Jyväskylä Summer School 2013

COM7: Electromagnetic Signals from The Human Brain: Fundamentals and Analysis (TIEJ659)

Experimental design and examples of MEG studies

Lauri Parkkonen

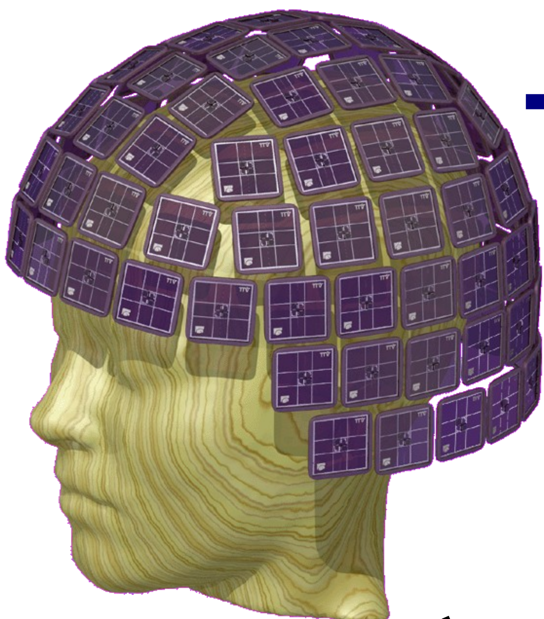
Dept. Biomedical Engineering
and Computational Science
Aalto University
Lauri.Parkkonen@aalto.fi

Elekta Oy
Helsinki, Finland
Lauri.Parkkonen@elekta.com

A MEG/EEG experiment

Stimuli (if any)

- auditory
- visual
- somatosensory
- olfactory
- pain
- ...?



MEG/EEG

- evoked responses
- single trials
- measures of oscillatory activity
- ...?

Task

- attend/ignore
- detect + react
- imagine
- observe/imitate
- ...?

Behavioral responses

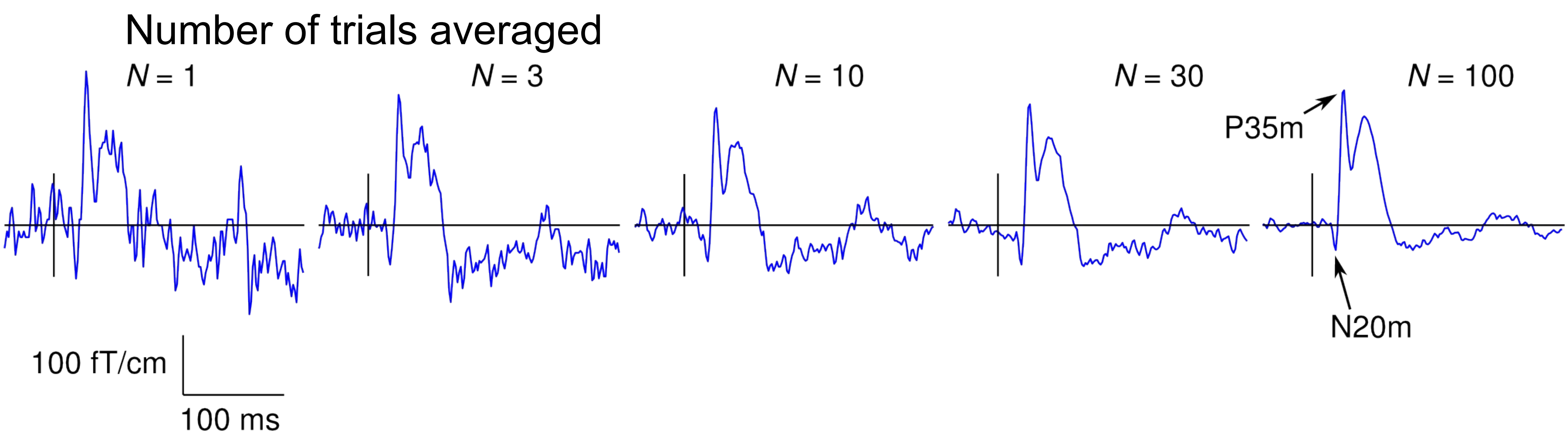
- limb/finger movement
- speech
- ...?

Some notes on experimental design

- MEG/EEG evoked responses mostly reflect transient changes in the sensory input rather than sustained activity as fMRI.
- Stimulus sequences for evoked responses
  - Optimize evoked-response SNR given the duration of the measurement. Competing factors:
    - noise which gets suppressed as 1 / sqrt(number of trials)
    - More trials => faster stimulation => more habituation => signal decreases
  - Optimal interval between consecutive stimuli depends on the sensory modality, cortical area under study, task, ...
    - 25 ms ... 30 seconds, typically 1 – 5 s
  - Oddball paradigms: frequent standard stimulus + intervening rare deviant
    - Optimal deviant probability

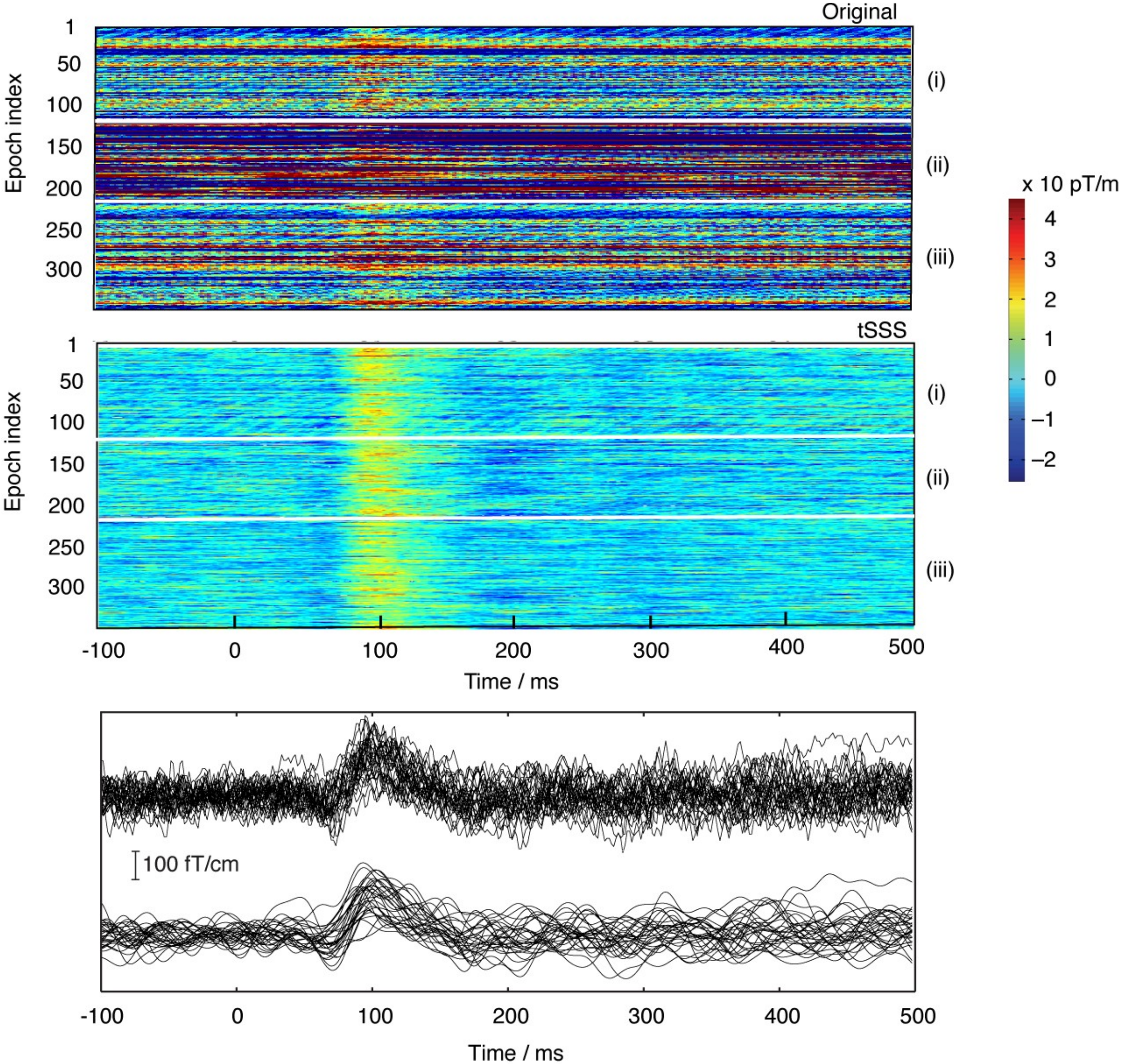
How many trials are needed?

Somatosensory evoked responses to electric median nerve stimulation



Single-trial evoked responses

Auditory evoked fields, no averaging

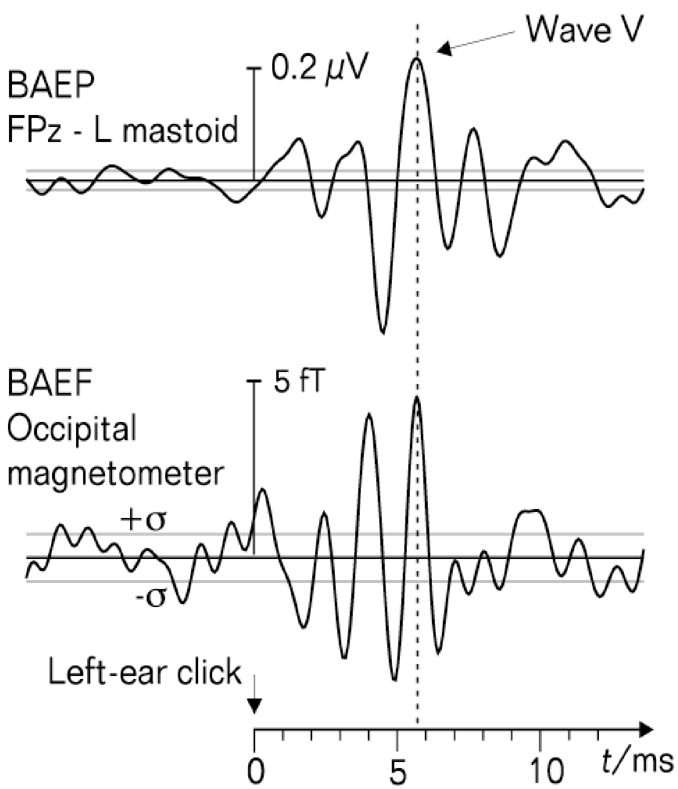


Taulu and Hari (2009) Hum. Brain Mapp.

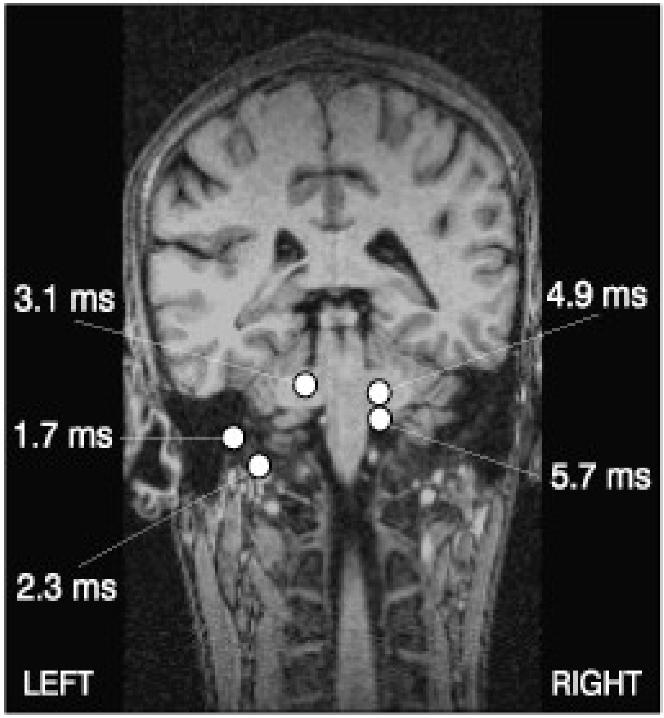
Deep brain structures and MEG

STIMULUS:
0.6-ms auditory clicks, 111 ms ISI
15000 epochs

RESPONSES:
Shown with pass-band 160 – 900 Hz



ANALYSIS:
- individual BEM models
- equivalent current dipoles

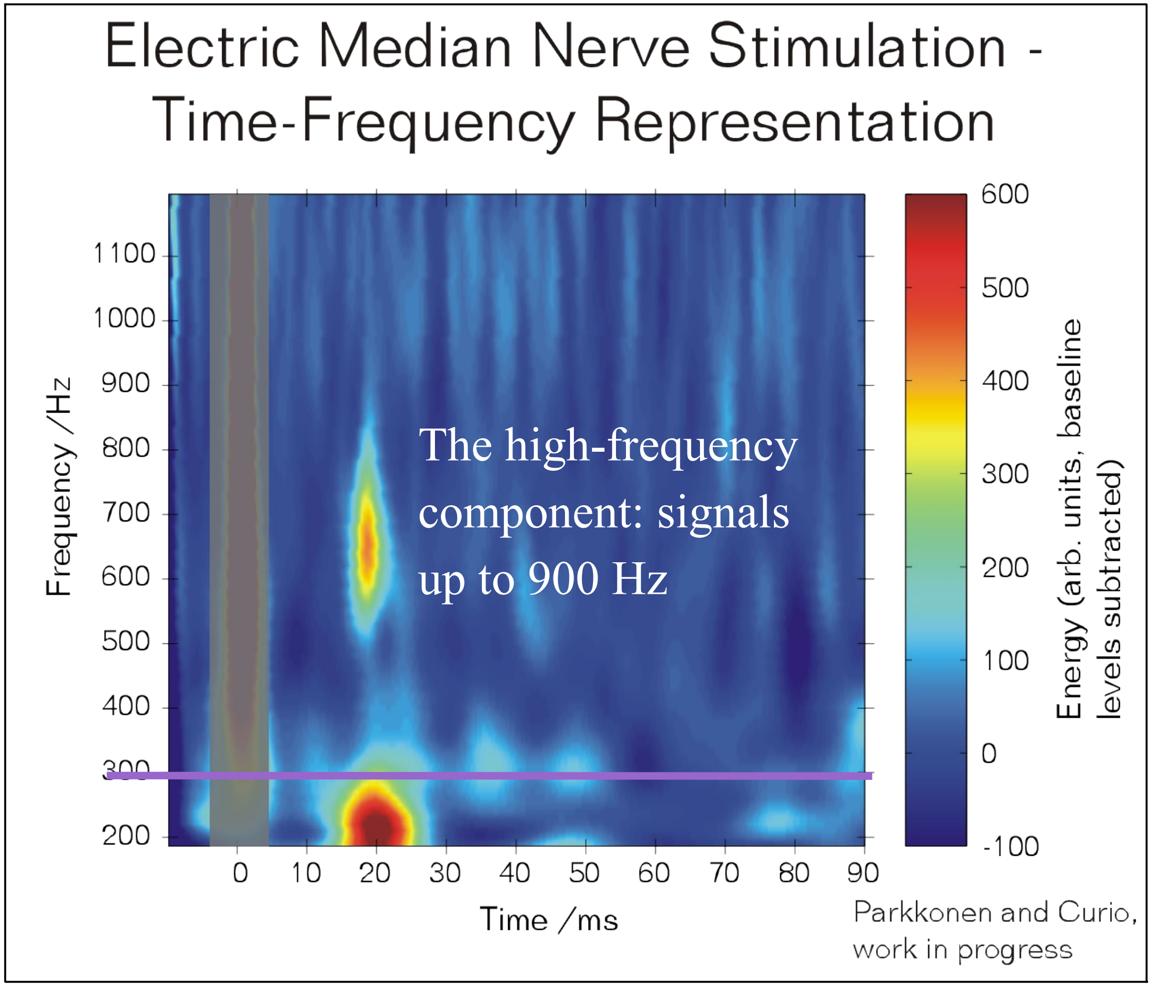


NOTE: All sources visualized on a single MRI slice.

Parkkonen et al. 2009

Experimental design: Temporal sampling

- Bandwidth of interest
  - Bulk of cerebral MEG/EEG signals 0.1 ... 100 Hz
  - f_{HP} = DC ... 1 Hz
  - f_{LP} = 100 ... 2000 Hz
- Sampling rate $f_S > 2 f_{LP}$ to avoid aliasing. Typical $f_S \sim$ 300 Hz ... 1 kHz.
- MEG/EEG sampling rate >> fMRI sampling rate, where f_S = 1/TR ~ 1 Hz



The traditional N20m response: signals below 300 Hz

fMRI vs. MEG responses

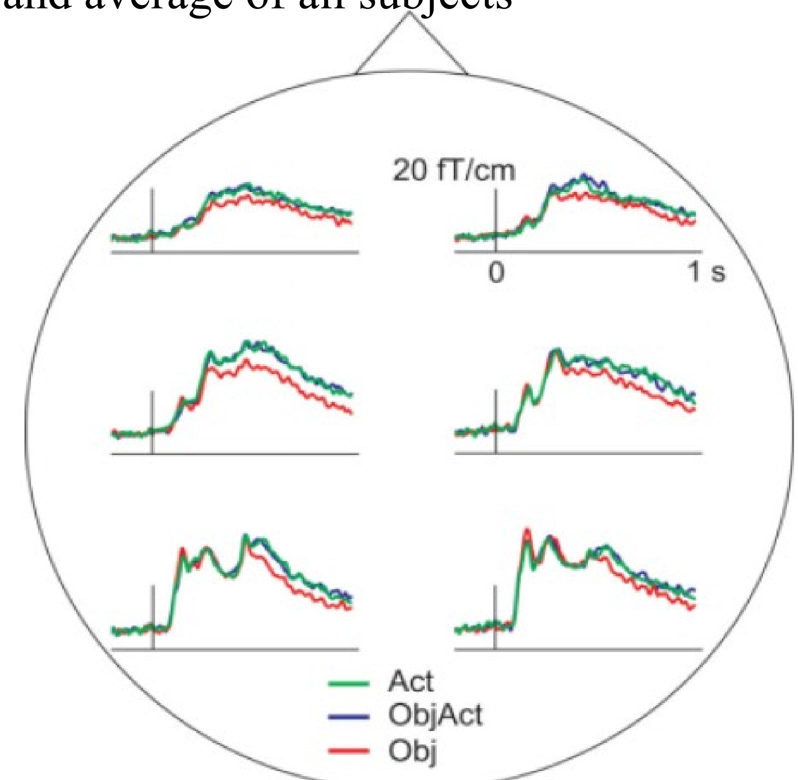
Covert action/object naming task.
Same design and same subjects (*N* = 11) in fMRI and MEG.
Each image shown for 300 ms at 1.8–4.2-s intervals
Alternating 30-s task blocks and 21-s rest blocks, total of 100 images

Act, ObjAct

Obj

MEG: Areal averages of the evoked responses, grand average of all subjects

L



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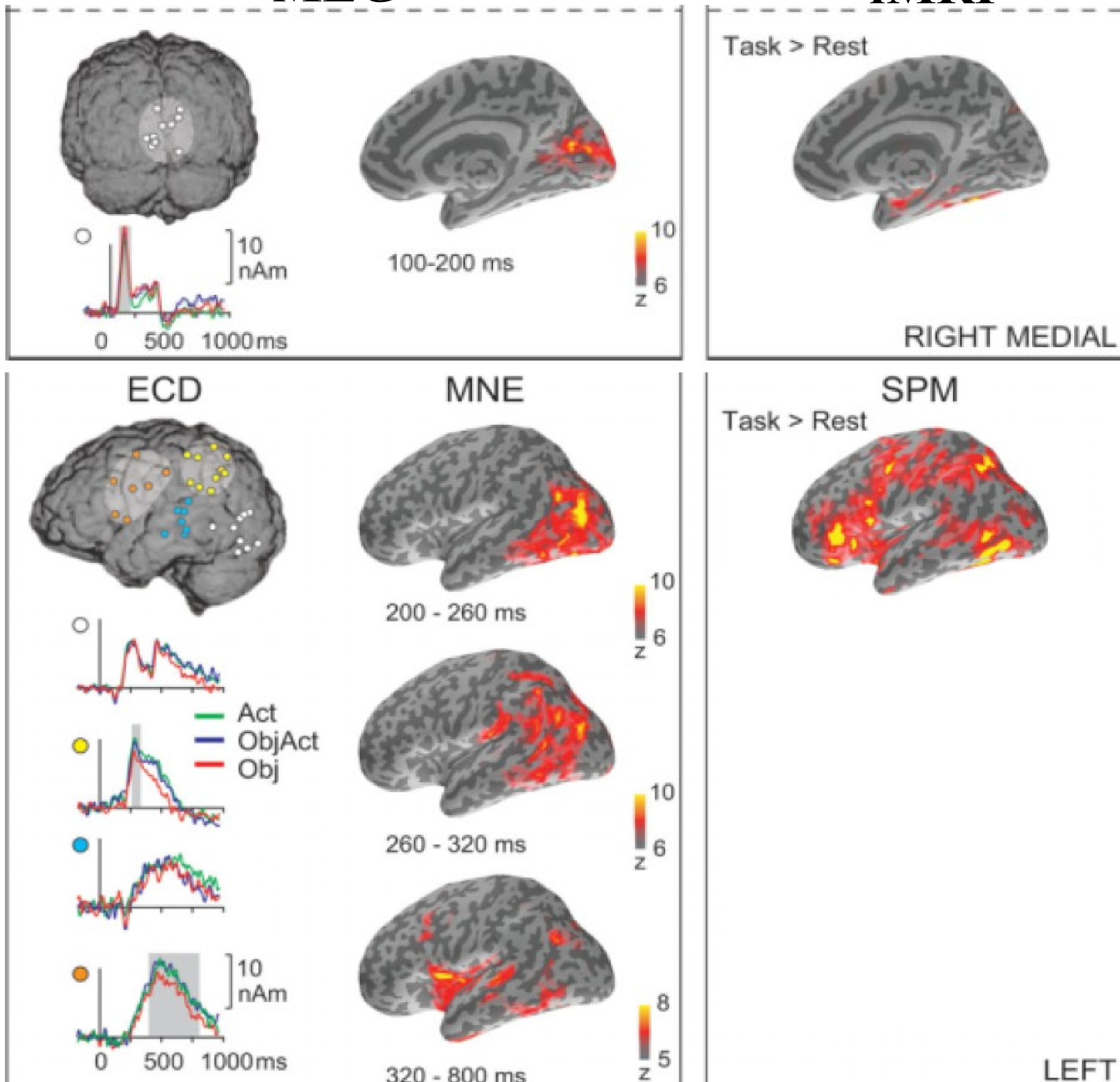
Liljeström et al., Hum. Brain Mapp. 2009

Act, ObjAct

Obj

MEG

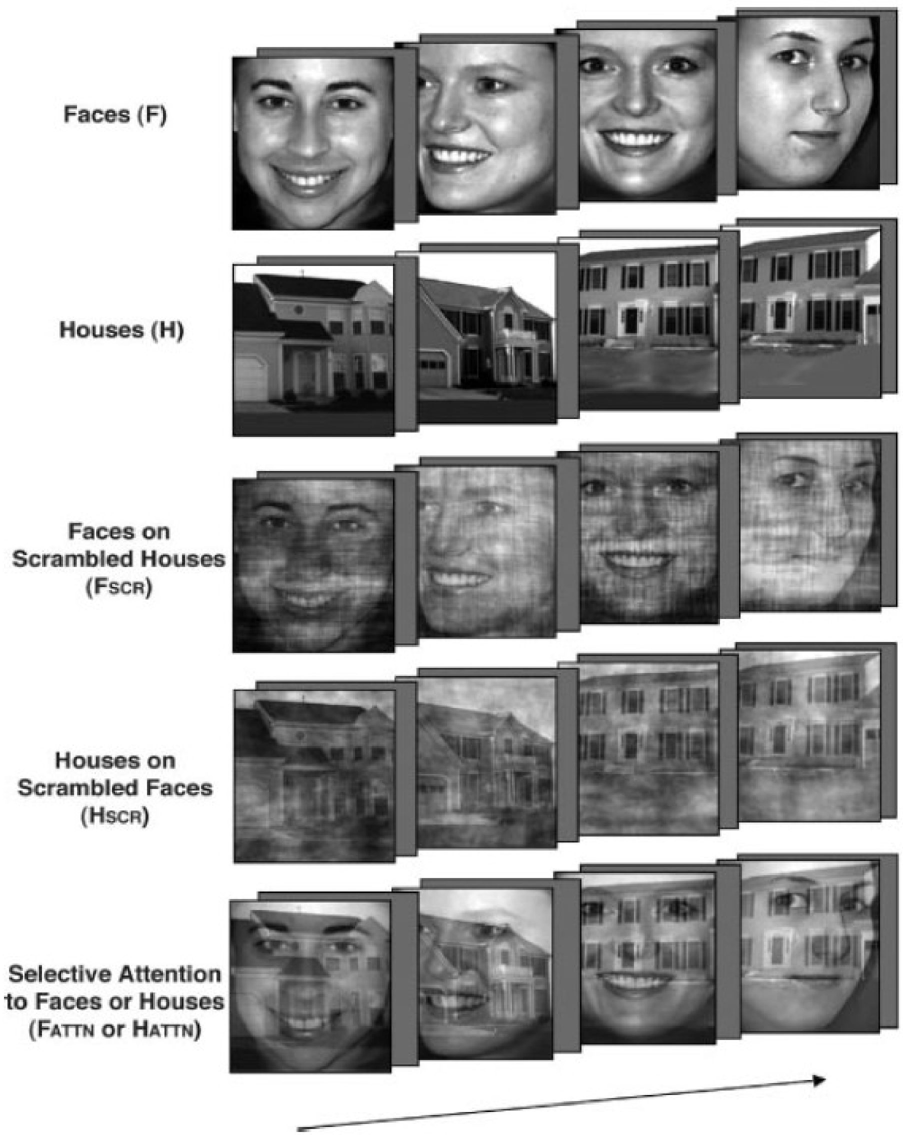
fMRI



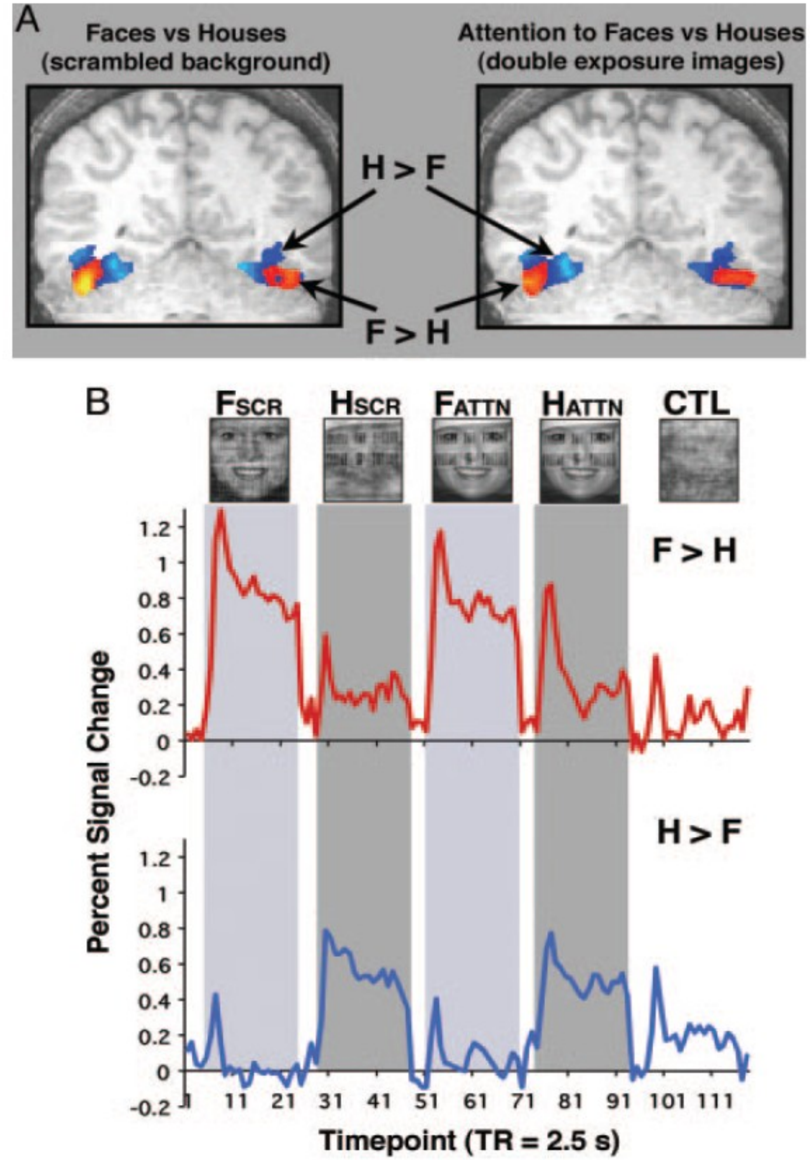
Liljeström et al., Hum. Brain Mapp. 2009

Selective attention

Stimuli



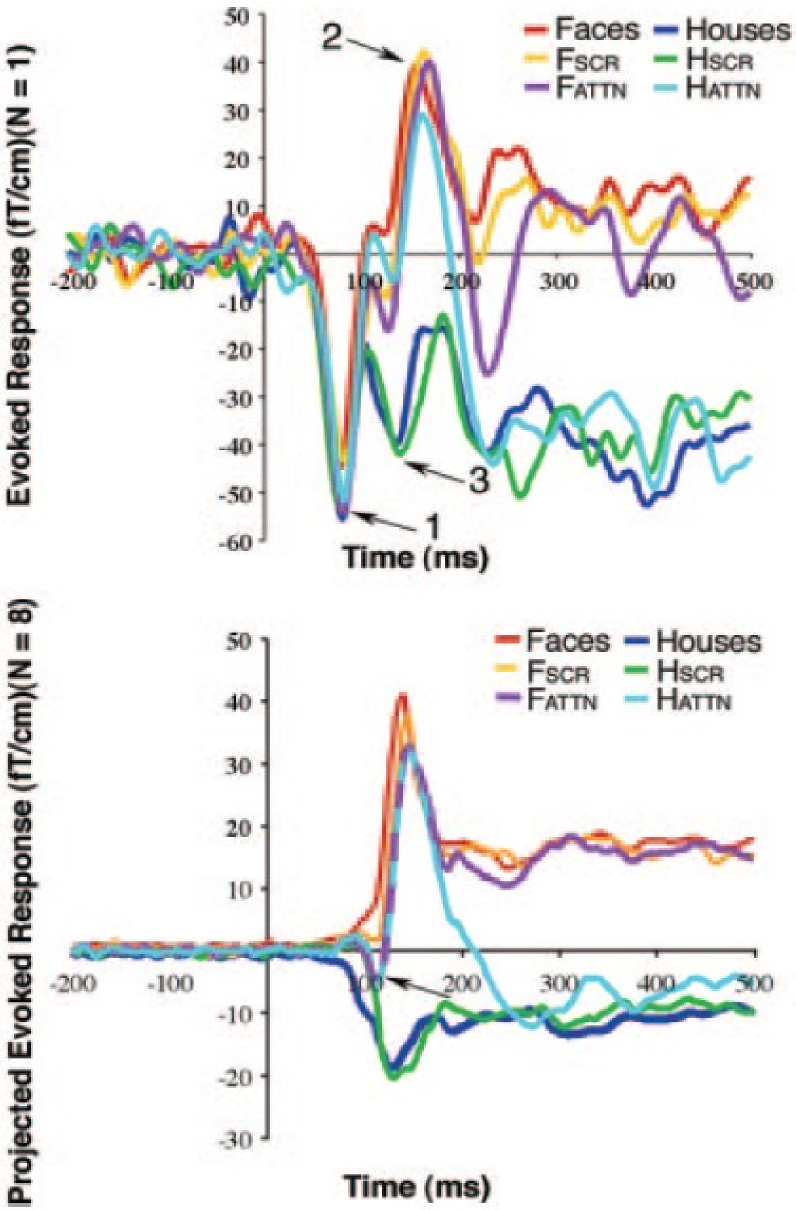
fMRI results

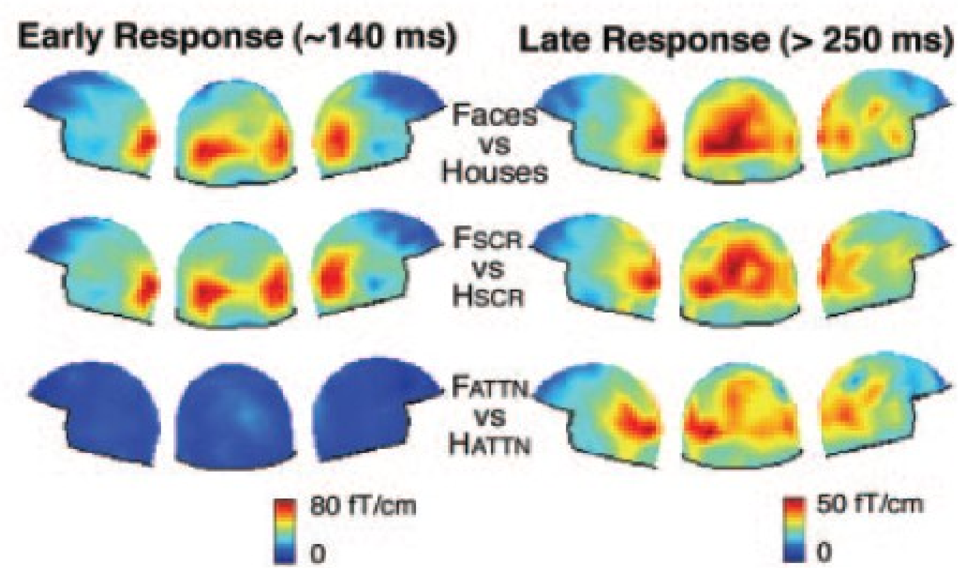


Furey et al., PNAS 2006

Selective attention (cont'd)

MEG results (evoked-response study)

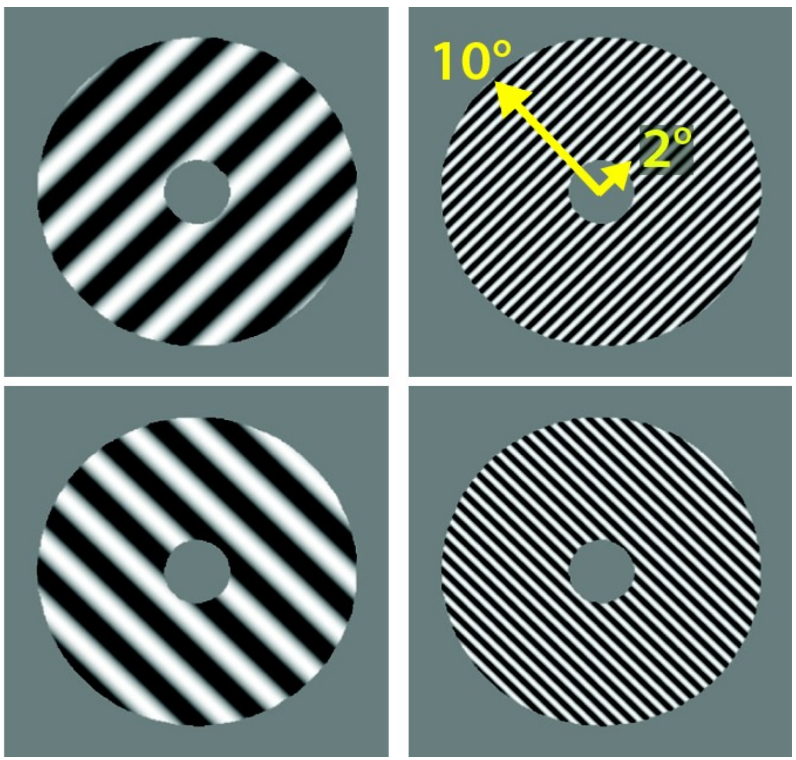




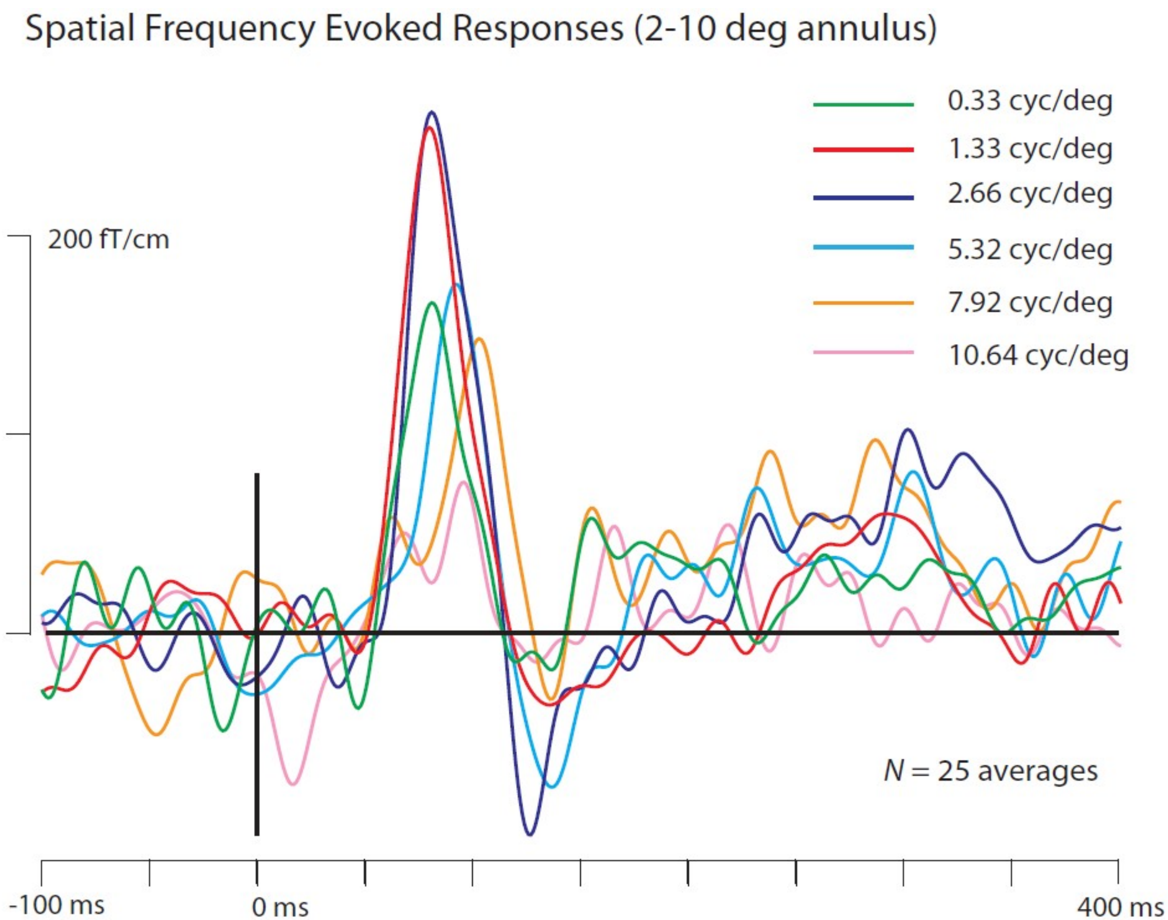
Furey et al., PNAS 2006

Classification of low-level visual features

Information about low-level visual features: Where and when is it available?



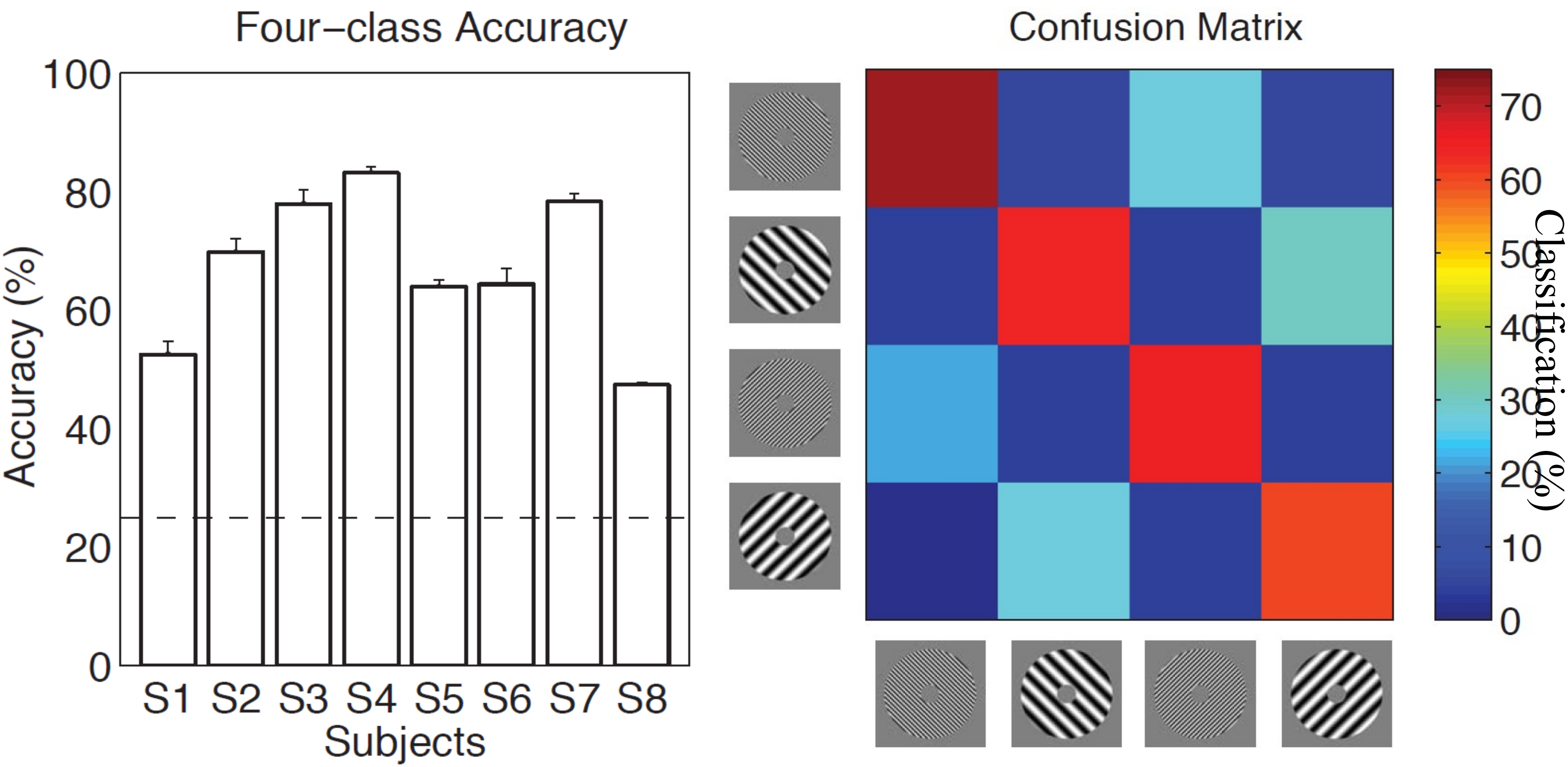
Presentation in random order, each stimulus shown for 1 s



Ramkumar et al. J Neurosci, 2013

Decoding single trials

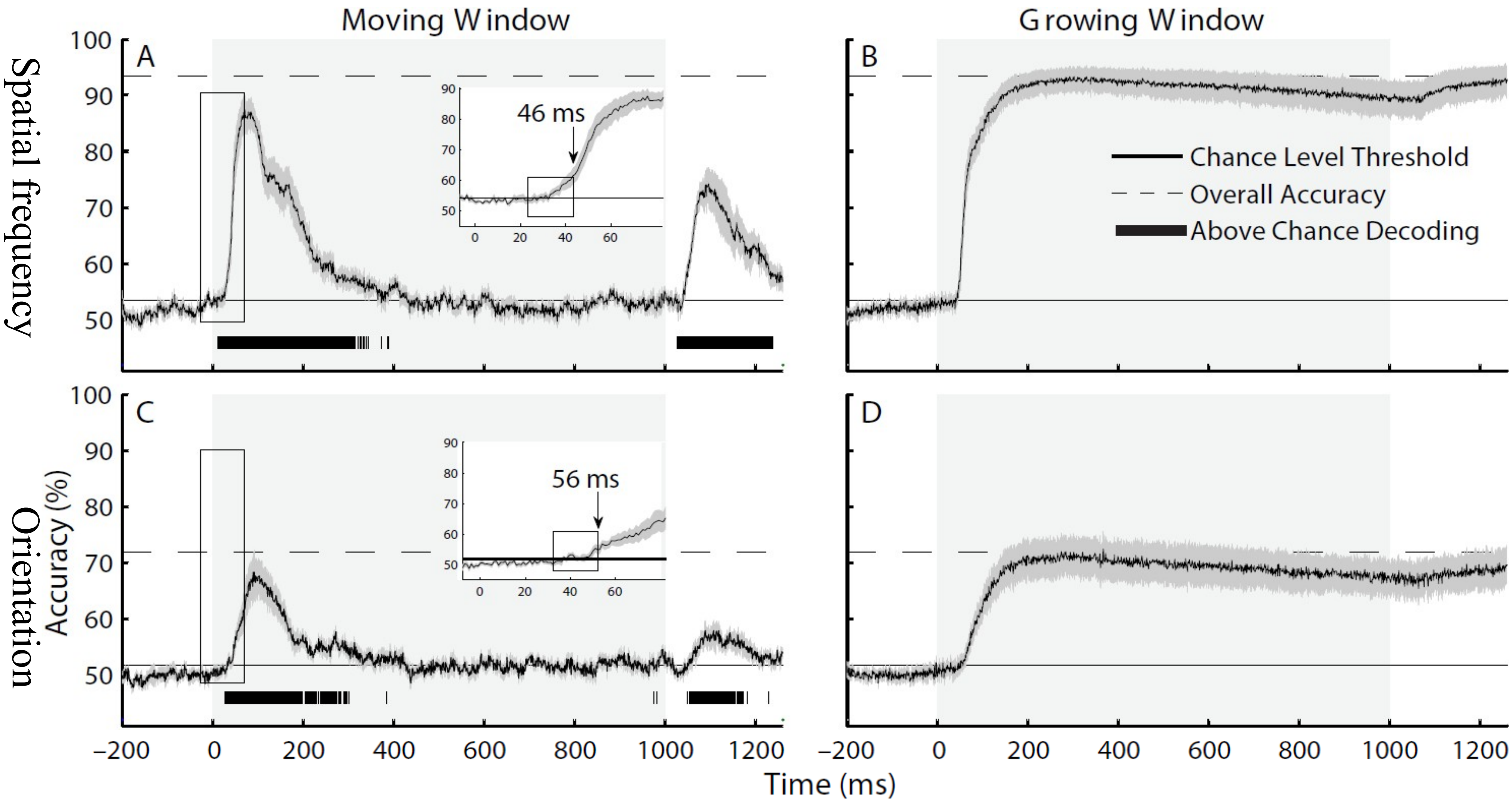
Support Vector Machine, 5-fold cross validation



Ramkumar et al. J Neurosci, 2013

Time-resolved decoding of single trials

Decoder uses MEG data from a 20-ms moving/growing window



$N = 8$

Ramkumar et al. J Neurosci, 2013

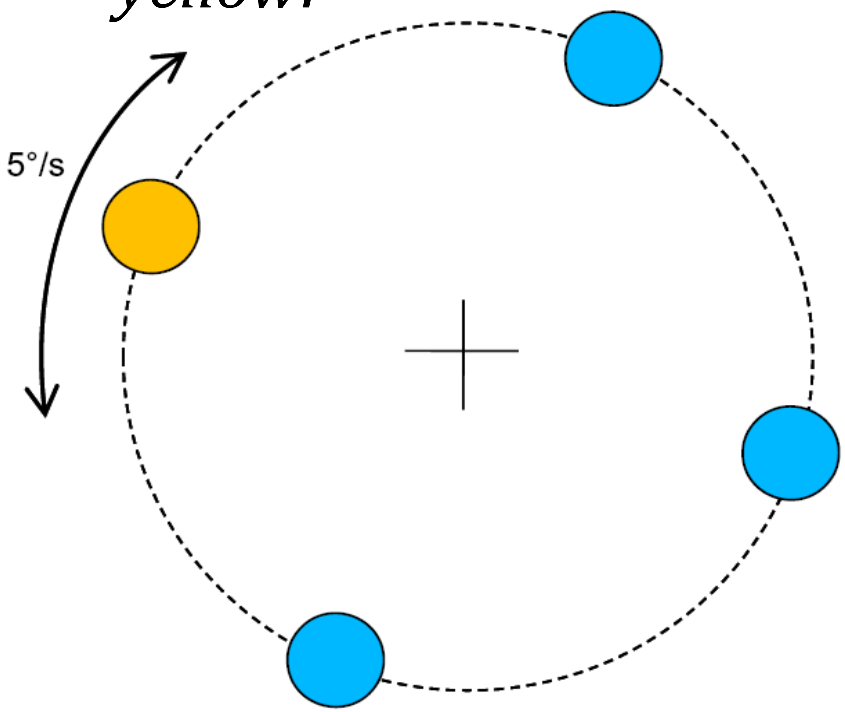
Discussion

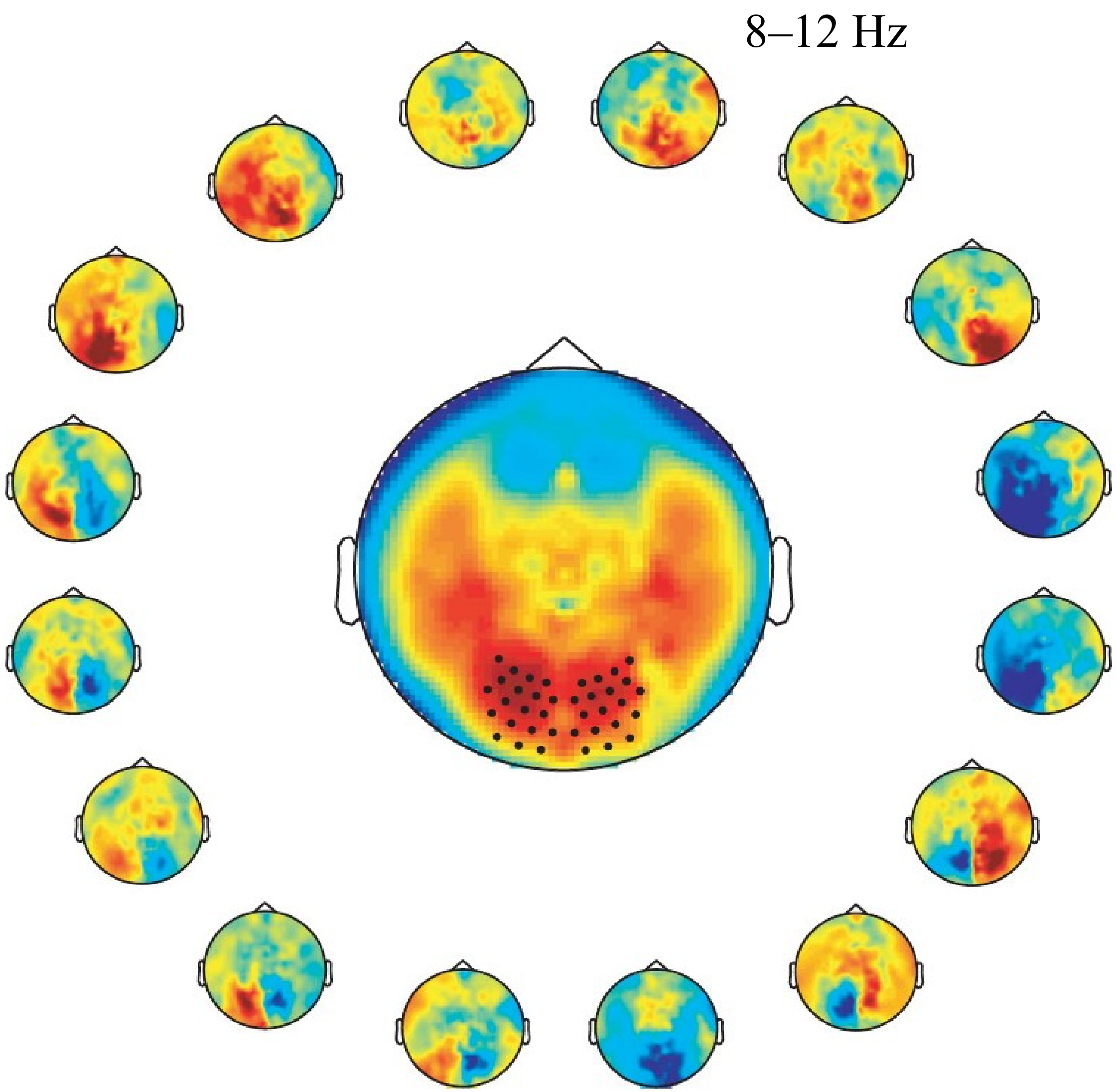
- Already 50 ms after the stimulus onset, there is enough information in the signals from the early visual cortices to decode spatial frequency and orientation of the stimulus
- Decoders of low-level visual features generalize also to some extent across subjects => the neural representations of these stimulus features are rather similar across individuals

Brain–Computer Interface by visual attention

Moving spatial attention changes the spatial distribution of posterior alpha activity

Task: Covertly follow the dot that occasionally turns yellow!





Bahramisharif et al., Eur J Neurosci, 2010

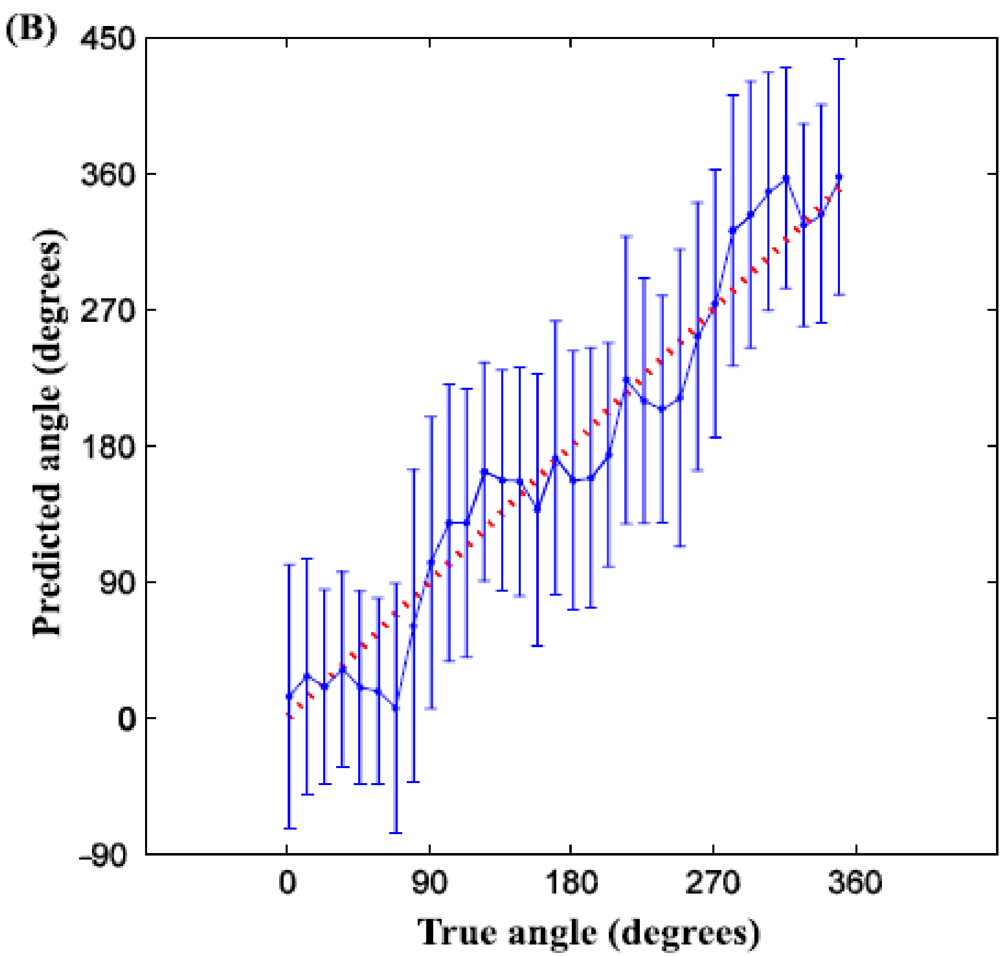
BCI by visual attention

Continuous estimate of the target of the attention

- 10-Hz power within a 500-ms sliding window
- Regression analysis

Average deviation 50–70 degrees (N = 11).

Optimal information transfer when using windows of 1700 ms

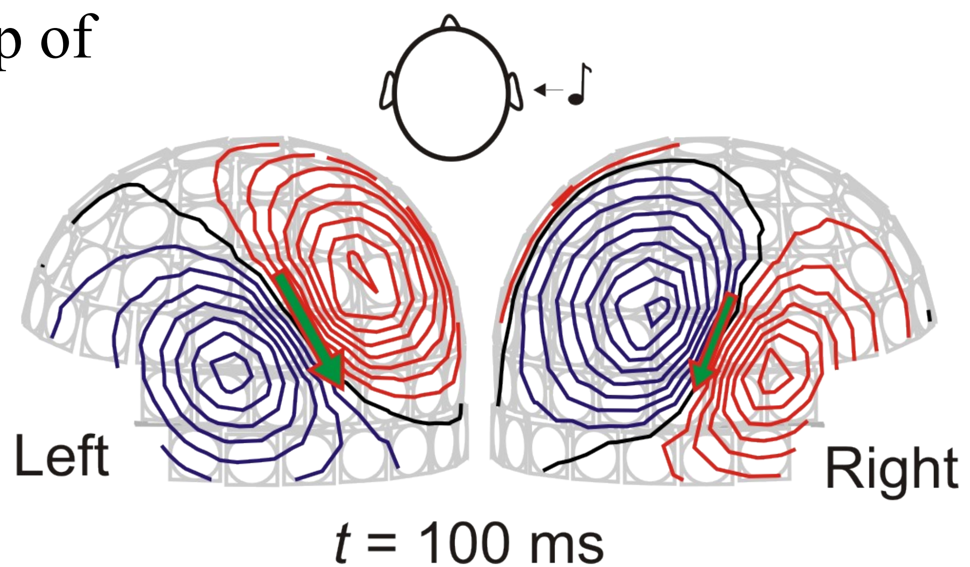


Bahramisharif et al., Eur J Neurosci 2010

Replicability of MEG results

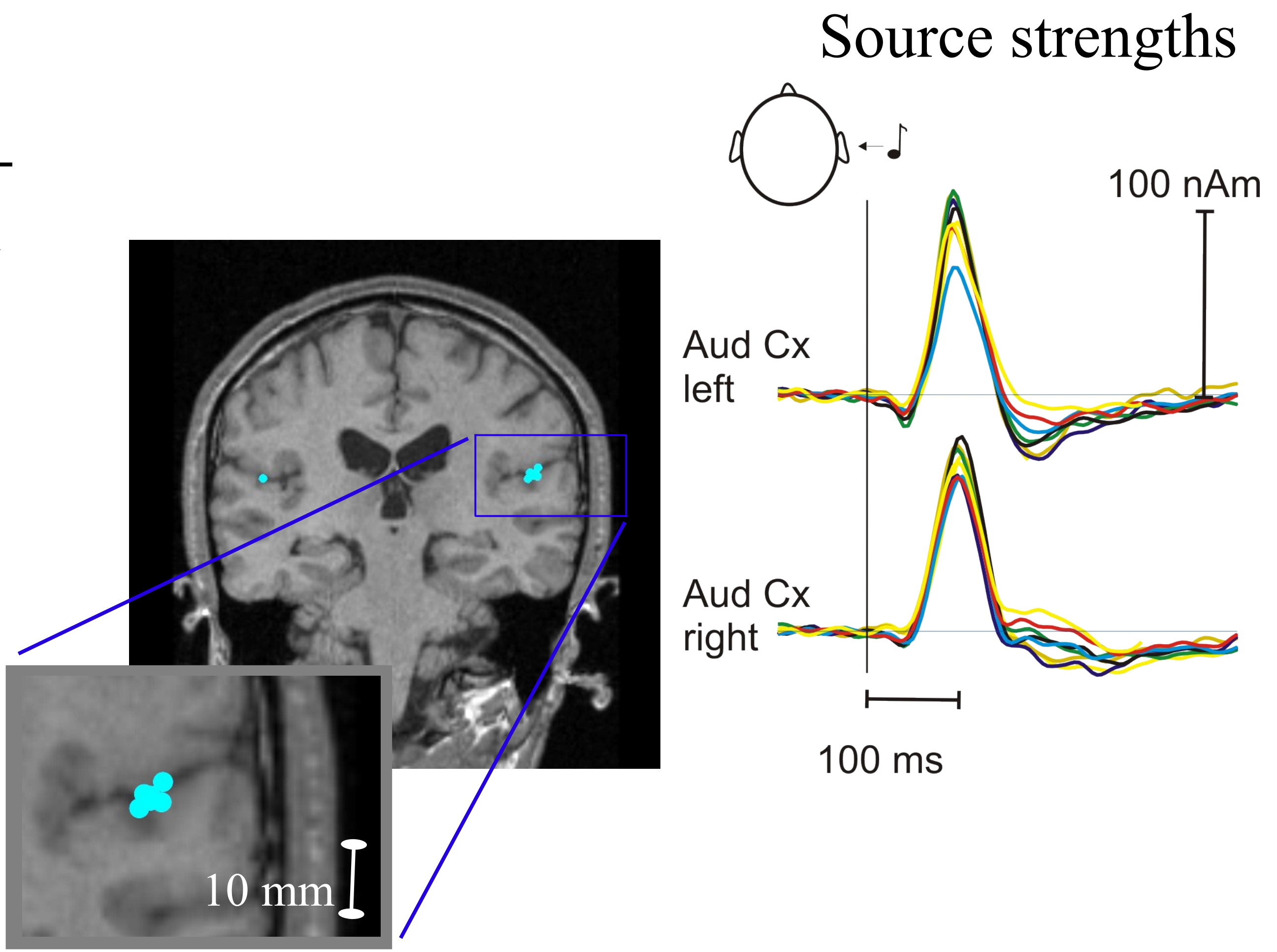
- Same experiment, same subject, 8 runs within 1.5 years
  - auditory stimuli, 1-kHz tone, 50-ms FWHM Hanning window, randomly to left/right ear, ~2 s ISI, 100 accepted trials averaged
  - sound level not controlled rigorously :-(
  - sampling at 600 Hz, 0.1 – 200 Hz pass-band

Field map of one run



Replicability of MEG results

- Source modelling
  - filtering 0.1 – 40 Hz prior to source modelling
  - 2-dipole model: goodness-of-fit >95% at the N100m peak
  - overlay on anatomical MRIs



Contents

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Comments and Controversies

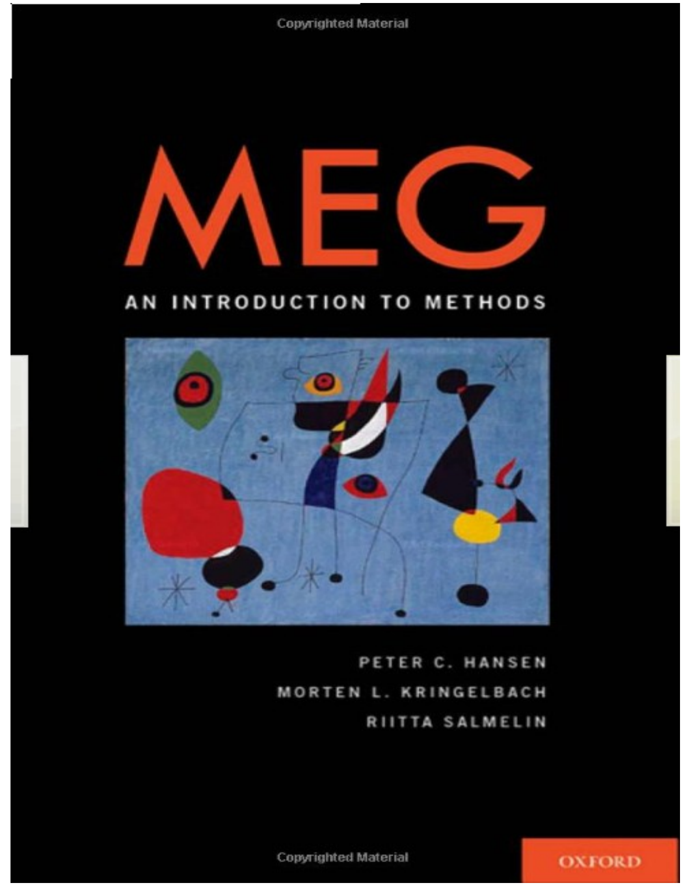
Good practice for conducting and

Joachim Gross[a,*], Sylvain Baillet[b], Gareth
Karim Jerbi[g], Vladimir Litvak[c], Burkhard M
Virginie van Wassenhove[k,l,m], Michael Wi

A B S T R A C T

Magnetoencephalographic (MEG) recordings are a rich
lying cognitive processes in the brain, with excellent te
have been considerable advances in MEG hardwar
techniques are now routinely applied and continuousl
cate dynamics of neural processes. However, the rapid
a MEG study make it difficult for novices, and sometim
and caveats. Furthermore, the complexity of MEG data
when describing MEG studies in publications, in order t
This manuscript aims at making recommendations for a
steps and suggests details that should be specified in m
tions will hopefully serve as guidelines that help to strengthen the position of the MEG research community within the field of neuroscience, and may foster discussion in order to further enhance the quality and impact of MEG research.

Gross et al., Neuroimage 2013



MEG: An Introduction to Methods.
Hansen, Kringelbach & Salmelin (eds)
Oxford University Press, 2010.