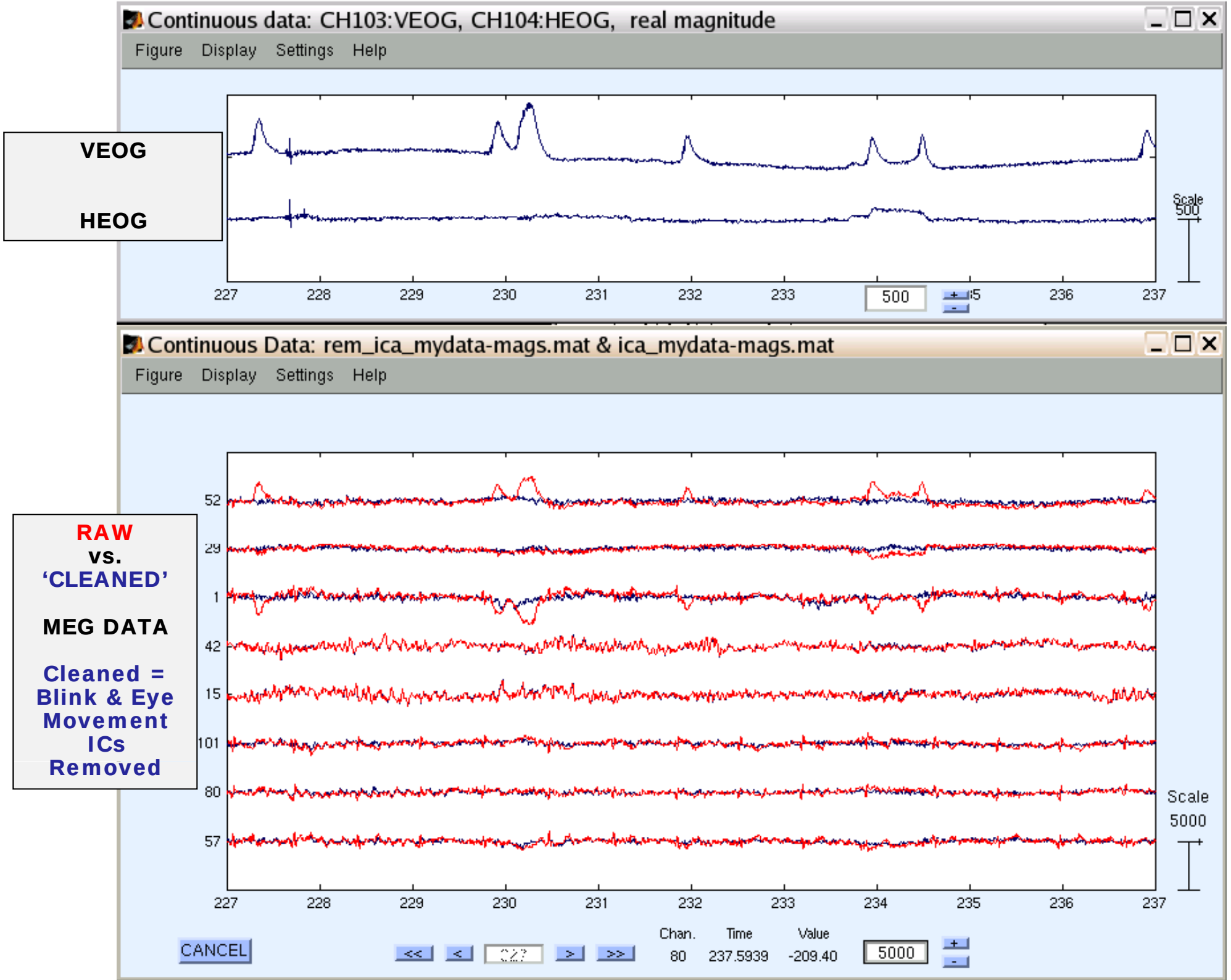
- Separates multi-channel data into independent components (minimised mutual information).
  - data = A*sources A is the 'mixing matrix'
  - sources = W*data where 'unmixing matrix' $W=A^{-1}$
- Assumes stationary sources with differing timecourses
- Data-driven ('blind' source separation)

Semi-Automated identification of 'artefact' ICs

- Correlate IC timecouse w/physiological signals
- Correlate IC topography with artefact template


Continuous data: CH103:VEOG, CH104:HEOG, real magnitude
Figure Display Settings Help
VEOG
HEOG
Scale
500
227 228 229 230 231 232 233 500 236 237
Continuous Data: ica_mydata-mags.mat
Figure Display Settings Help
MEG CHANNEL DATA
52
29
1
42
15
Scale
5000
27 228 229 230 231 232 233 234 235 236 237
CANCEL
<< < 227 > >>
Chan. Time Value
1 225.8939 144.929
5000


Continuous data: CH103:VEOG, CH104:HEOG, real magnitude
Figure Display Settings Help
VEOG
HEOG
Scale 500
227 228 229 230 233 236
500
IC1
r=0.777
Z=7.386
IC2
r=0.639
Z=7.472
IC4
ICA 'ACTIVATION' TIMECOURSES
Display Settings Help
1 2 3 4 5 6 7 8 9 10 11 12
227 228 229 230 231 232 233 234 235 236
IC7
CANCEL
<< < > >>
Chan. Time Value
1 237.5224 -0.0147
8.1

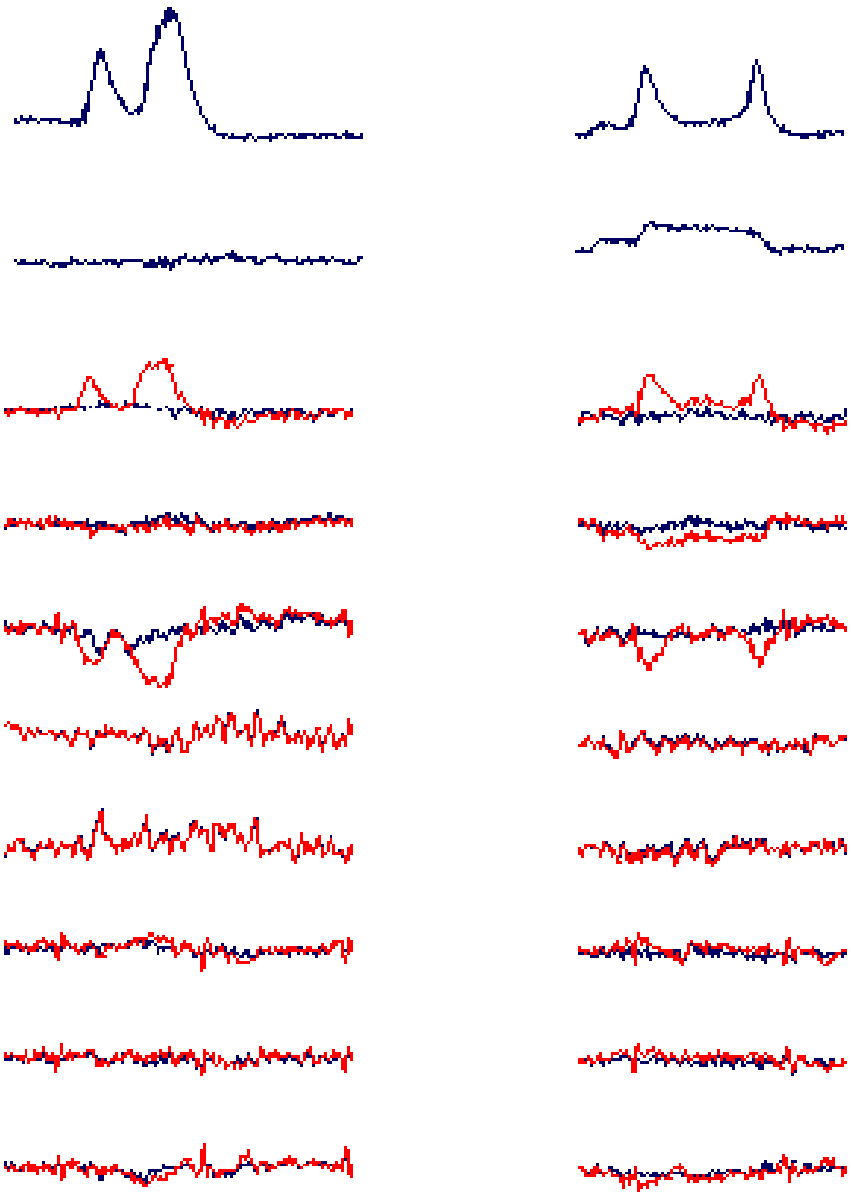

Continuous data: CH103:VEOG, CH104:HEOG, real magnitude
Figure Display Settings Help
VEOG
HEOG
227 228 229 230 231 232 233 500 236 237
Scale 500
Continuous Data: rem_ica_mydata-mags.mat & ica_mydata-mags.mat
Figure Display Settings Help
RAW
vs.
'CLEANED'
MEG DATA
Cleaned = Blink & Eye Movement ICs Removed
52
29
1
42
15
101
80
57
227 228 229 230 231 232 233 234 235 236 237
Scale 5000
CANCEL
<< < > >>
Chan. Time Value
80 237.5939 -209.40
5000

VEOG

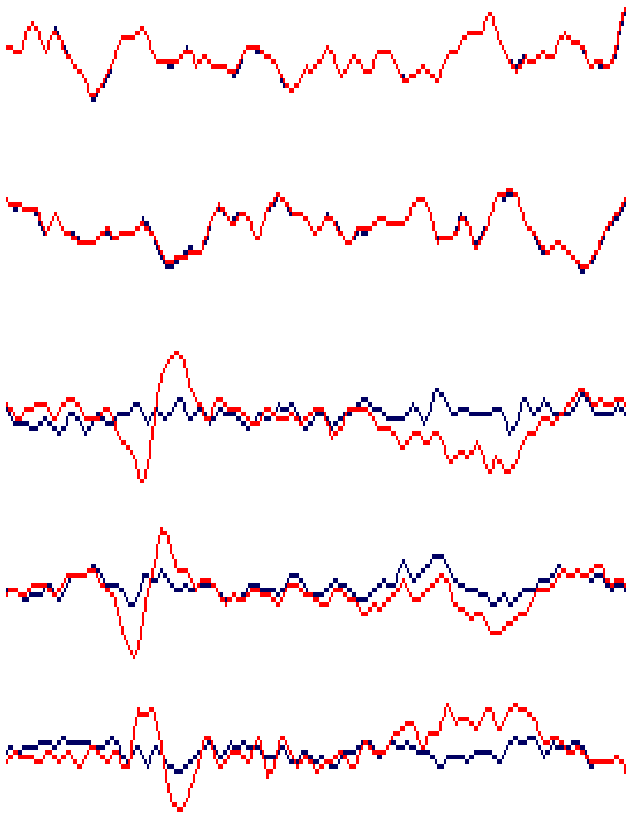
HEOG

RAW
vs.
'CLEANED'

MEG DATA



Blink & Eye Movement ICs Removed



Pulse ICs Removed

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STATISTICS
(Talk later in session)

[Artefact Compensation with ICA]

ICA = Independent Component Analysis

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- Assumes stationary sources with differing timecourses
- Data-driven ('blind' source separation)

Semi-Automated identification of 'artefact' ICs

- Correlate IC timecouse w/physiological signals
- Correlate IC topography with artefact template

Issues:

- How many components?
  * rank of data < # chans
- Filter/Reject first?
  * Works better on cleaner data (free of one-off noise events, e.g., cough, shift of position)
  * But can use high-frequency information
  * Continuous data easier to interpret

Limitations:

- Head position must be constant!
- Works very well for blinks (high signal), well for eye movements, well for pulse
- Effects on source localisation unexplored

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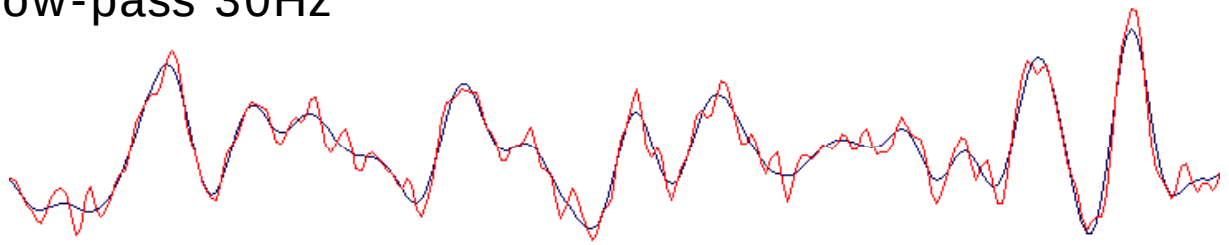
STATISTICS
(Talk later in session)

[Filter]

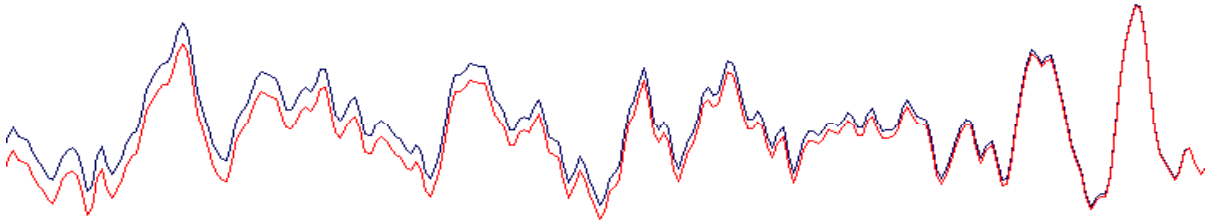
= Remove high-frequency noise and/or low-frequency drift

Often used for visualisation only

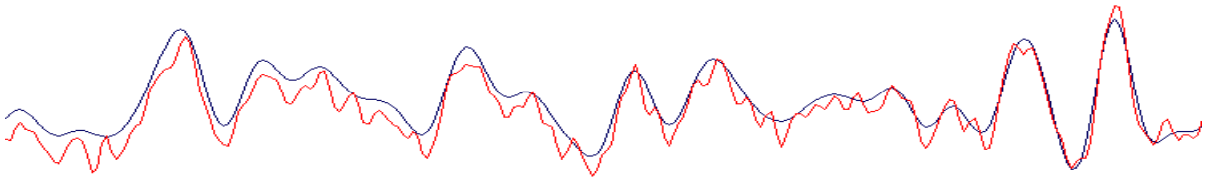
low-pass 30Hz



high-pass 0.5Hz



band-pass 0.5 – 30Hz



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STATISTICS
(Talk later in session)

[Epoch]

= Cut up data into stimulus- or response-locked segments

Size depends on what you are studying

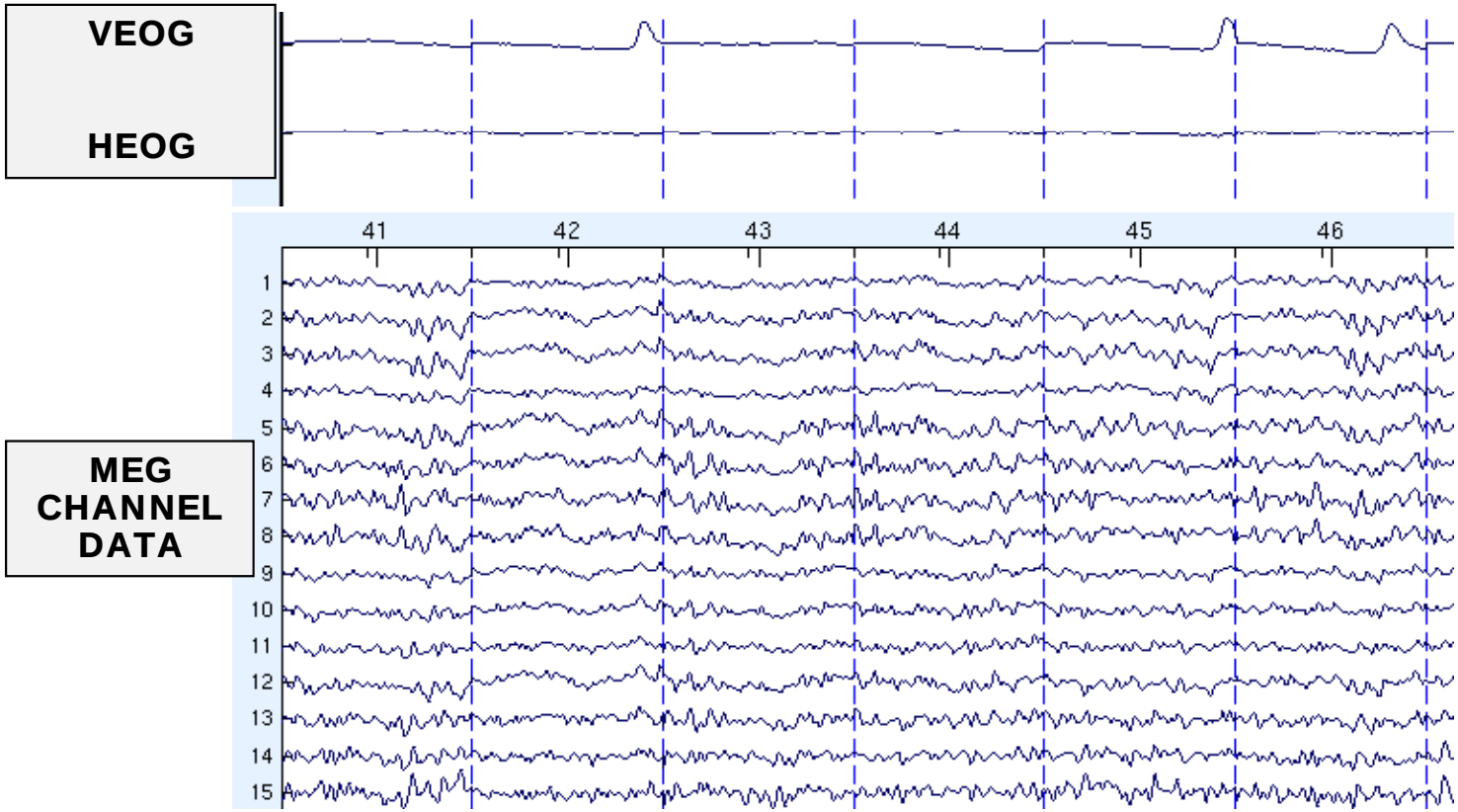
- Time-Frequency: long epochs (to avoid edge effects)
- If ICA after epoching: long epochs

Baseline-period

- Should be free of stimulation, responses

Jitter ISI between critical and preceding stimuli

- Avoid phase-locking induced by stim, anticipatory responses



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STATISTICS
(Talk later in session)

[Concatenate Sessions]

= Stick multiple sessions (same subject) together into one

Note: head position must be the same across sessions!

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STATISTICS
(Talk later in session)

[Reject]

= Remove noisy epochs from further analysis

Even after artefact compensation…

- unaccounted-for physiological (or other) artefacts remain
- remove epochs with, e.g., blinks during stimulus

Decision may be based on:

- Hard thresholds (common or subject-specific)
- Statistical outliers
- Eye / expert judgement (*gasp*)

Alternative to rejection: Robust Averaging (SPM)

- weight points by similarity to mean

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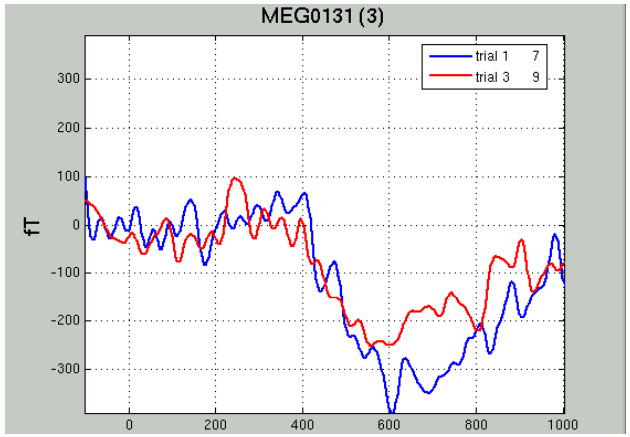
STATISTICS
(Talk later in session)

[Average / Contrast]

= Compute mean timecourse over epochs of same condition, or apply contrast to compare/combine conditions (as in SPM GLM for fMRI)

Theory:

- ERF/P = 'signal'; background M/EEG = noise
- Averaging increases signal:noise
- Compute point-to-point average



Problems:

- Can't be sure this is true since it relies on averaging!
- Latency jitter flattens averages

Alternatives:

- Analyse EEG (power in different frequency bands)
- Visualise epochs

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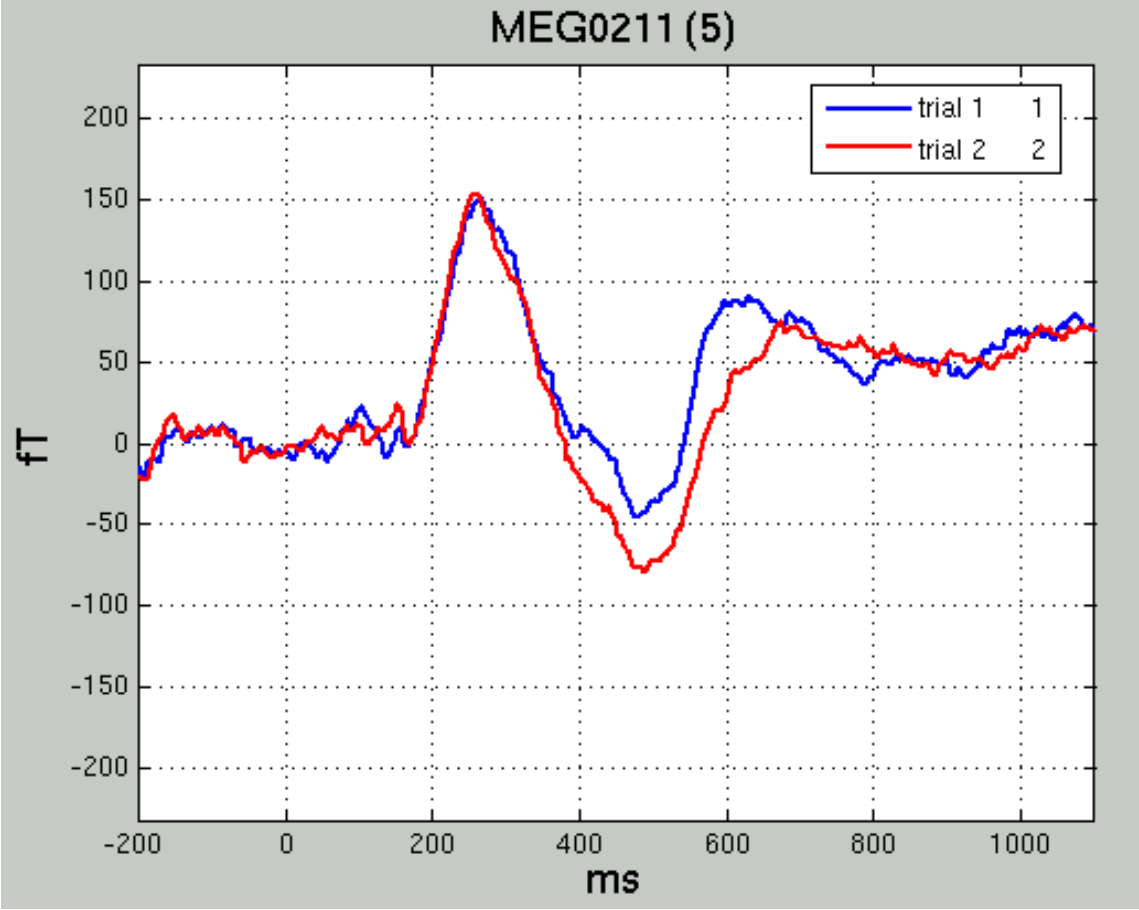
STATISTICS
(Talk later in session)

[Grand Average by Condition]

= Average (or contrast) of subjects' condition averages



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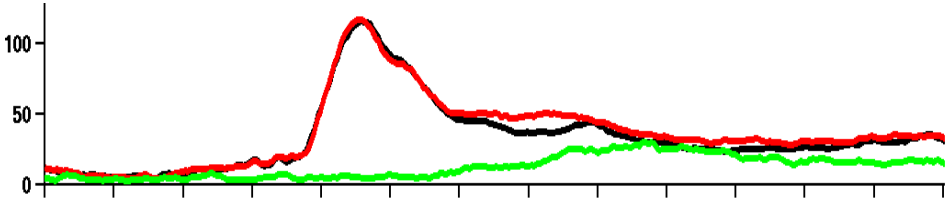
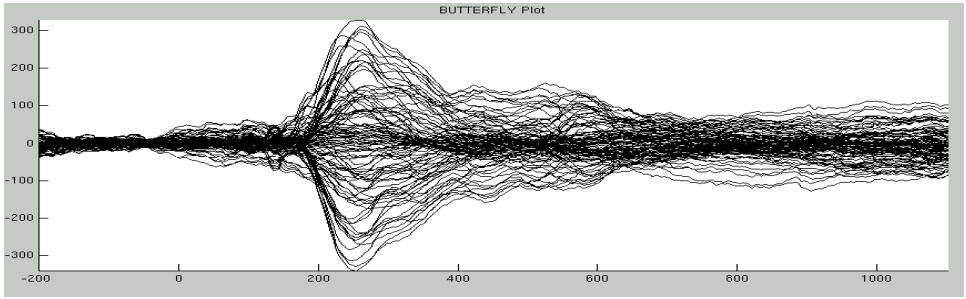
STATISTICS (Talk later in session)

[Display Data] – Timecourse

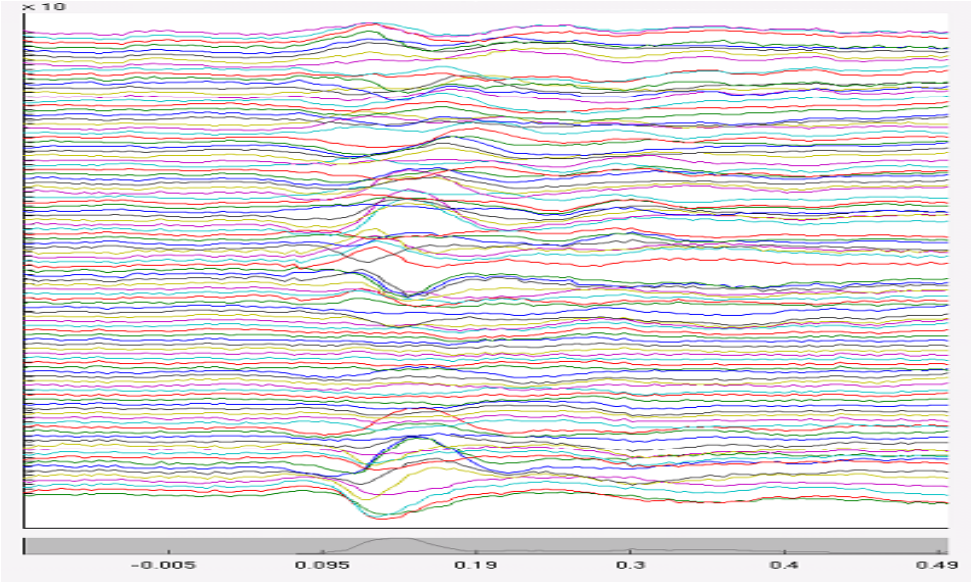
Global Field Power (GFP) = Power collapsed over space



Butterfly Plot = all sensors superimposed



Event-Related Field (ERF) = timecourse at each sensor



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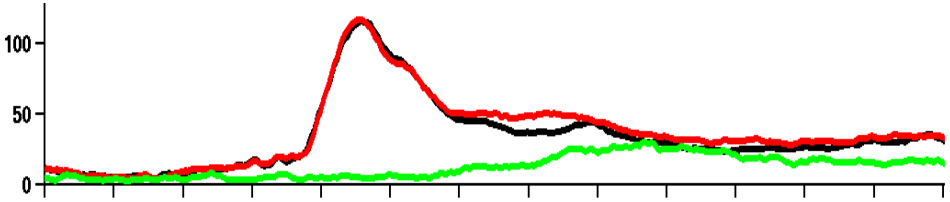

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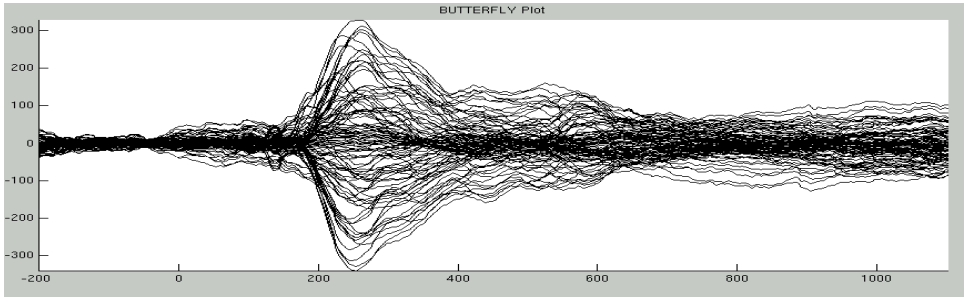
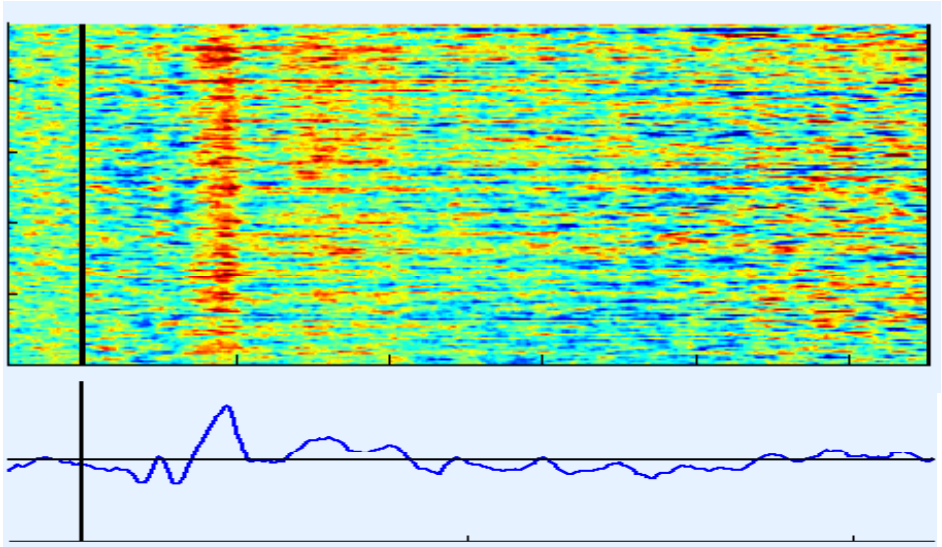


ERFimage = each trial (/subject) at 1 sensor as scaled image



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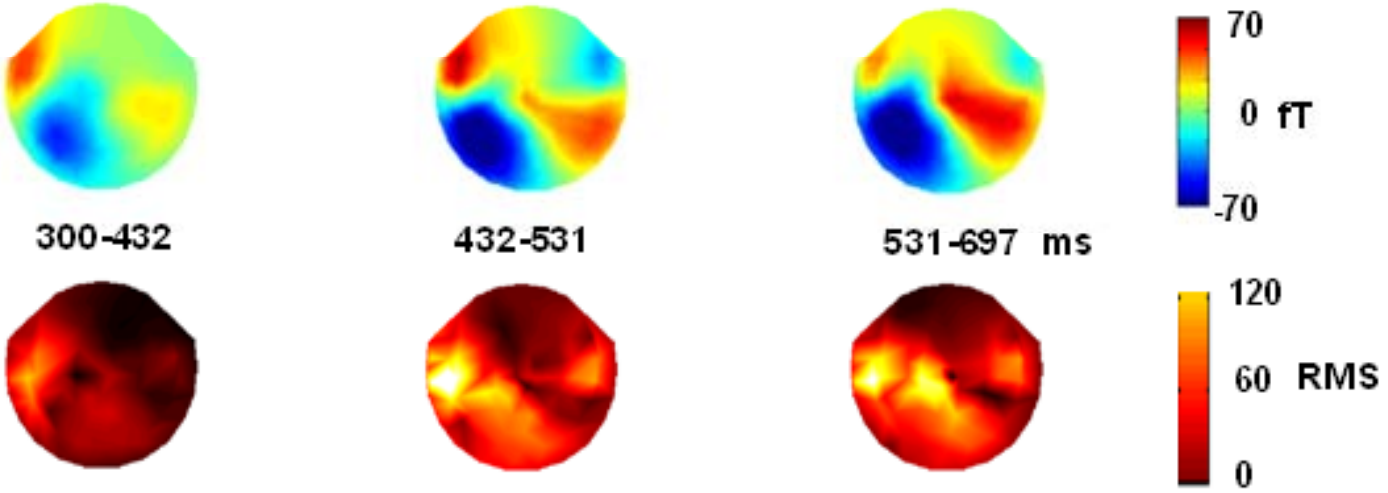
STATISTICS (Talk later in session)

[Display Data] – Spatial Distribution

Topography = spatial distribution of field at points in time



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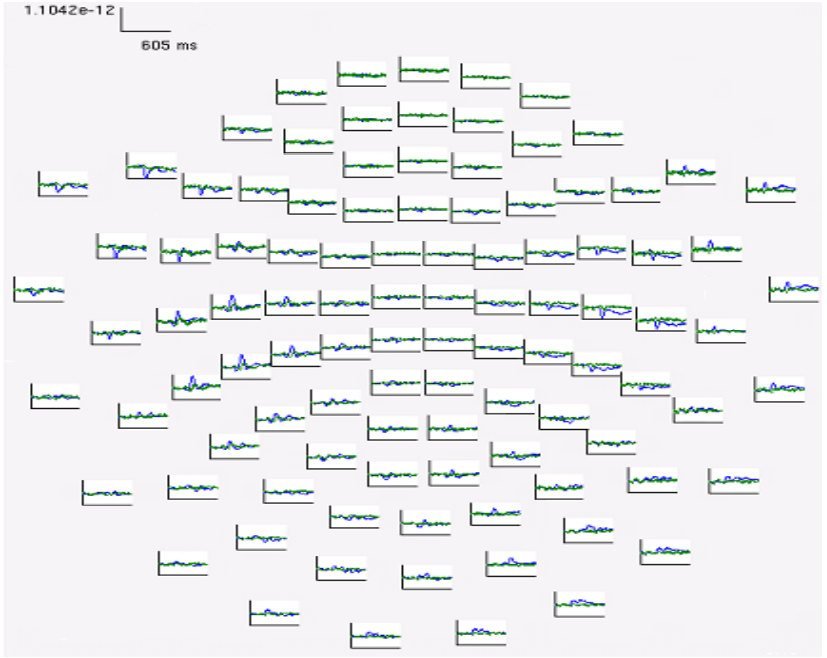

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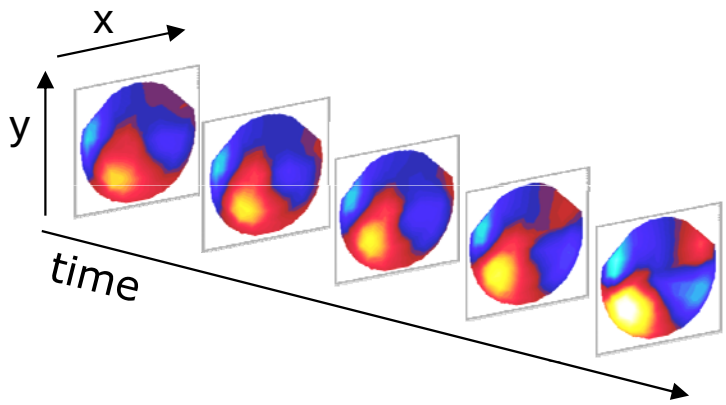
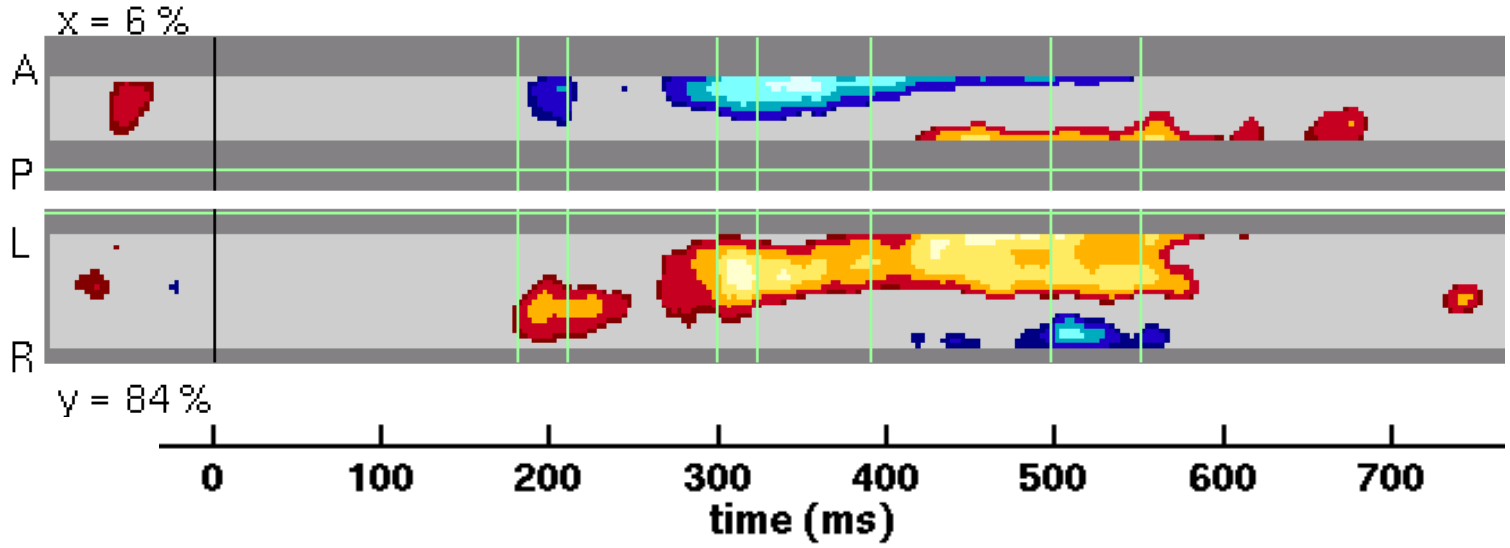
STATISTICS (Talk later in session)

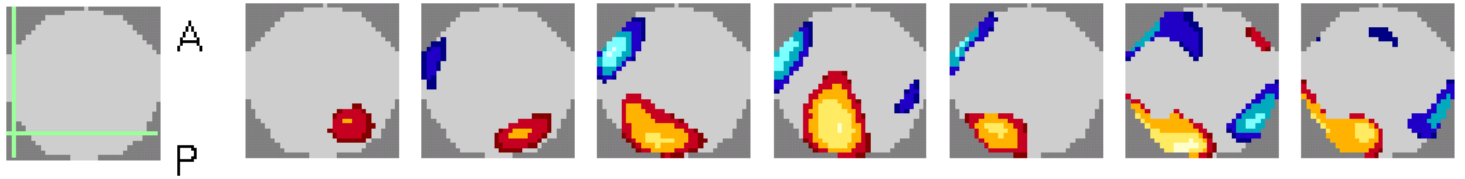
[Display Data] – Timecourse AND Spatial Distribution

Topography-by-Time Images

= Image volumes formed by layering topographies from each time point (imagine a stack of poker chips)







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STATISTICS
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-- The end --

- Thanks for listening

- Acknowledgements:
  - Rik Henson (MRC CBU)
  - Vladimir, Karl, and the FIL Methods Group

- More info:
  - **CBU wiki: http://imaging.mrc-cbu.cam.ac.uk/meg**
  - **SPM: http://www.fil.ion.ucl.ac.uk/spm**
  - **EEGLAB (ICA): http://sccn.ucsd.edu/eeglab**
  - **Book: An Introduction to the Event-Related Potential Technique by Steve Luck**

jason.taylor@mrc-cbu.cam.ac.uk