Aalto University

Functional Brain Imaging

Experimental design – MEG

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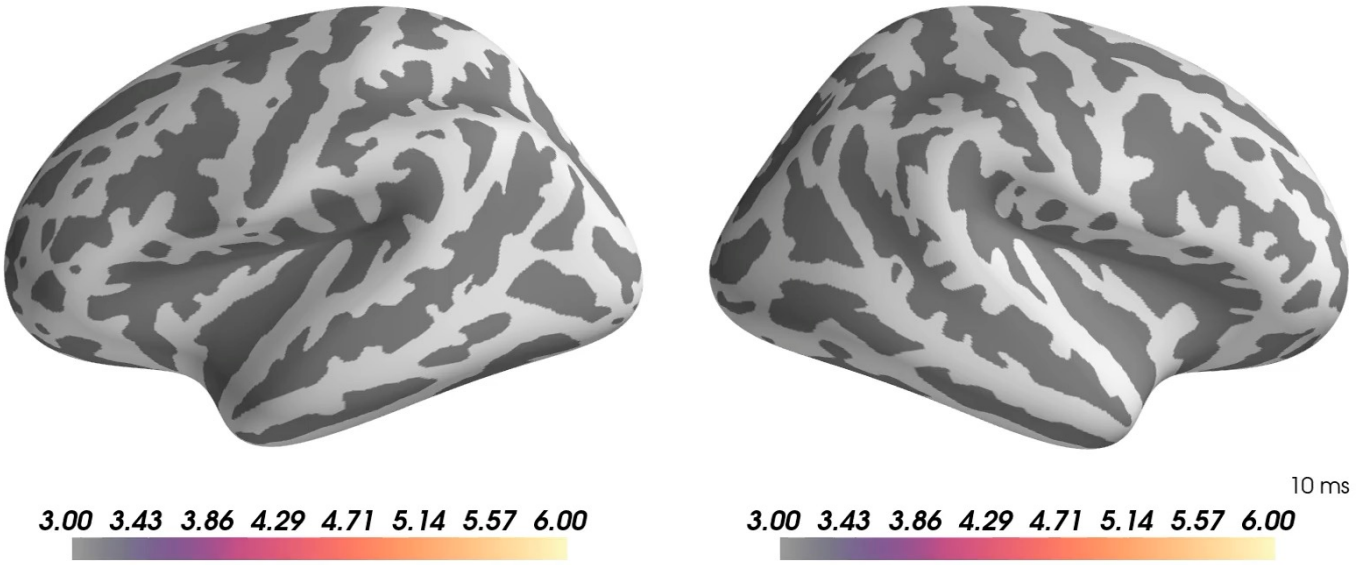
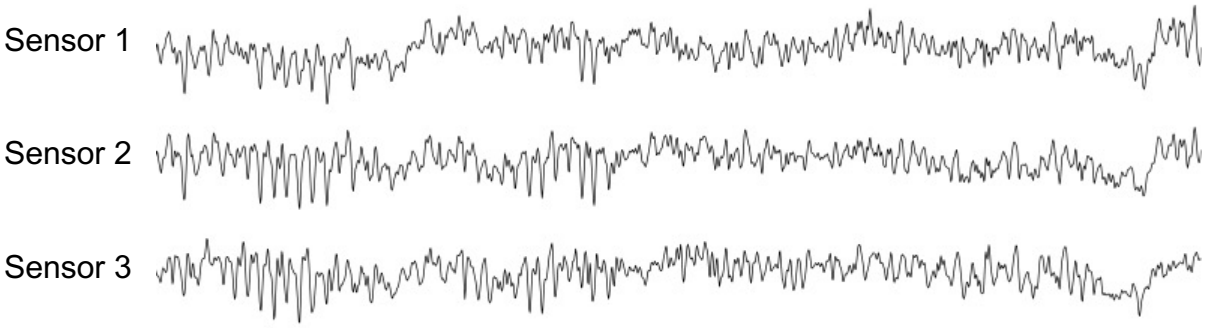
12.9.2023

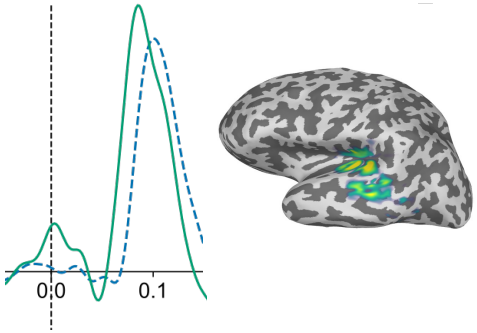
MEG tracks brain signals with millisecond time resolution and good spatial accuracy



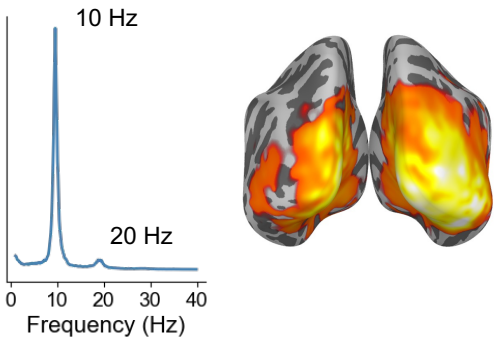
Multidimensional MEG data provide multiple measures of brain function



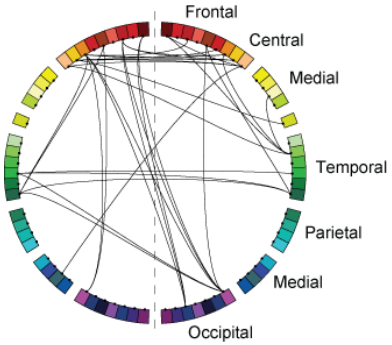
Evoked responses



Oscillatory activity



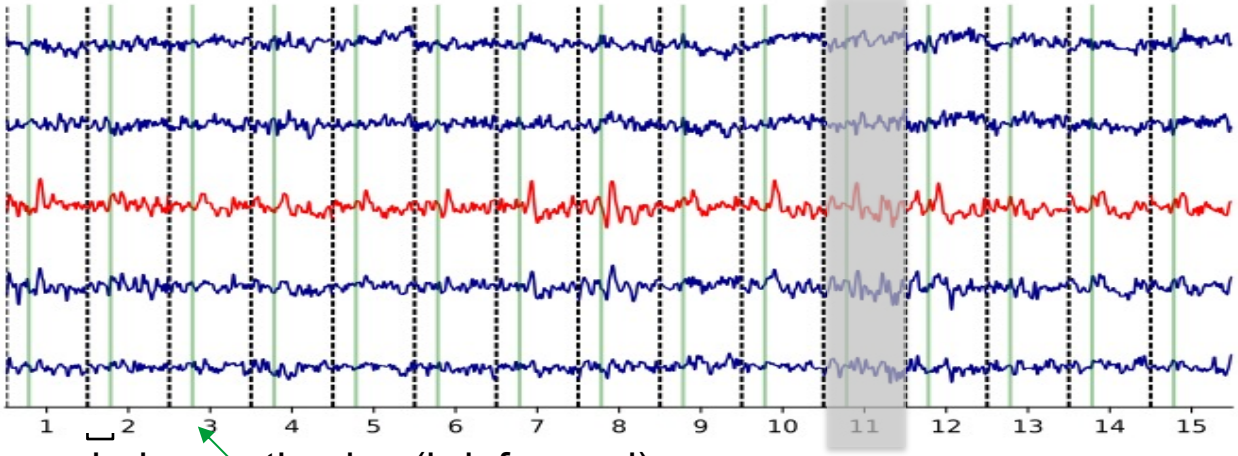
Functional connectivity



From raw data to evoked responses

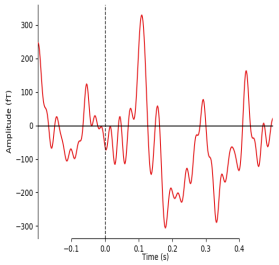
MEG raw data

epoch

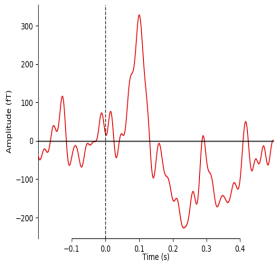


baseline period

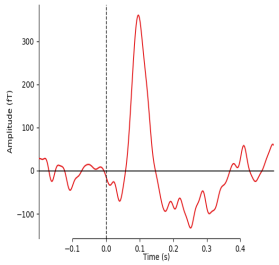
stimulus (brief sound)



N=1 repetition



N=5 repetitions



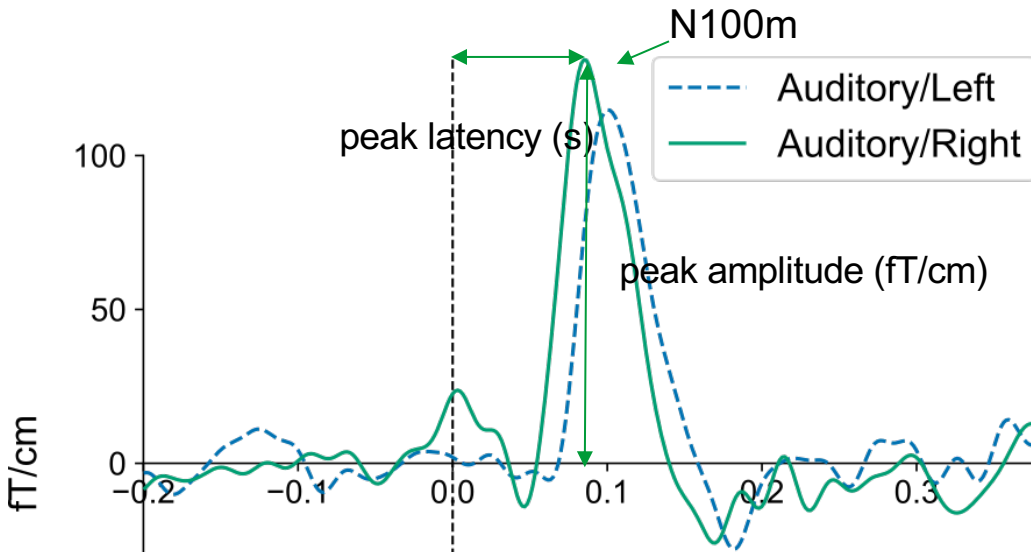
N=50 repetitions

Signal-to-noise ratio improves with $\sqrt{N}$

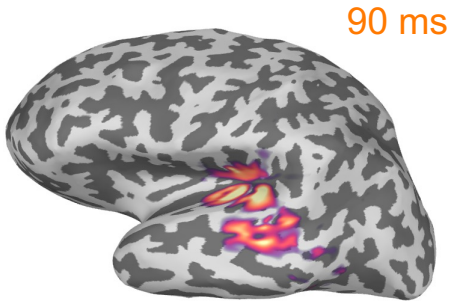
Evoked responses and typical naming conventions

Evoked response:
Time- and phase-locked EEG or MEG response, typically stimulus-driven
Event-related potential (ERP):
EEG response to external stimuli, internal mental event, or task-related activity
Event-related field (ERF):
The same, but measured with MEG

EEG: 'N100'
MEG: 'N100m'



MEG: Auditory evoked fields - AEFs

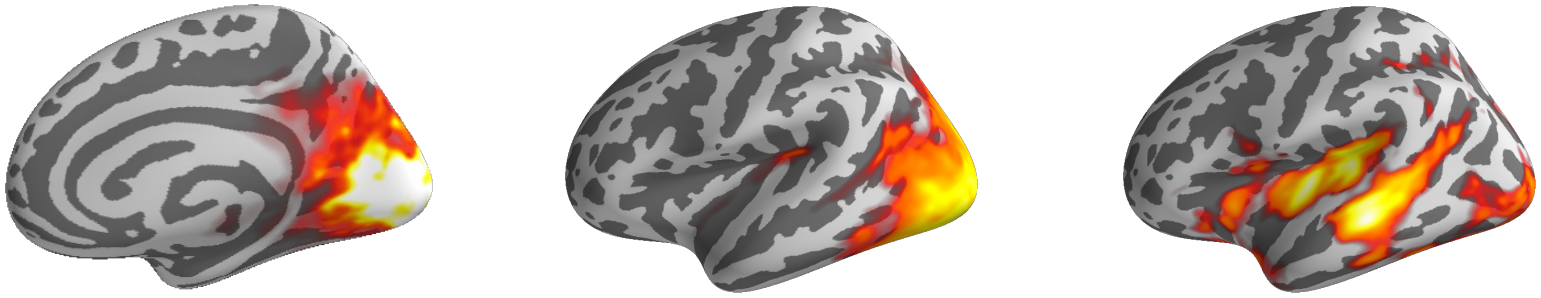


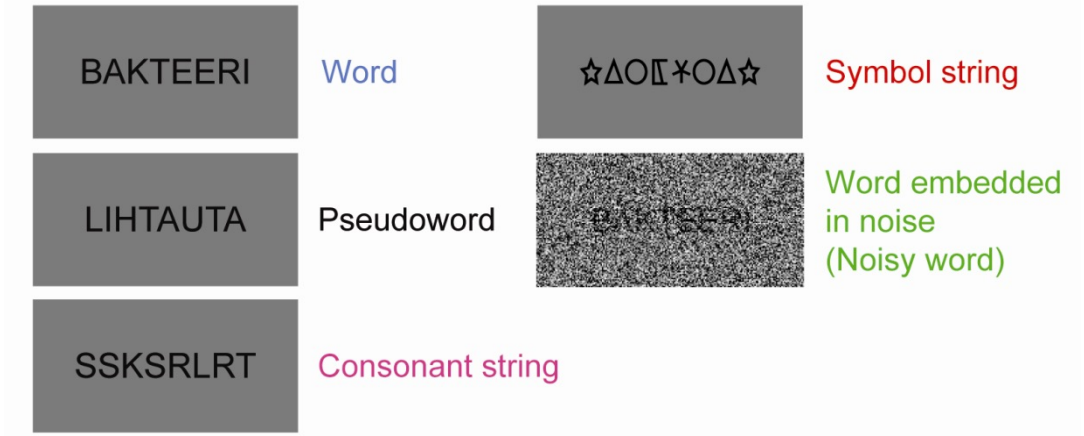
Source reconstruction: Auditory/Right condition

Reading activates a sequence of areas:

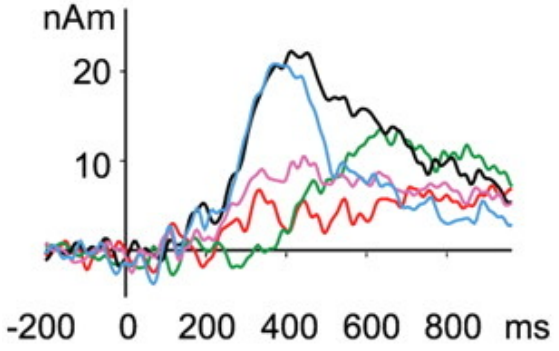
from early visual cortex, to inferior occipitotemporal cortex and superior/middle temporal cortex

100 ms **150 ms** **400 ms**





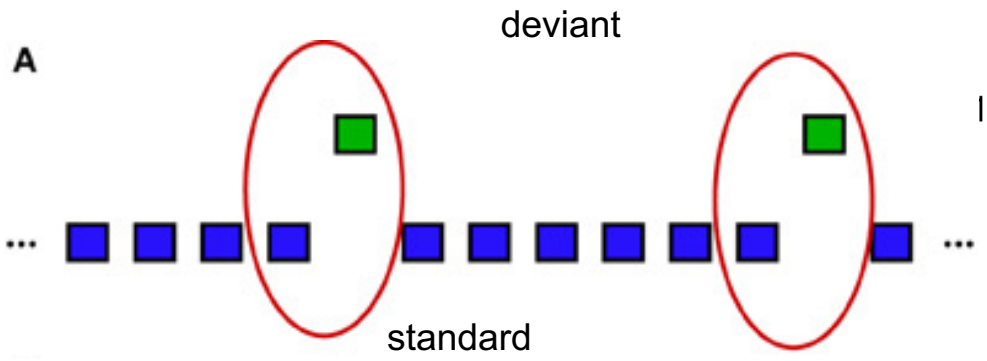
Left temporal cortex



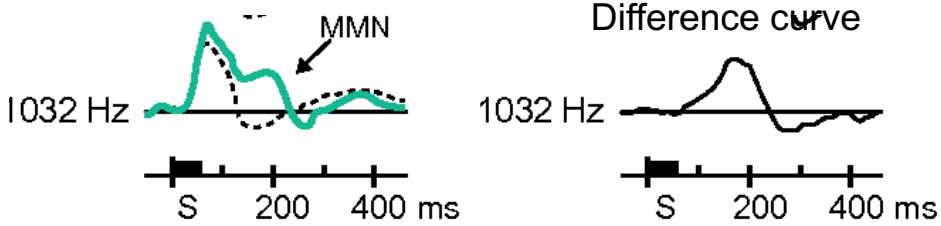
Vartiainen et al., 2011, J Neurosci

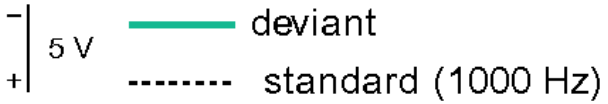
112 stimuli/catgegory, ISI 1.5 s (stimulus duration 300ms), presented in blocks of 7 stimuli
Target task: respond if the same stimulus appears twice (1-back), discard targets in analysis

Mismatch negativity/oddball design

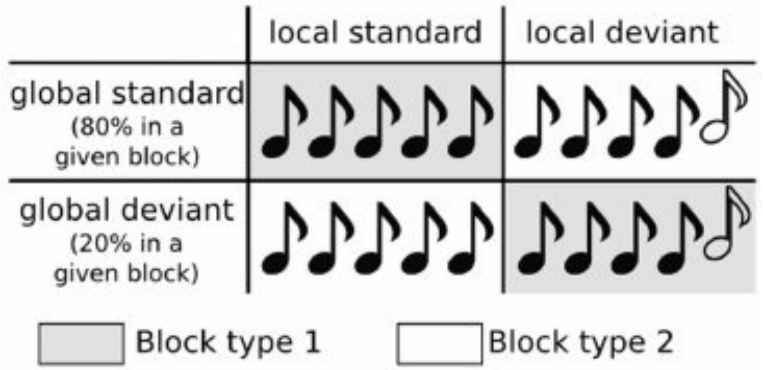


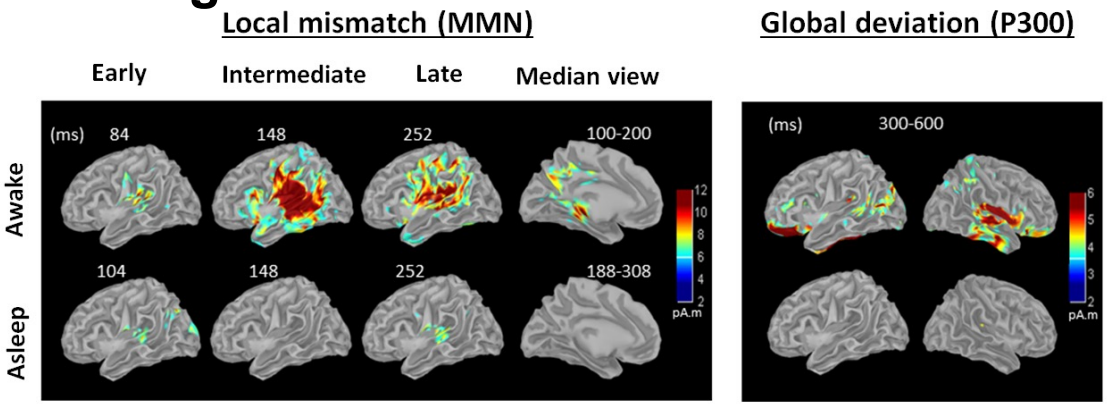
Review by Näätänen et al., 2007





Local/global variant of an oddball design

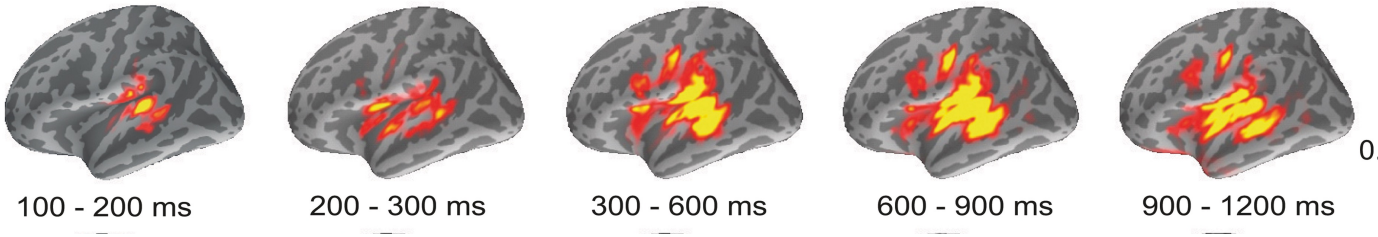




Strauss et al., 2015, PNAS

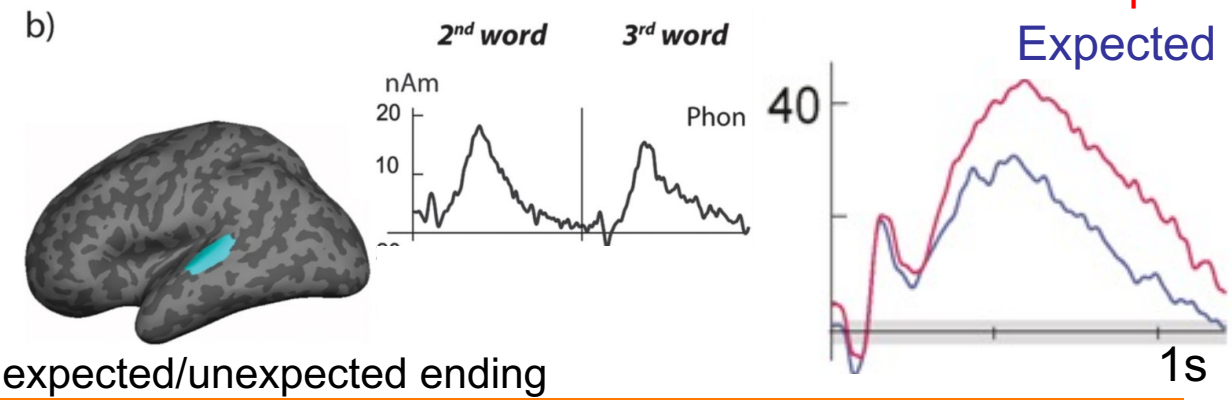
Evoked responses: N400

EEG: Kutas and Hillyard, 1980 ”The pizza was too hot to … sing”



Processing of spoken words in the temporal cortex

MANGO
MELON
KIWI
TABLE



Final word:
Unexpected
Expected

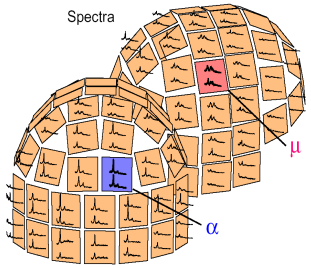
Modification: Word lists with expected/unexpected ending

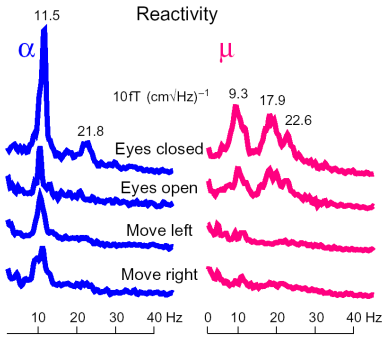
Nora et al. 2015, Kujala et al. 2011, Vartiainen et al., 2009

MEG experimental design – evoked responses

- Averaging increases SNR
  - How many trials you need depends on the strength of your signal
- Timing
  - ISI (inter-stimulus interval) depends on latency of the response
  - Save the timing information (triggers/events) with your measurement data
- Baseline
  - include a (pre-stimulus) baseline

Oscillatory activity





Canonical frequency bands

Delta 1-3 Hz

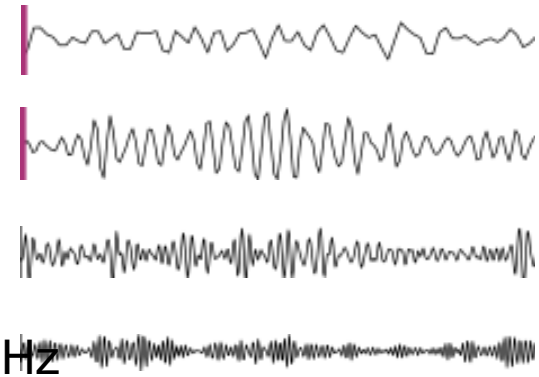
Theta 4-7 Hz

Alpha 8-13 Hz

Beta 13-30 Hz

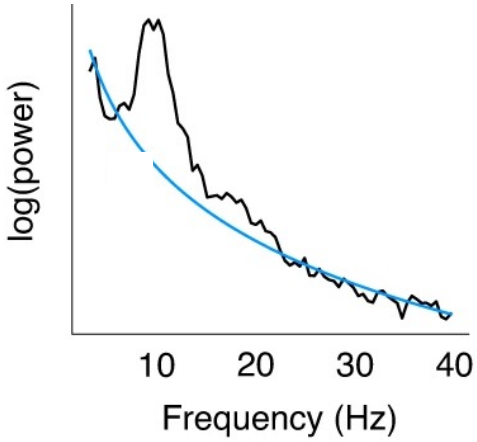
Gamma > ~30 Hz

High gamma > ~60 Hz



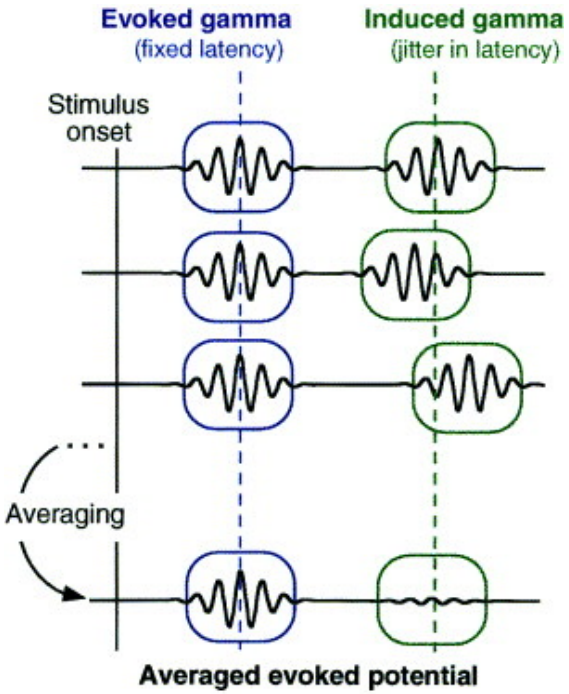
Filtered raw signals

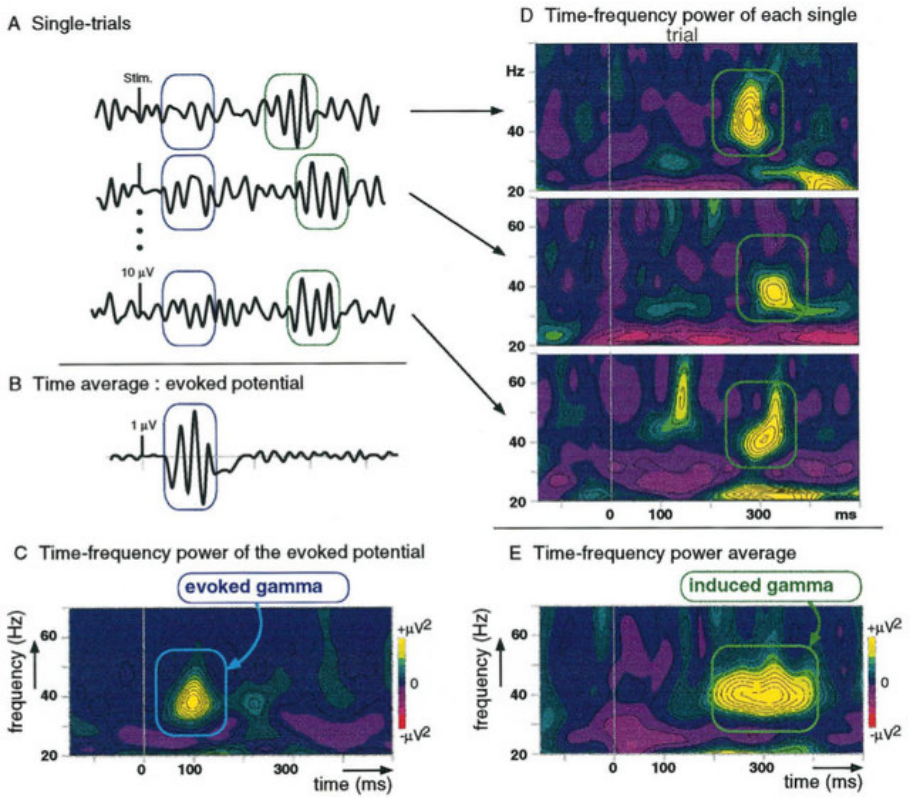
Periodic and aperiodic (1/f) components



Donoghue et al., 2020

Evoked vs. induced responses





Evoked response : same latency and phase in each single trial
Induced response: appears with a jitter in latency from one trial to another

Tallon-Baudry and Bertrand, 1999

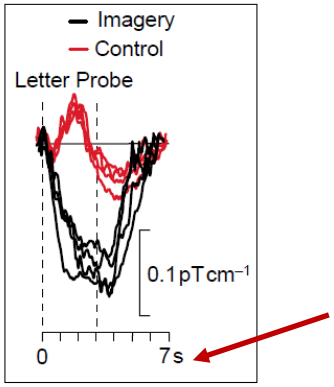
Parieto-occipital alpha oscillations modulate…

… when you close your eyes

… when you are feeling drowsy

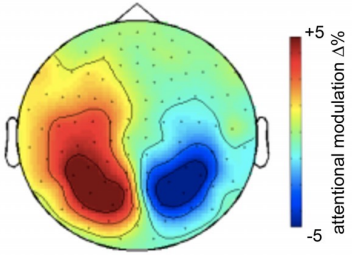
… in visual tasks, also visual imagery

… with attention



visual imagery

attend left vs. right



visual spatial attention

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Images from Salenius et al., 1995, Wildegger et al., 2017

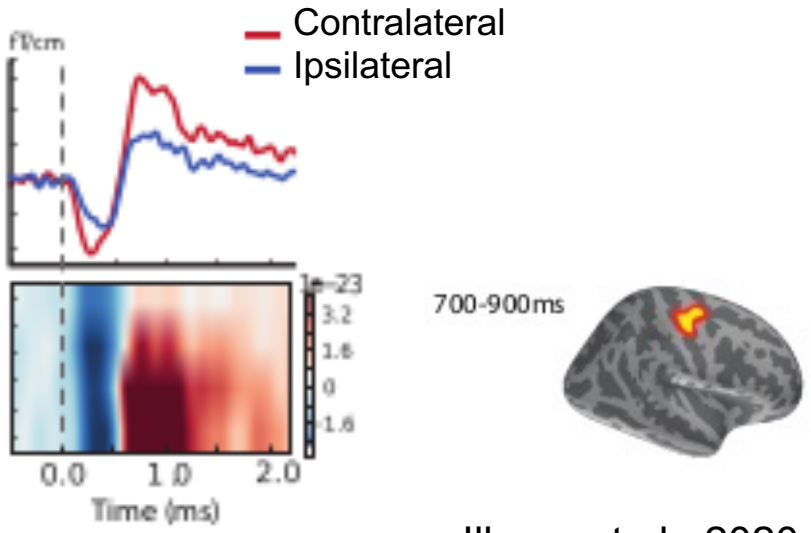
Modulations of beta oscillations: event-related (de)synchronizations (ERD/ERS)

Motor, tactile and proprioceptive tasks induce modulations in 20-Hz beta oscillations in the sensorimotor cortex.

Pre-stimulus beta-frequency events affect detection probability.

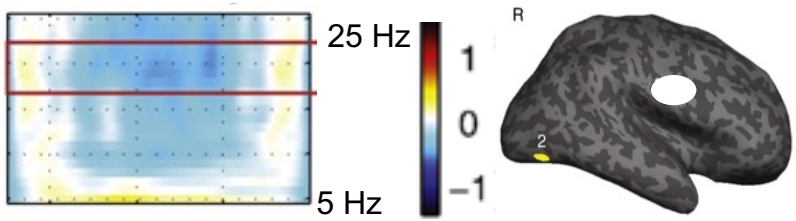
Shin et al., 2017

Passive movement



Illman et al., 2020

Overt naming



Laaksonen et al., 2012

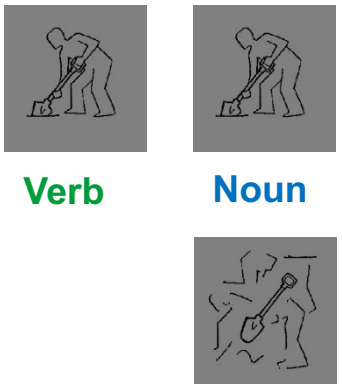
mu: 10-Hz and 20-Hz oscillations in sensorimotor cortex
beta: 20-Hz oscillations

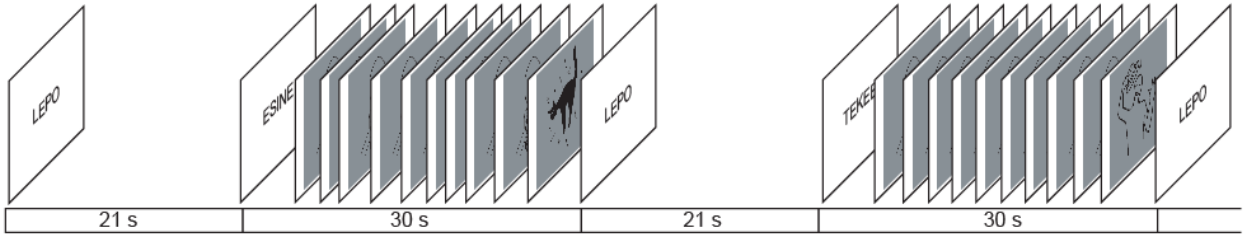
Hari and Salmelin, 1997

Experimental design: combining fMRI & MEG

Naming task

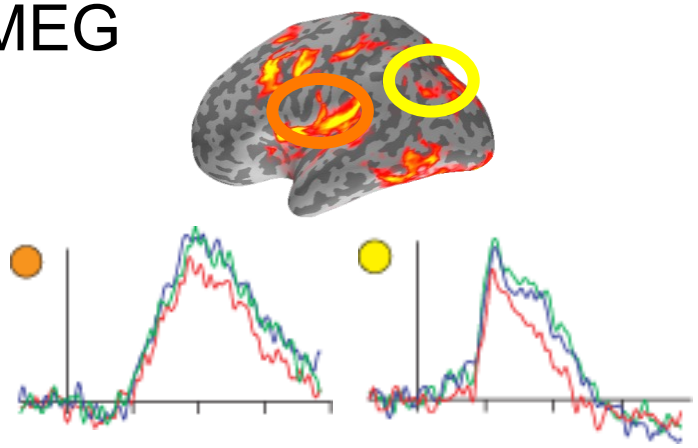
Stimuli



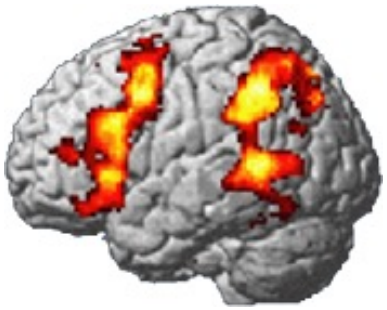


- Task periods (30 s) and rest periods (21 s) alternated in a block design
- 10 images (duration 300 ms, interval 1.8-4.2 s), 10 blocks per task, altogether 100 images/category
- Same subjects, exactly the same paradigm

MEG



fMRI



action image > object image

Liljeström et al., 2009

What is the subject doing?

- Primary task: we are interested in the actual task the subject is performing
  - Naming, N-back, attending, finger tapping, etc.
- Secondary task: keep the subject alert, divert attention
  - Target stimuli (press button if...), remove target from analysis
- Confounds due to
  - Movement (different groups, different tasks)
  - Match conditions for difficulty, motor demands
- Collect behavioural/physiological responses?
- Give clear instructions
- Consider practice session

Experimental design – things to think about

- What is your question? And how can you evaluate it?
- A good control condition: low-level/high-level
- Confounds?
- Do you need a baseline/rest?
- How long is your experiment? Trade-off between more data and fatigue
- Counter-balancing conditions
- Inter-stimulus intervals (ISI), randomizations, jittering, efficient designs, number of trials

Extra reading

Neuroimage. 2013 65(100): 349–363.
Good practice for conducting and reporting MEG research
Gross, Baillet, Barnes, Henson, Hillebrand,Jensen,Jerbi, Litvak, Maess, Oostenveld ,Parkkonen, Taylor, van Wassenhove, Wibral, Schoffelen

Neuroimage. 2008 40(2): 409–414.
Guidelines for reporting an fMRI study
Poldrack, Fletcher, Henson, Worsley, Brett, Nichols