Group Sensing for EEG Analysis

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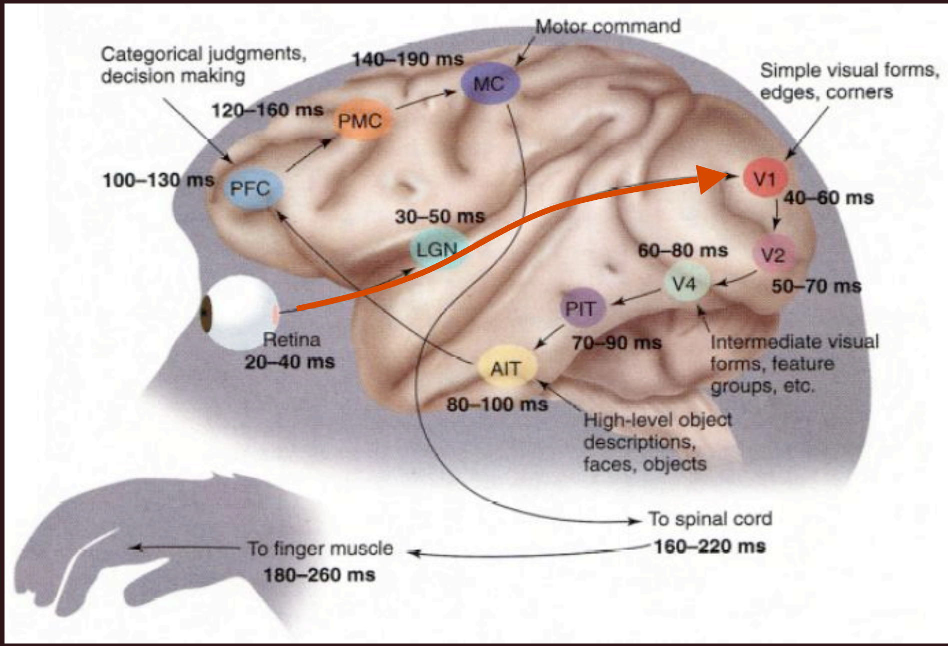
Joint work with S. Muthu Muthukrishnan and Dr. David Rosenbluth (Telcordia) for the DARPA grant 'Group Brain Imaging'

Stimulus – Response

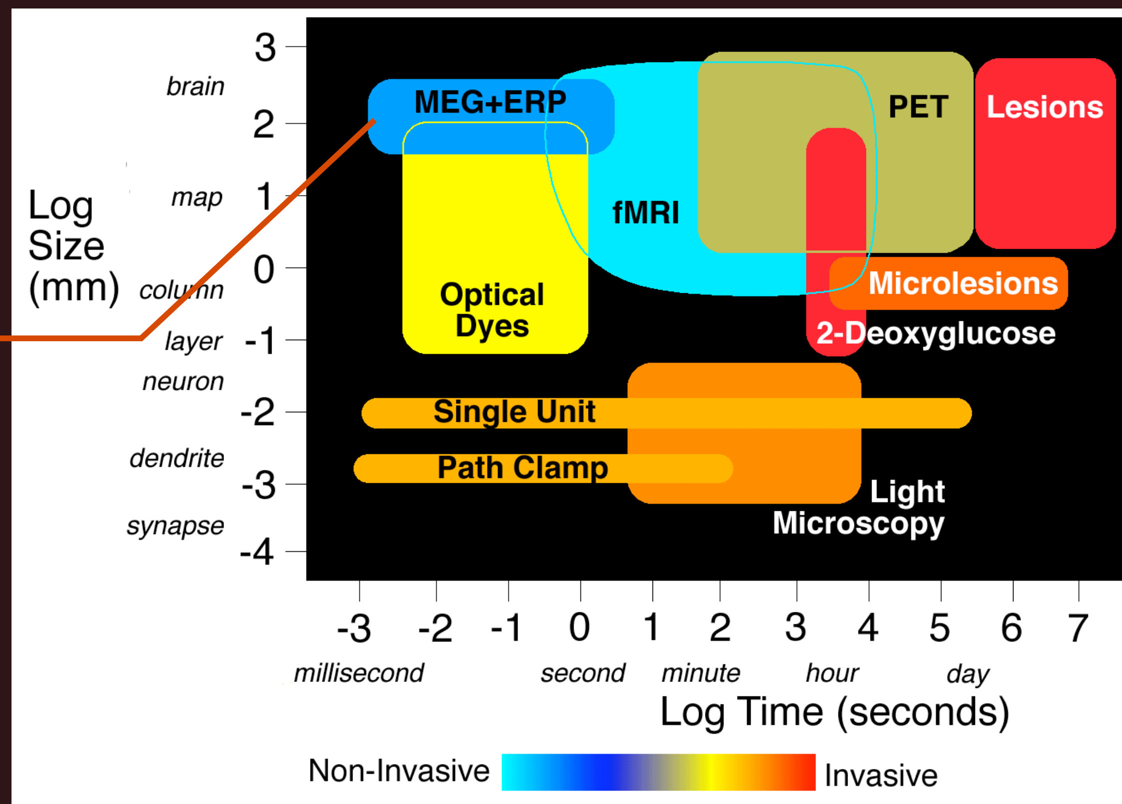
- Sensory – motor loops
- Stimulus – response
- Complex processing



Stimulus Presentation → Brain analyzes the stimulus → Brain invokes a motor response → Motor action performed

Brain Imaging Techniques

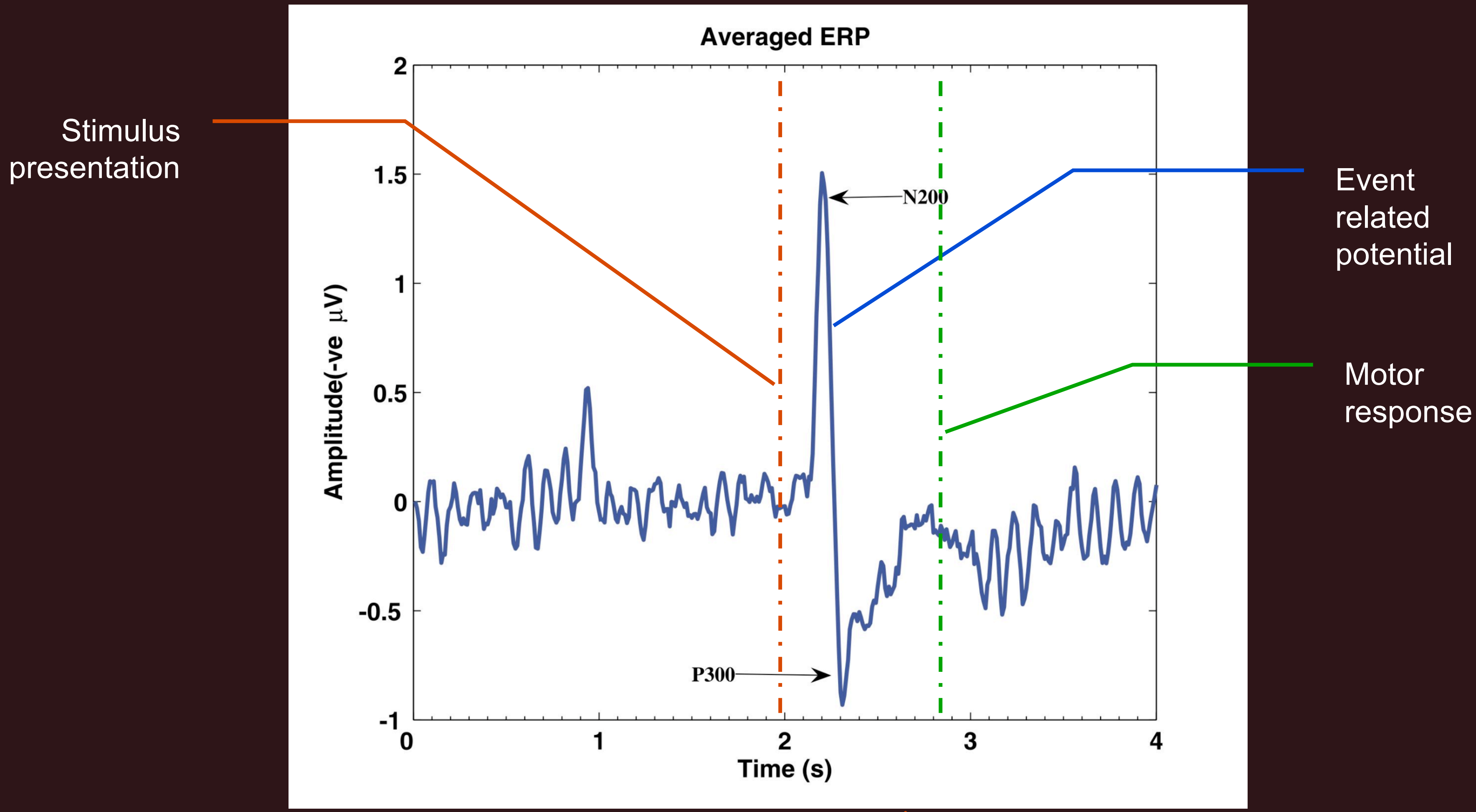
EEG is non-invasive and has high temporal resolution



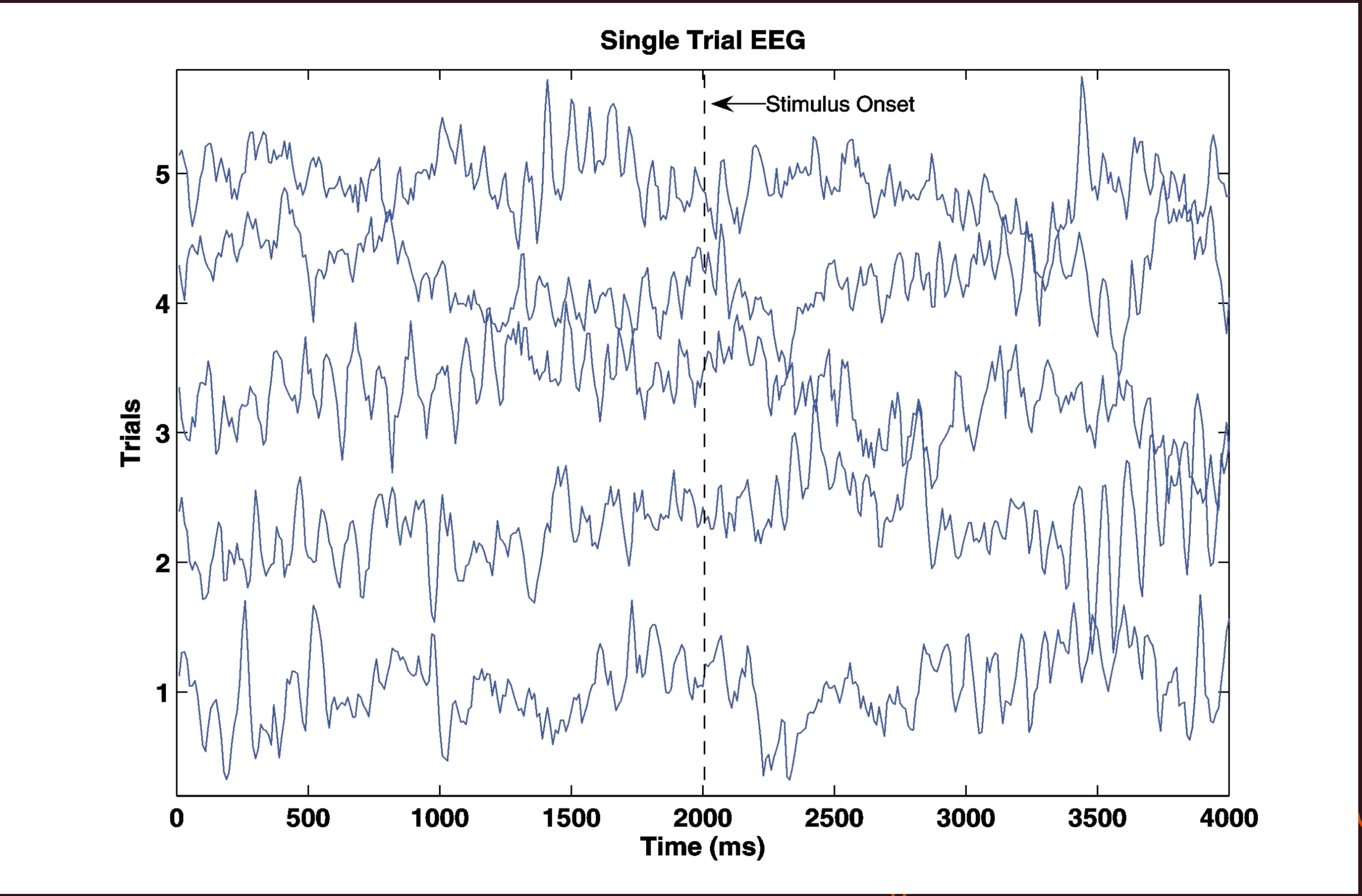
Why EEG?

- Characterize brain's response to stimuli
- Understand functional relationships
- Clinical applications – Sleep, epilepsy …
- Brain Computer Interfaces
- Neuro-marketing

Event related potential (ERP)



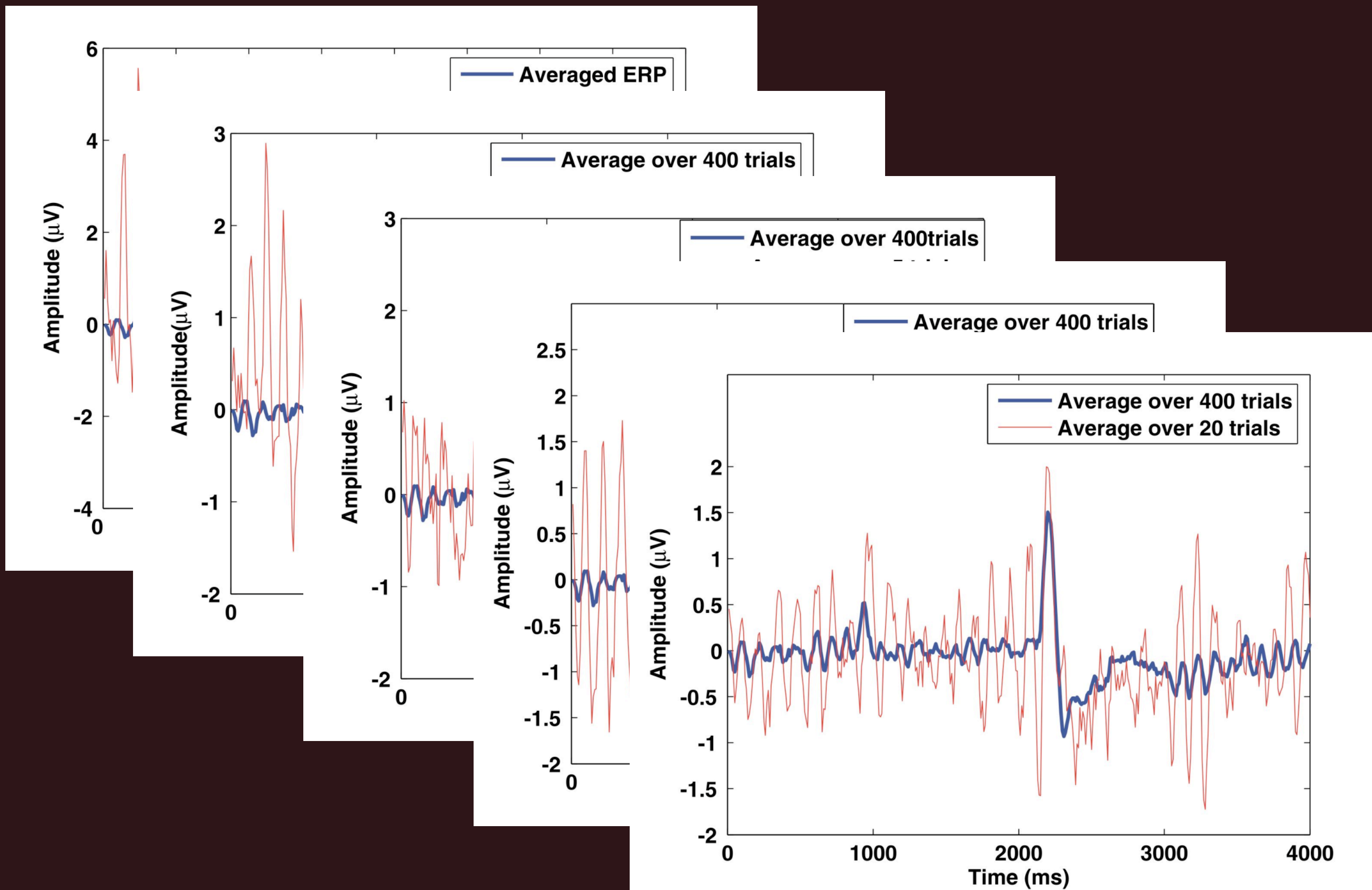
Single trials



Averaging over time

- Conventional solution
- Increases signal-to-noise by
  - Averaging different states of mind
  - Reducing variability
- Performed over many many trials

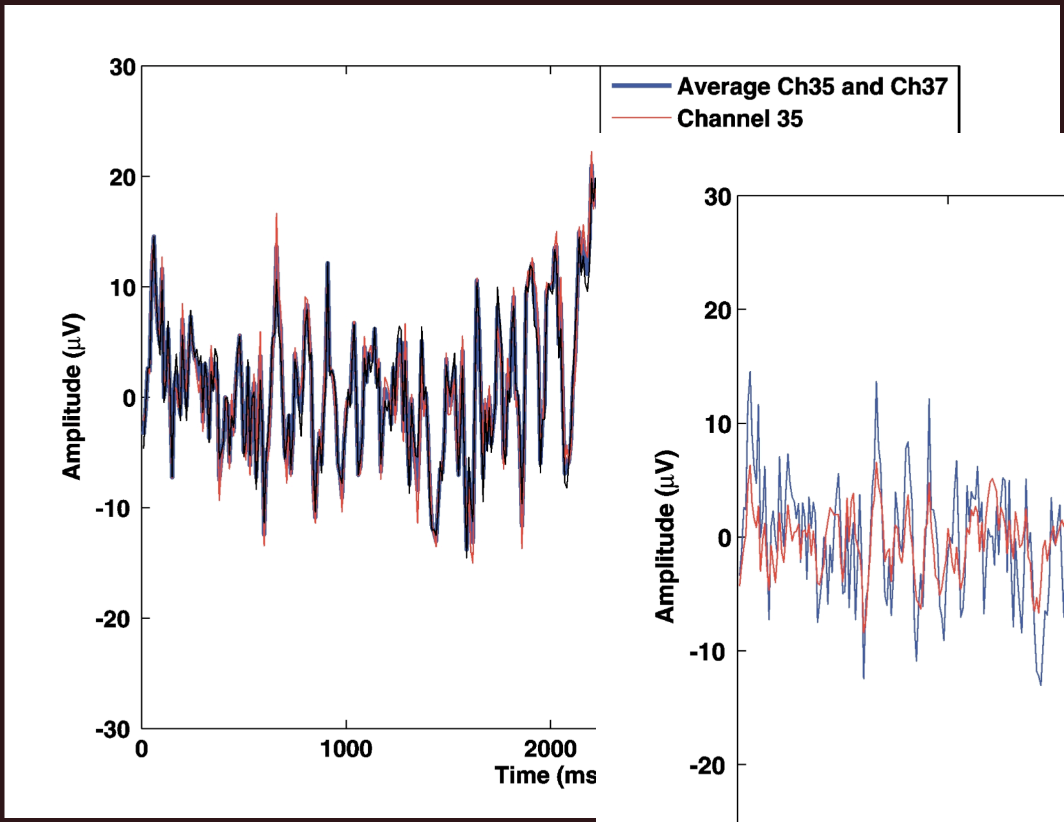
How many trials?

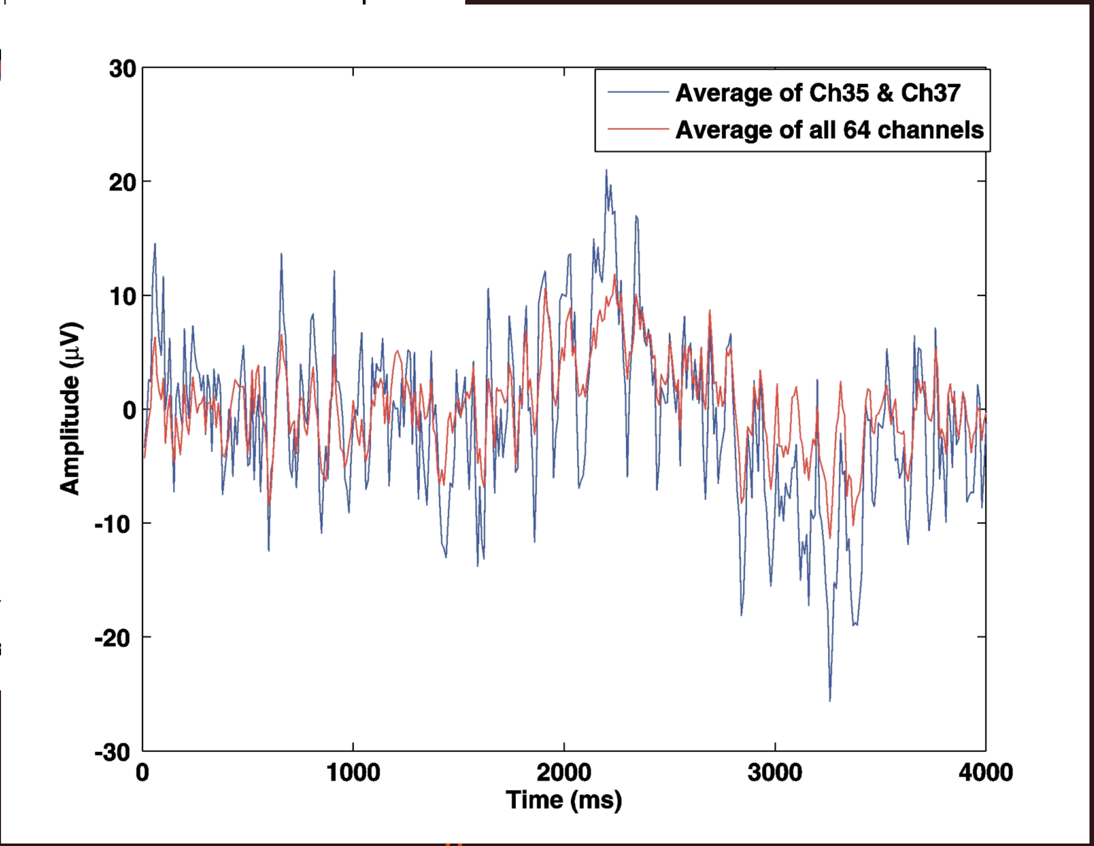


Averaging trials

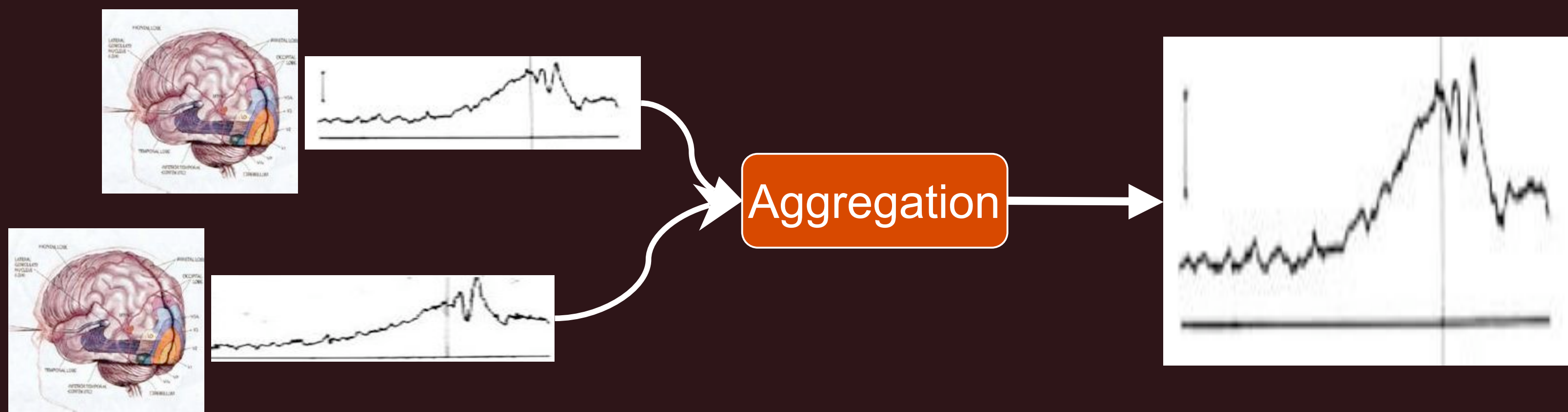
- Masks functionally significant trial-to-trial variations
  - state of the mind
  - state of the world (stimulus)
- Not suitable for single-trial analysis

Average multiple sensors





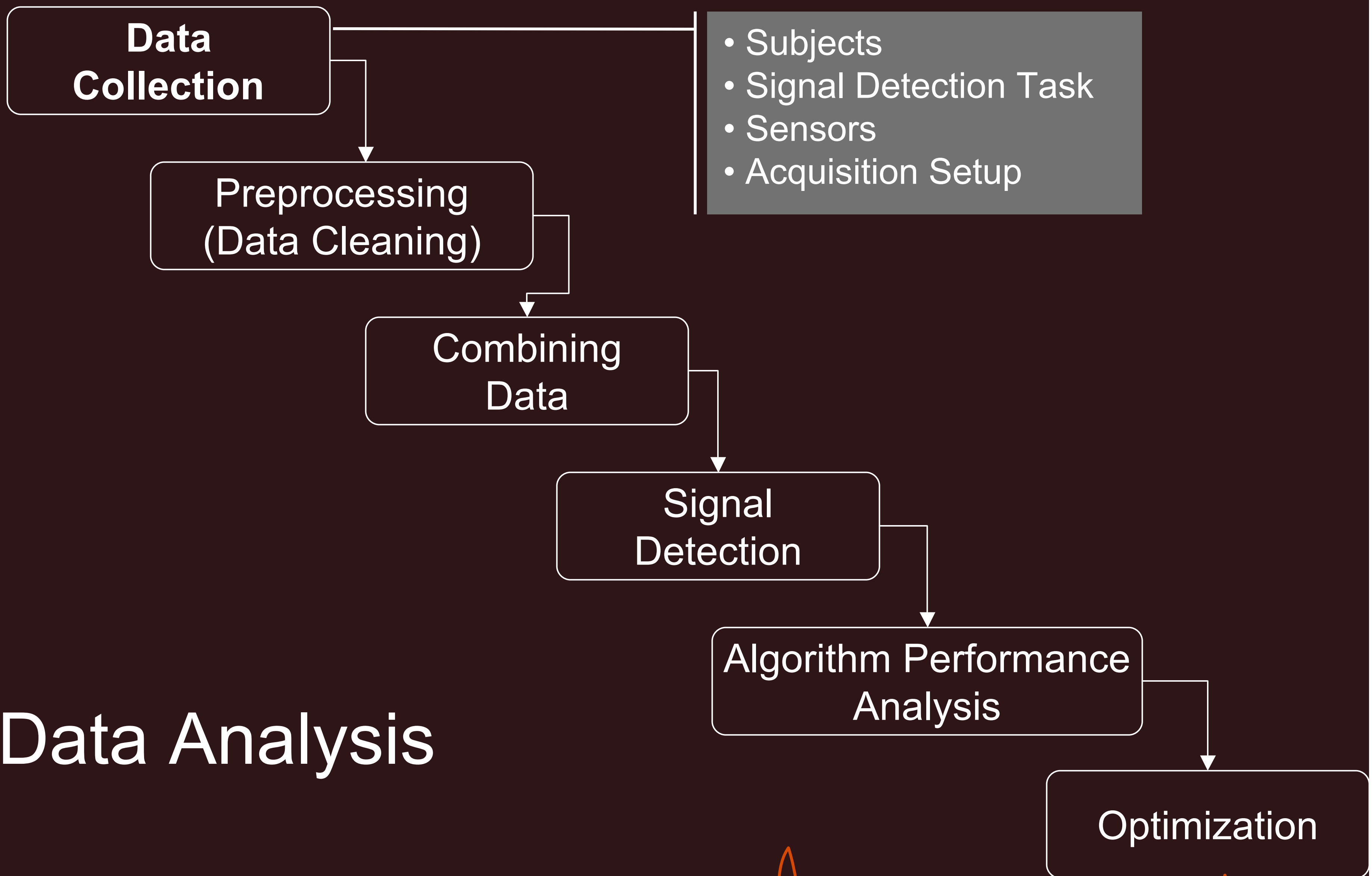
Our contribution



- Average EEG from multiple observers over single trials
- Improve signal detection accuracy by using multiple observers (Green & Swets)
- Group sensing never used with physiological data

Our approach - Group Sensing

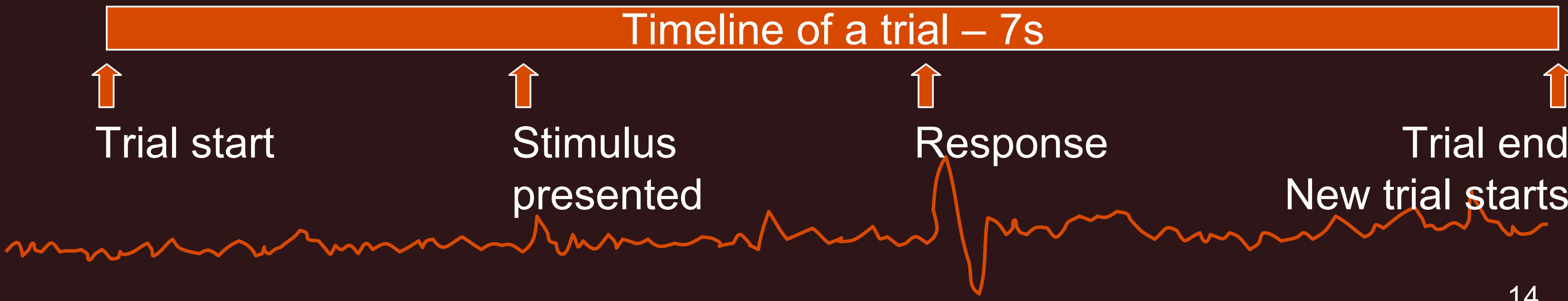
- Combine signals from multiple observers
- Improves detectability of the signal
- Appropriate for
  - single-trial analysis
  - comparing brain response from different observers



Data Analysis

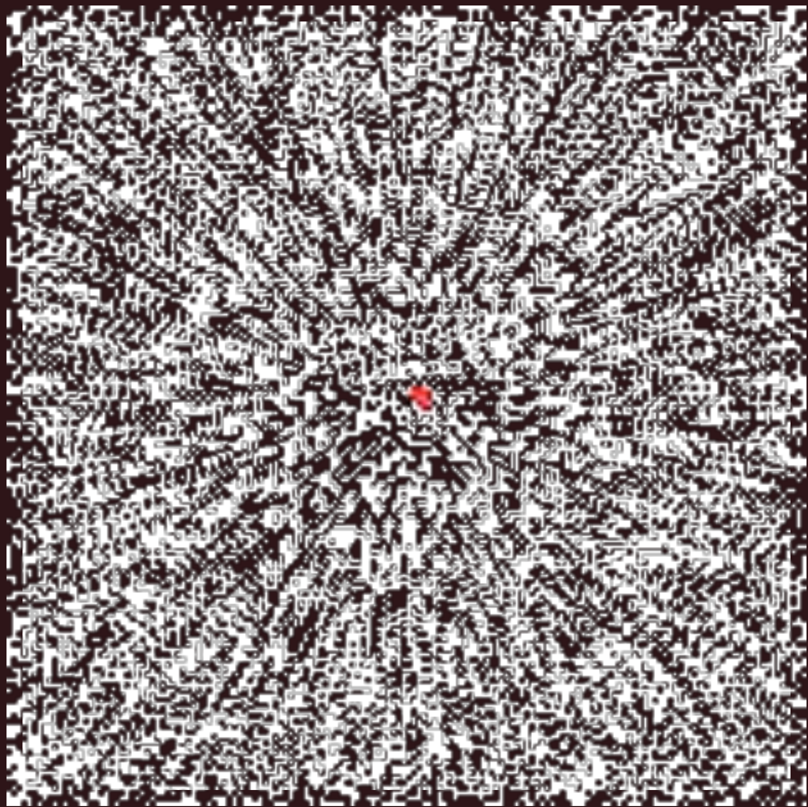
Task

- Determine the direction of the arrow
- Subject responds by a button press (left/right)
- 400 trials, each 7s long
- Each recording is about 45 min

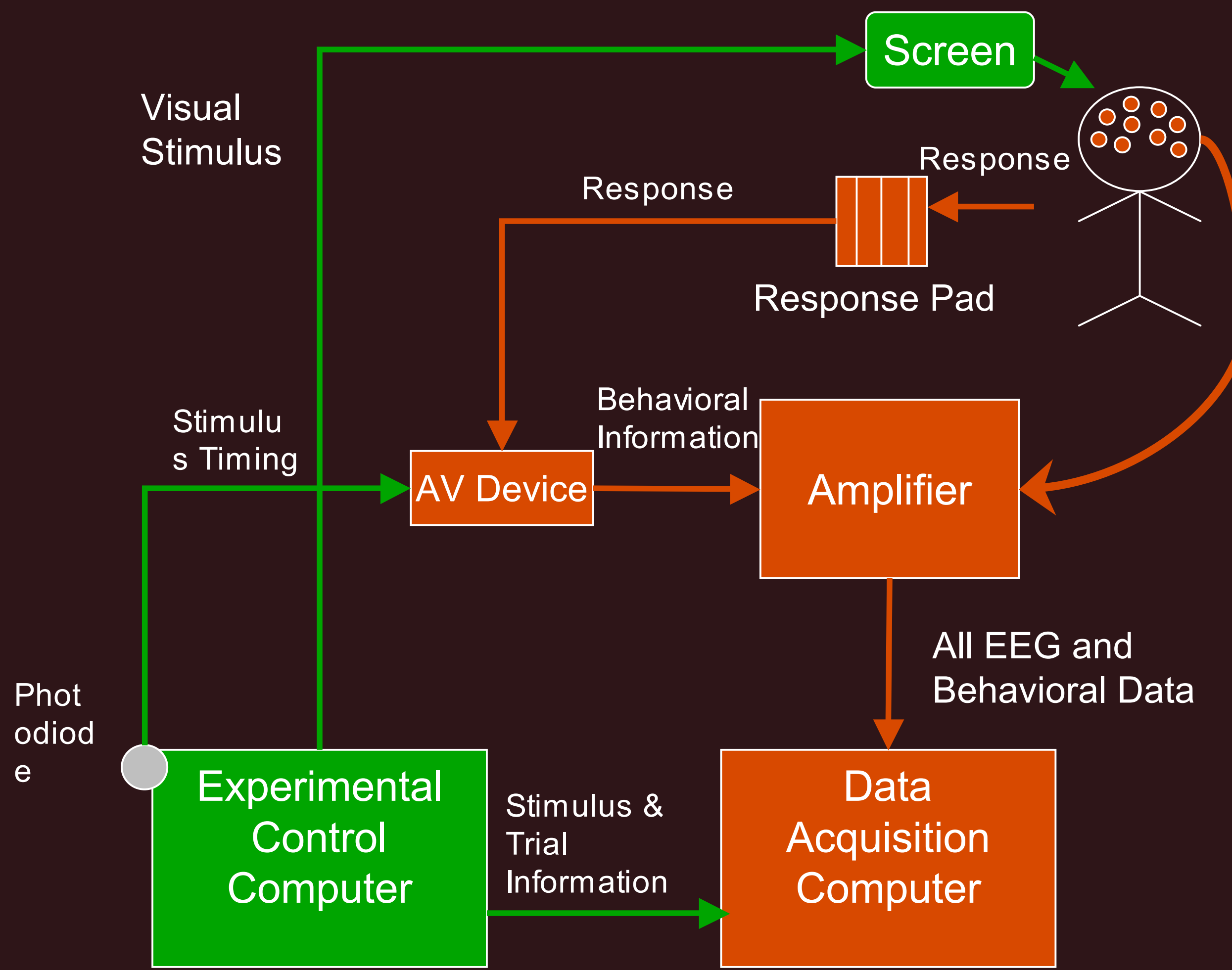


Stimulus

- Target detection task
- Stimulus is a motion-defined shape; arrow moves left or right
- Arrow points left or right
- Stimulus parameters are unique for each trial

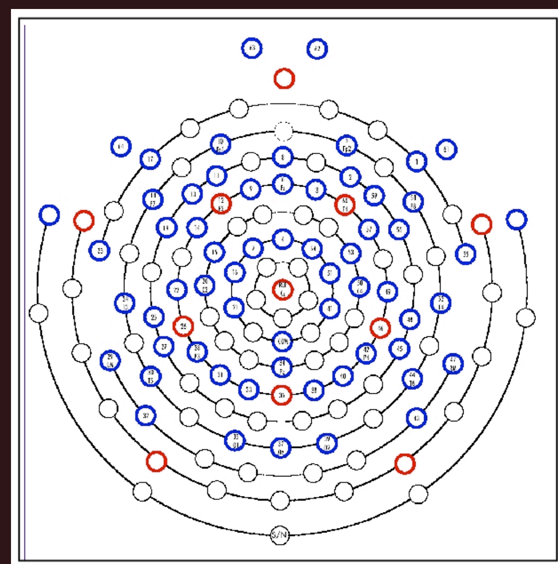


Acquisition Setup

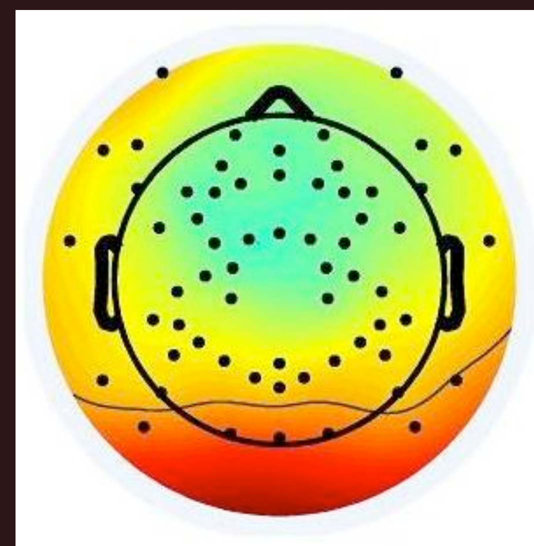


Sensors

High-density 64
sensor array



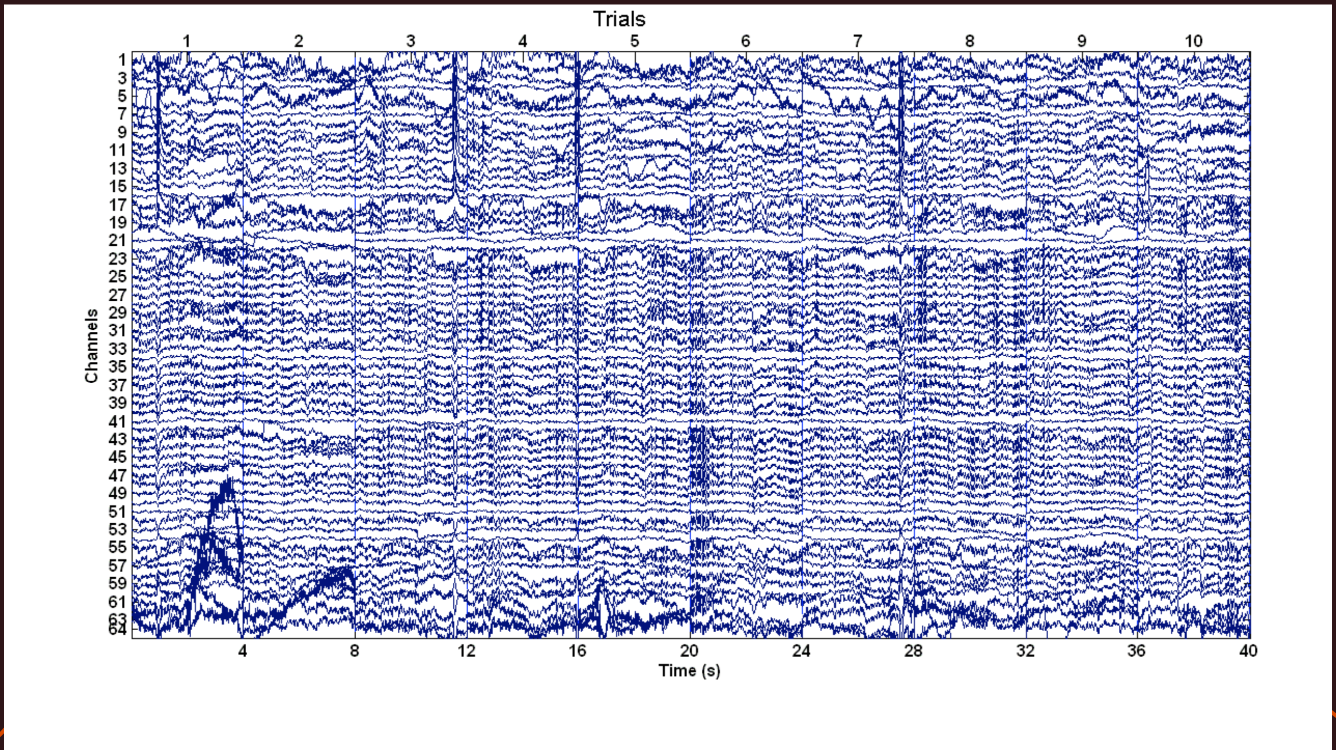
Geodesic layout of sensors



Scalp map

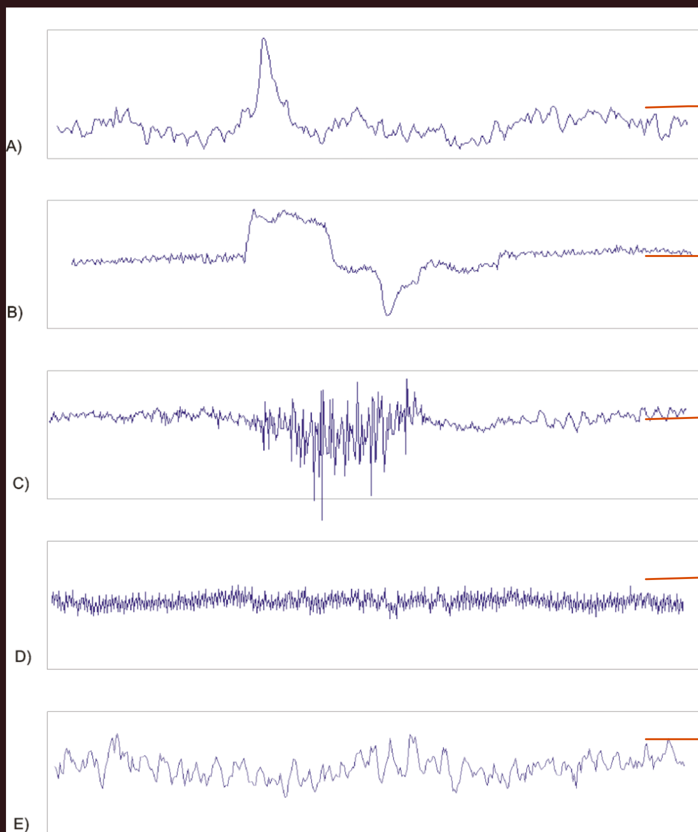
Data acquisition

- 11 datasets from 8 subjects
- EEG is recorded at 1000Hz
- Each dataset is about 1 Gb of data

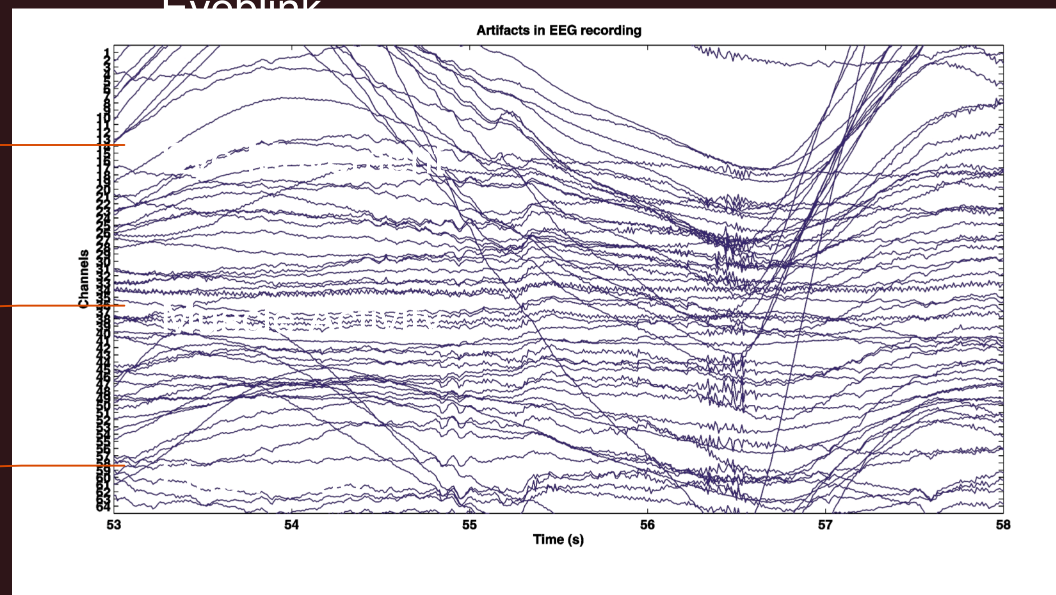


Continuous EEG data

Artifacts

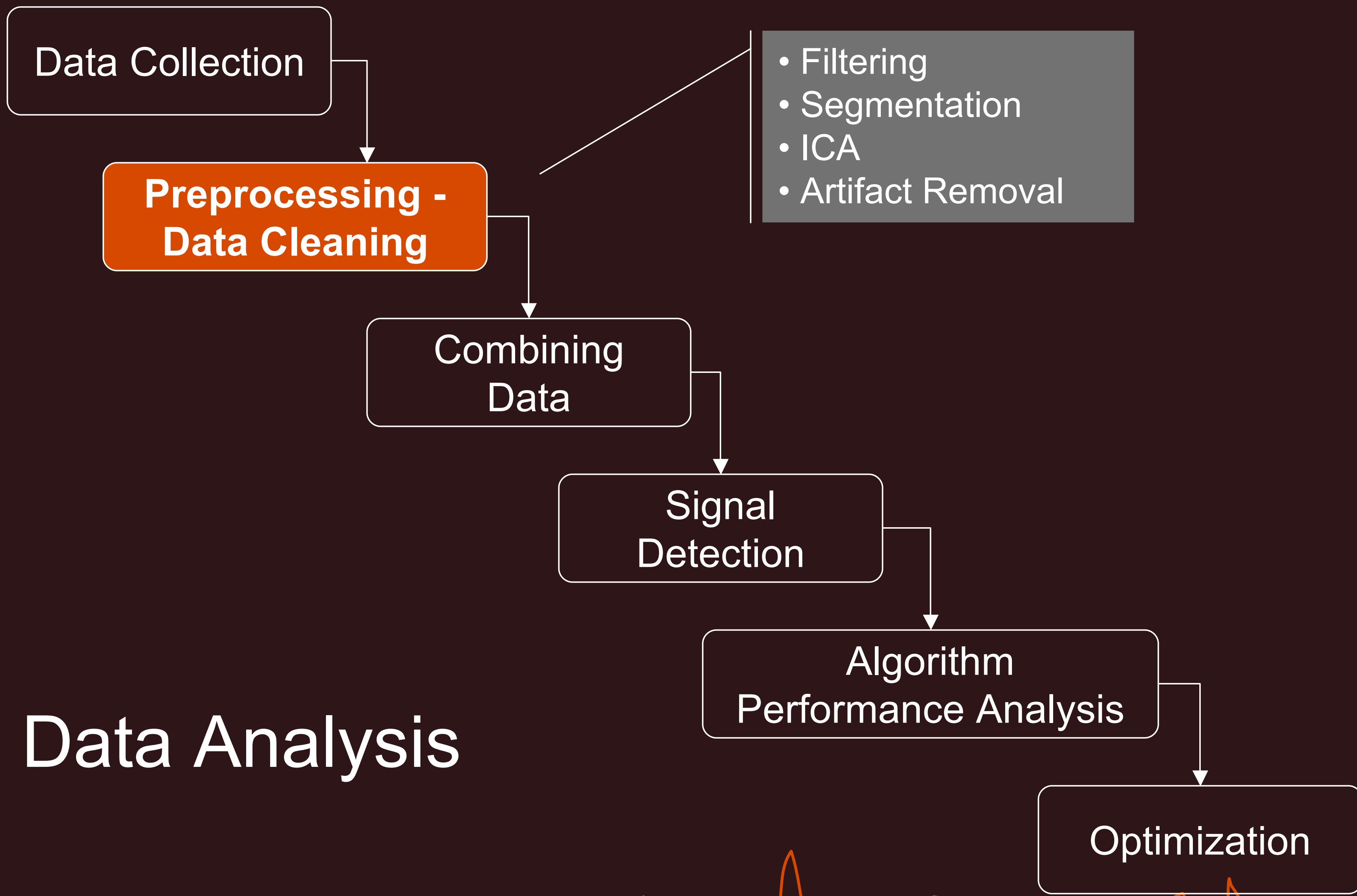


Eyeblink



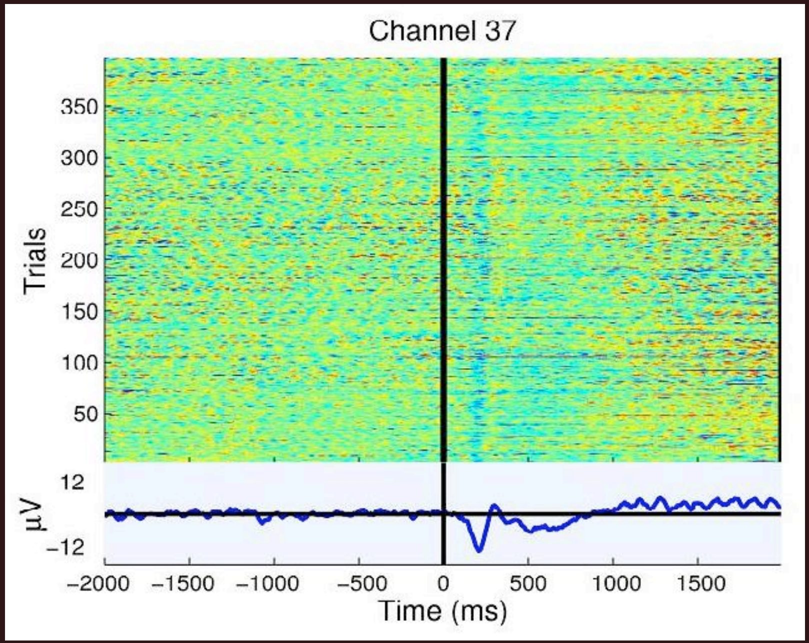
Clean EEG

Data Analysis



Segmentation

- Continuous EEG trial data is segmented into 4s intervals centered on the stimulus onset
- Segmentations time-locked to different events highlight different features like, correct, missed trials, fast responses etc.

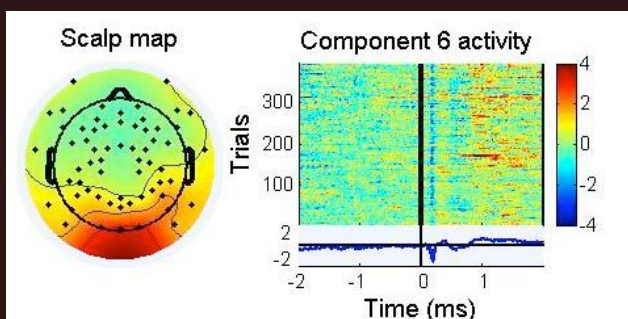


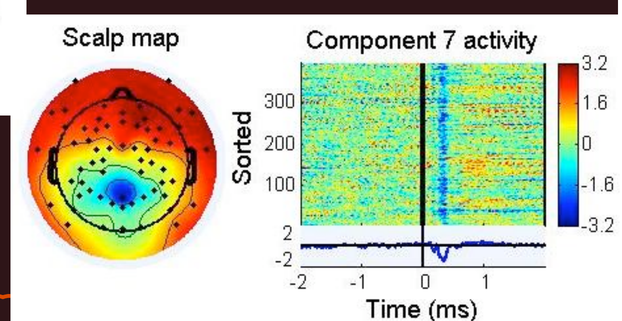
Signal separation

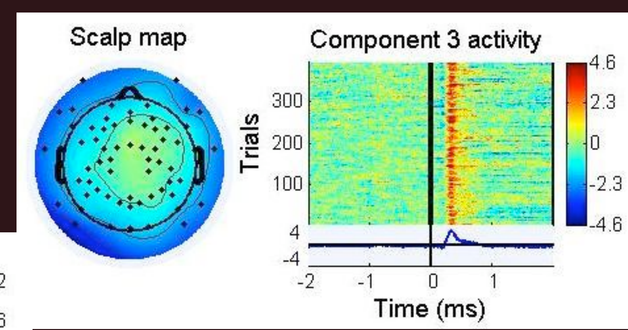
- Observed signal is the contribution of activity within and outside the brain
- Independent signals should be separated for:
  - feature extraction of EEG data
  - data reduction
  - artifact detection

Signal separation : ICA

- ICA is similar to PCA
- Results in maximally independent projections of data
- Independent components highlight different features

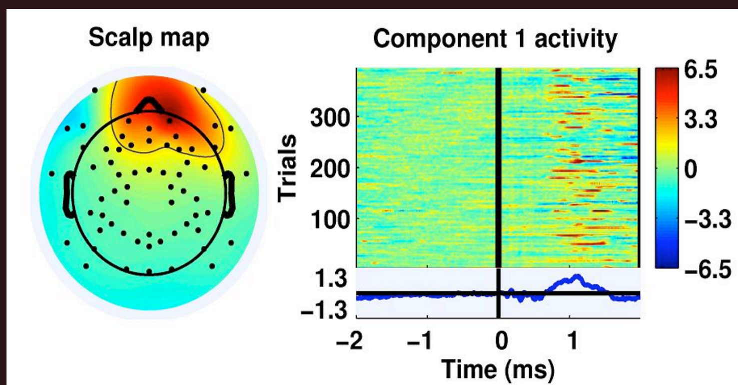


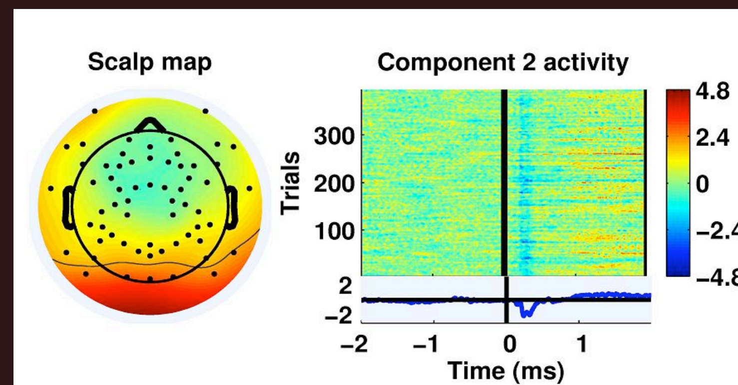


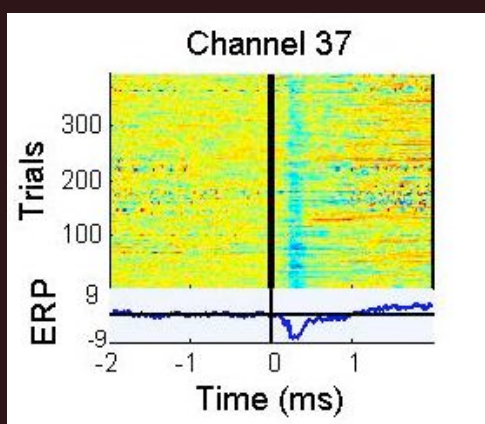


Independent Components

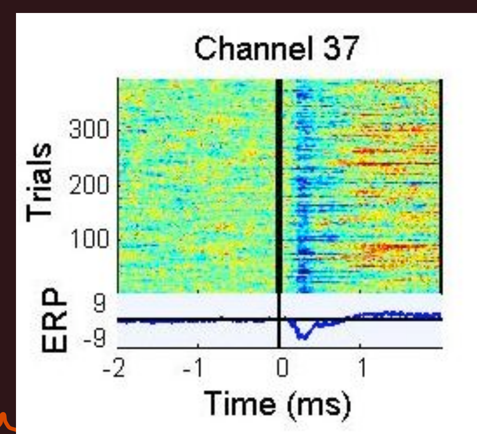
- ICA consolidates information

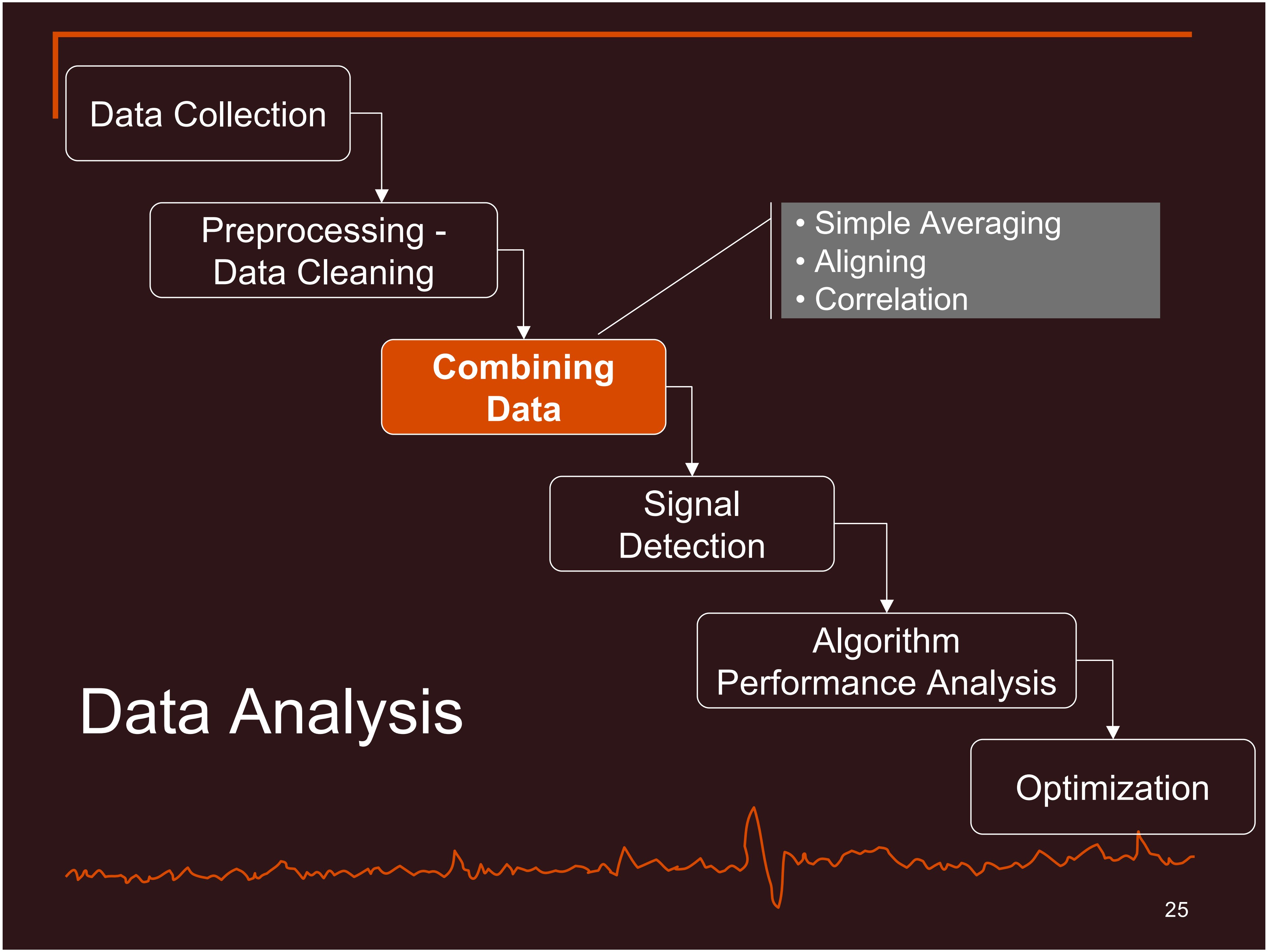






Artifact Removal




Data Collection
Preprocessing - Data Cleaning
Combining Data
• Simple Averaging
• Aligning
• Correlation
Signal Detection
Algorithm Performance Analysis
Optimization
Data Analysis
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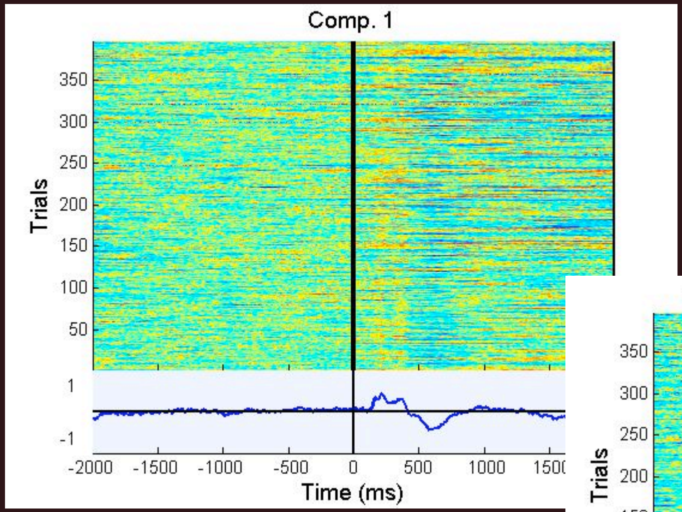
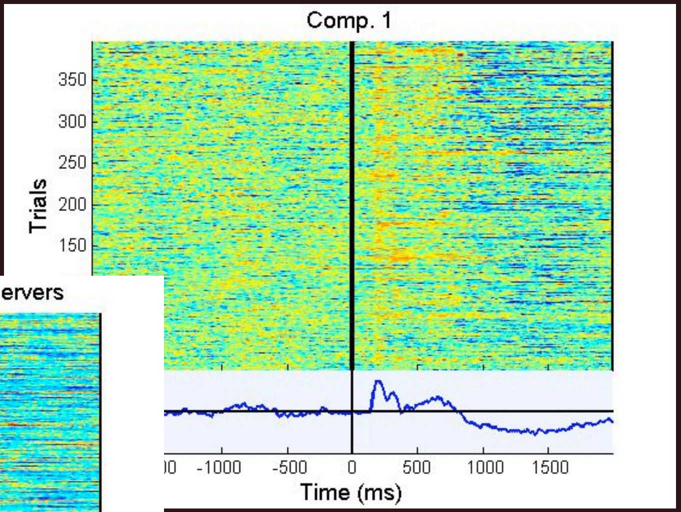
Combining EEG data across subjects

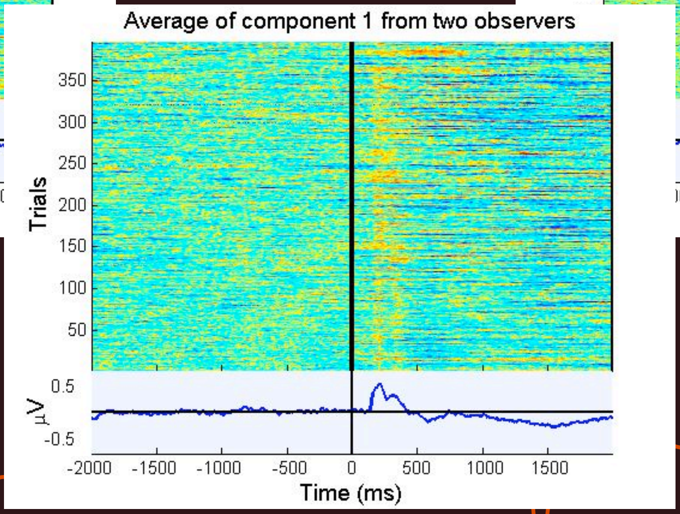
- Variability across subjects
- Variability in ERP latency, amplitude and shape



Subject 1



Subject 2



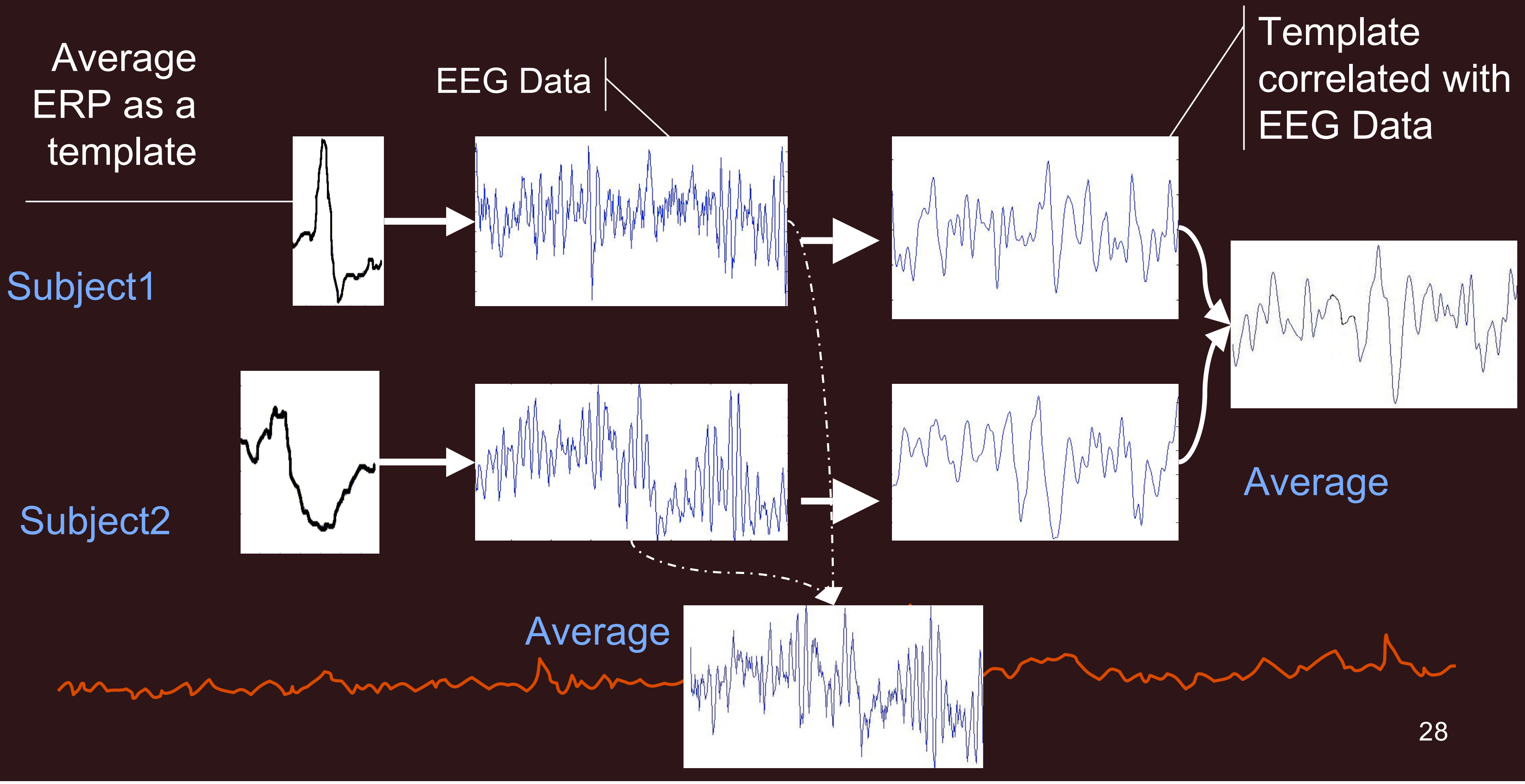
Combination of Subject 1 and 2

Dealing with variability

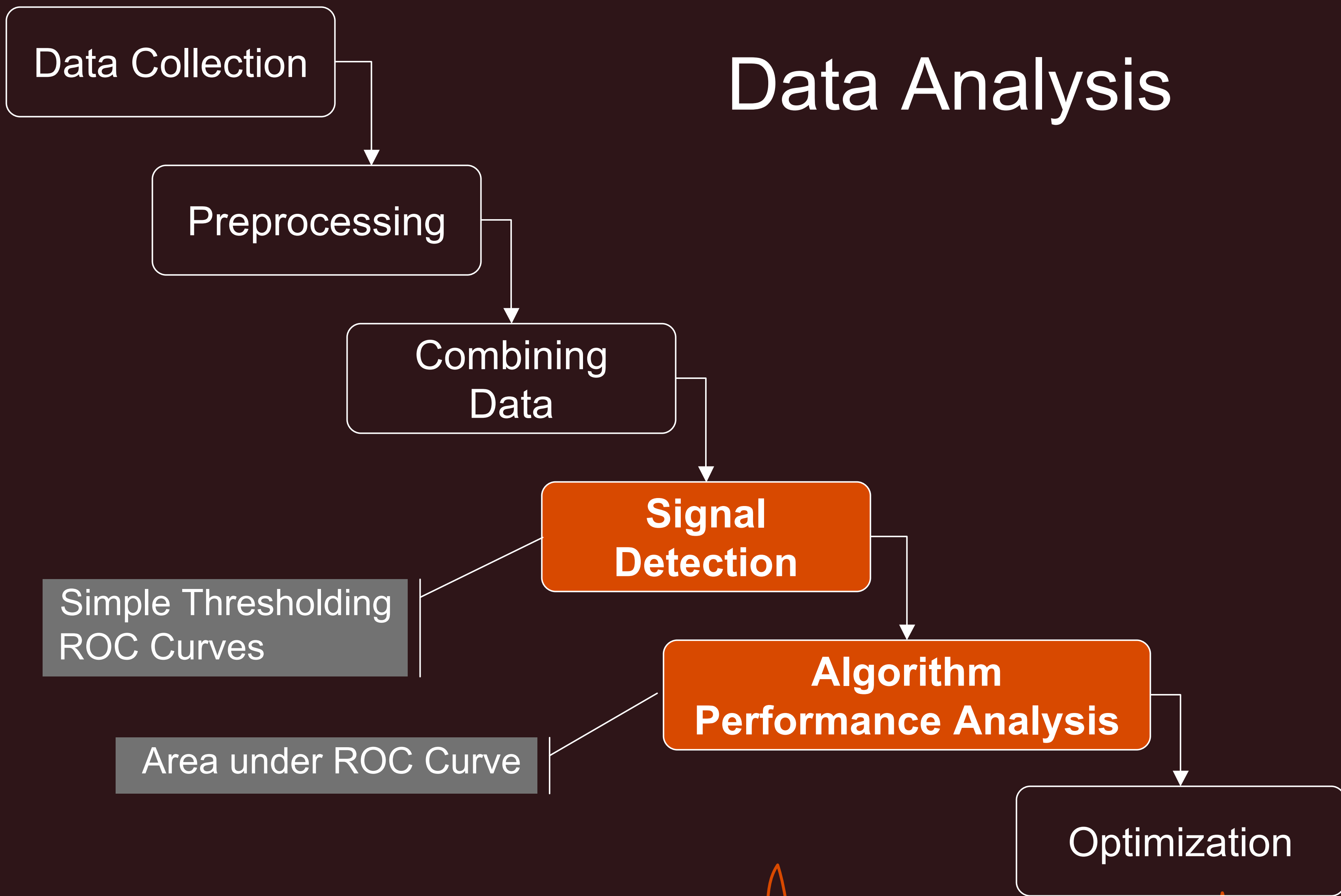
- Time Aligning
  - Overcome latency differences
  - Match the P300 latency of average ERP and shift to align the data

Dealing with variability

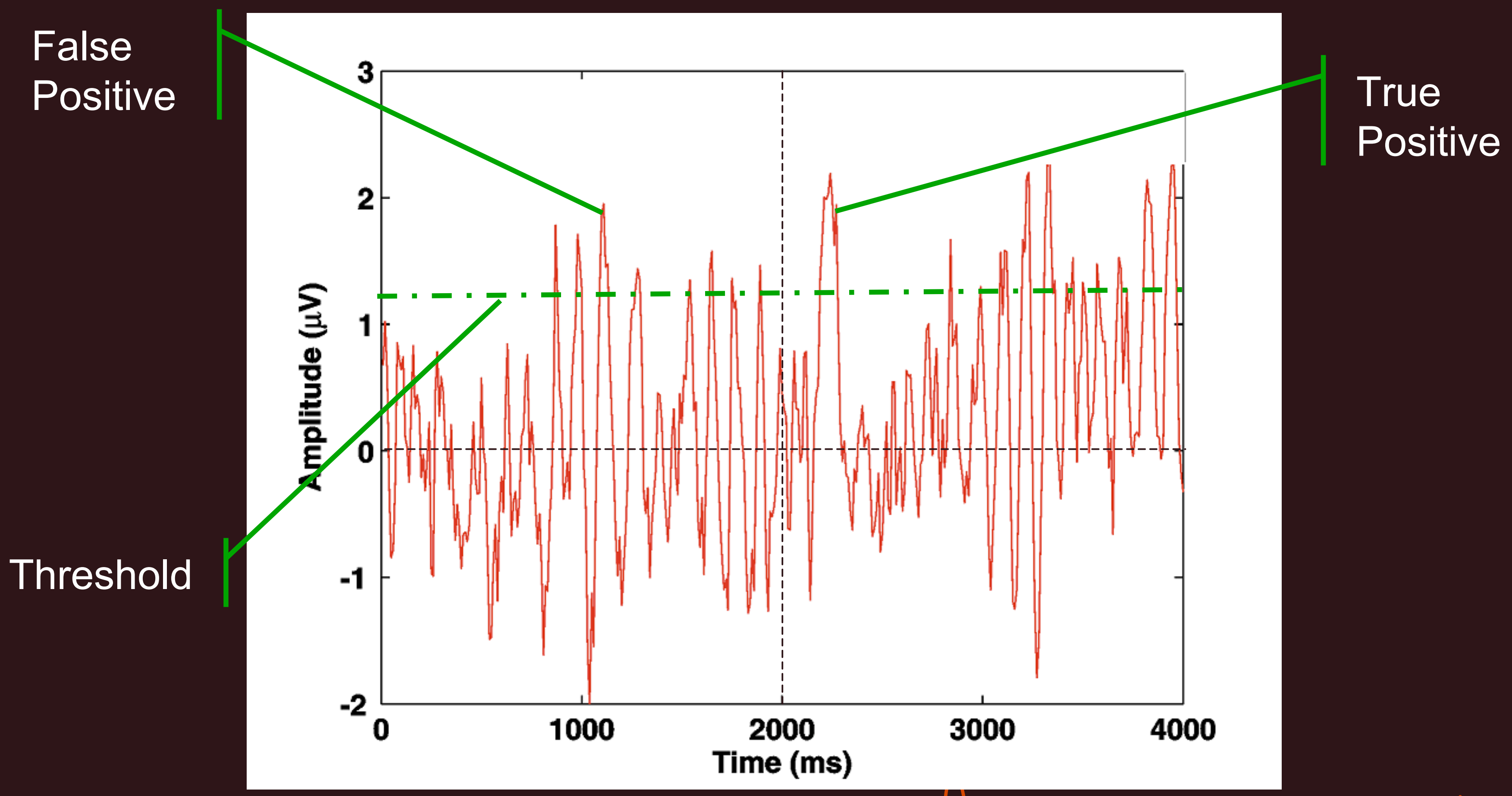
- Template Matching
  - for overcoming variability in structure of ERP



Data Analysis

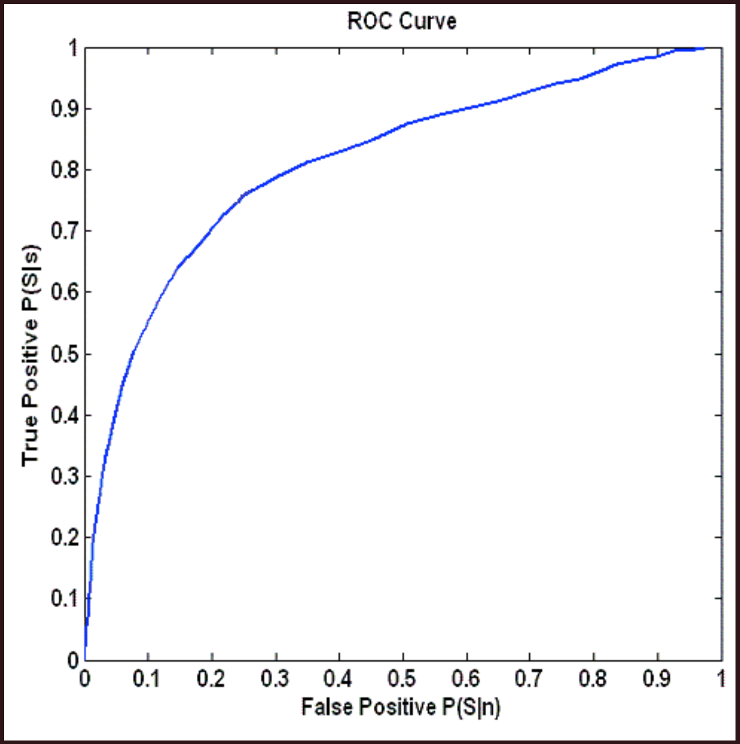


Simple Threshold



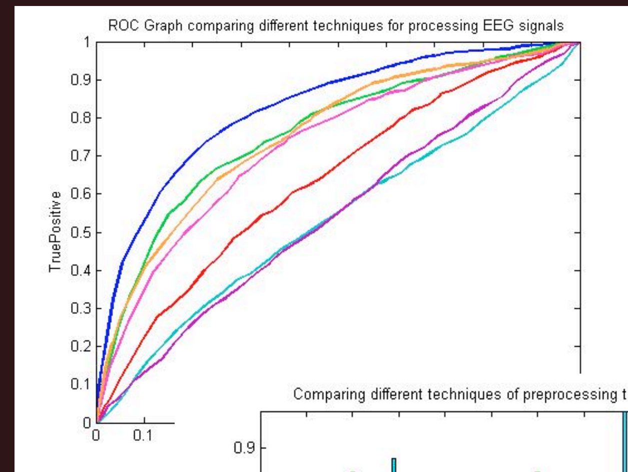
Receiver operating characteristics (ROC)

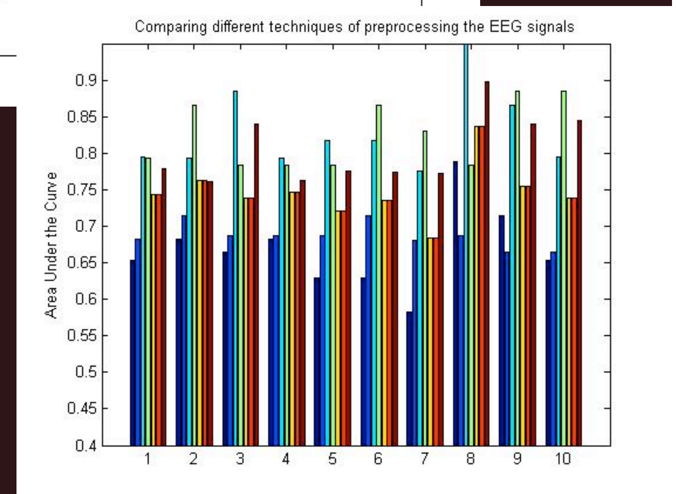
- Simple thresholding algorithm
- False positive vs True positive rate
- Several observations yield one point
- Each point represents a decision strategy (threshold)
- Area under the ROC curve represents percentage correct



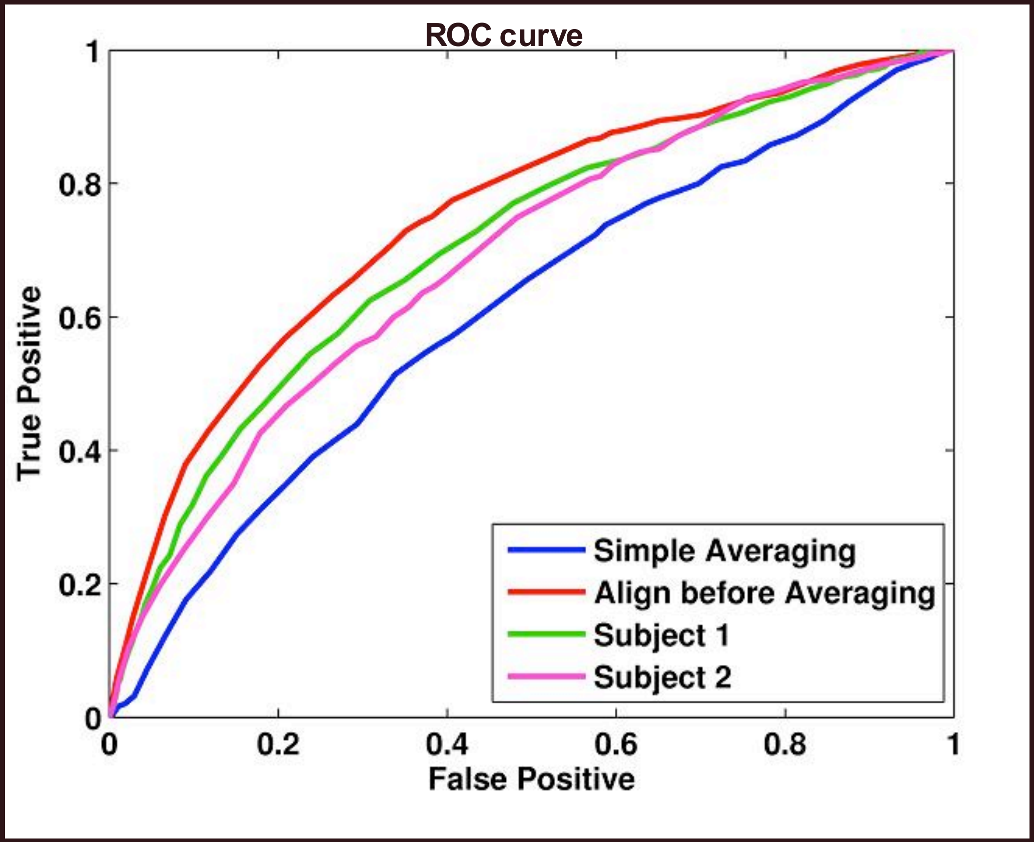
Results

- Single observers:
  - Individual data
  - Averaged in time
  - Template matching
- Combining across observers:
  - Simple averaging
  - Time aligning
  - Template matching
  - Aligning and Template matching
- Inter-subject vs Intra-subject combination of EEG
- Component and Channel data



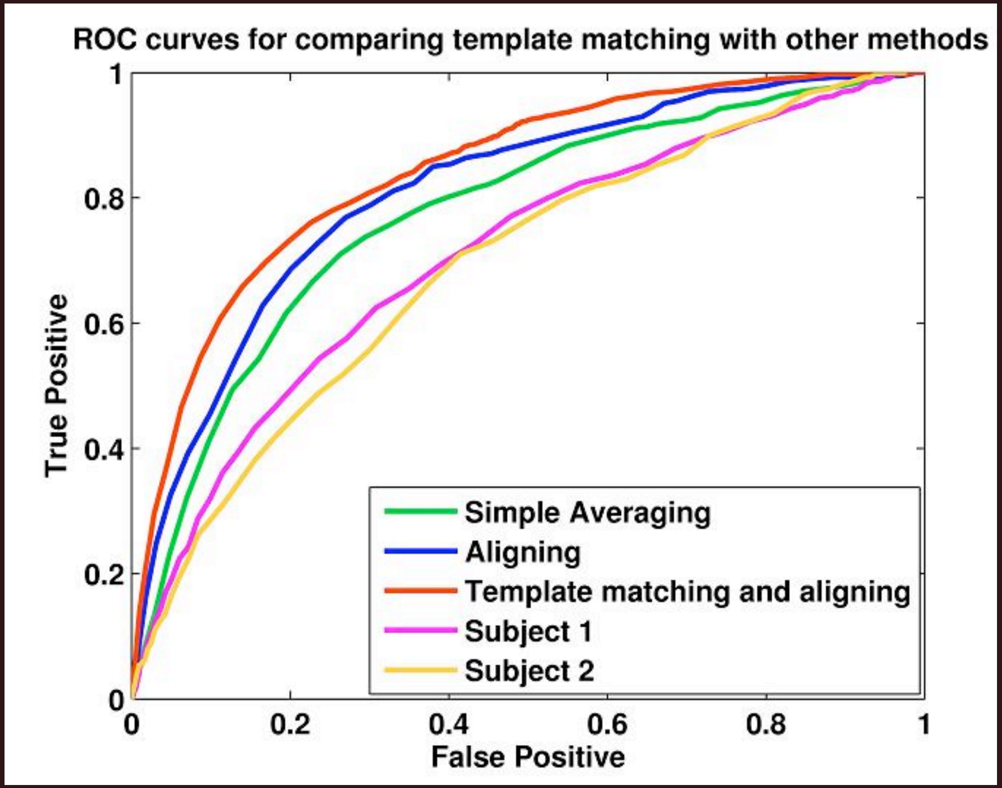


Results - Aligning



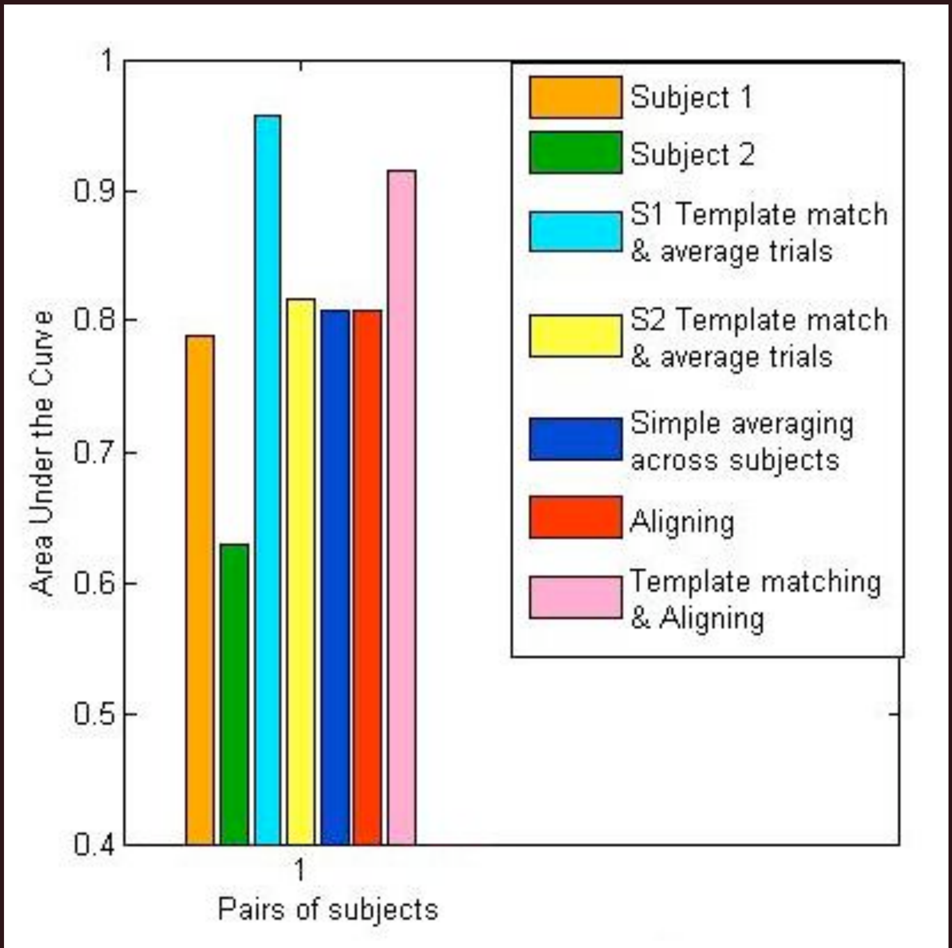
- Simple averaging is sometimes worse
- Aligning attenuates the inter-subject ERP latency variation

Results – Template Matching



Gain	Mean Gain	Max Gain
Over single observer	6.2 %	19.2 %
Over simple average of a pair of observers	8.5 %	30.9 %

Results - Area under ROC curves

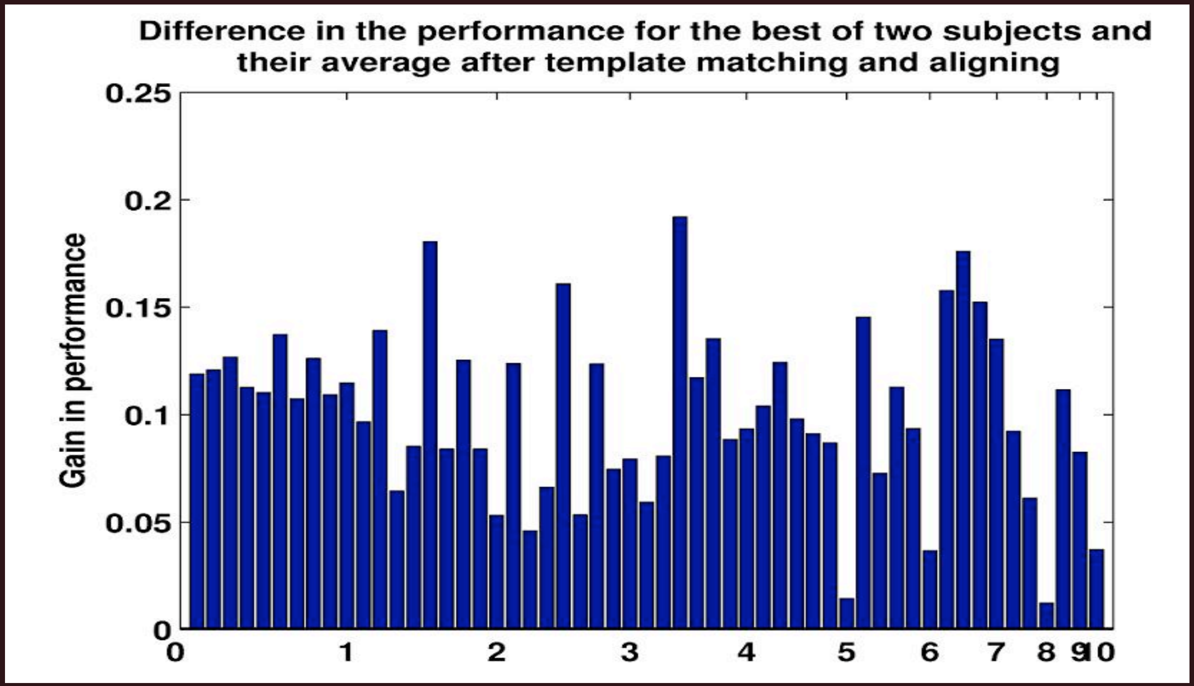


Different techniques of combining EEG signals and their performance

(Shown only two pairs of subjects)

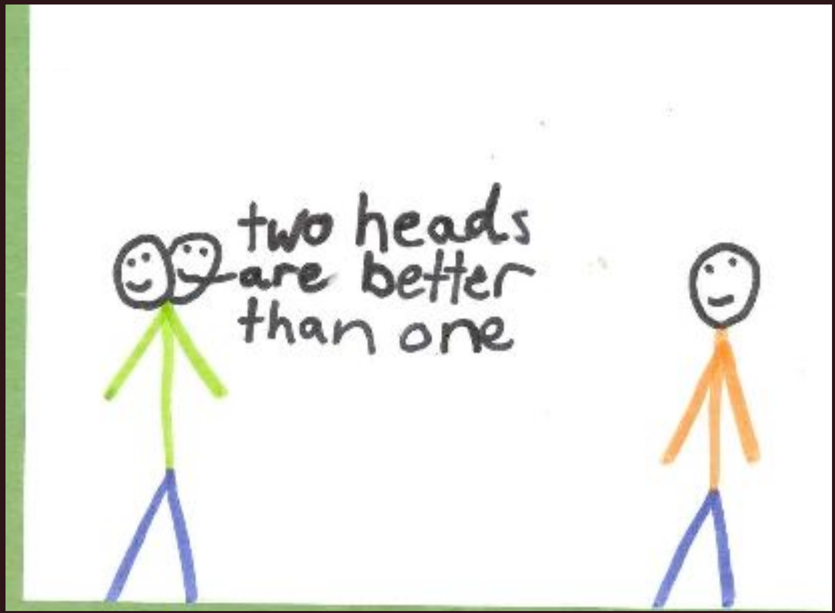
Results – Template Matching

Gain over single observers on combining multiple observer EEG after aligning & template matching



Conclusions

- Combining single trial EEG across subjects it is possible to boost the signal-to-noise
- The more we compensate for inter-subject differences, the better the performance
- Some pairs of subjects are similar and result in greater boost in performance



Thank You!

References

Group Performance

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EEG

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