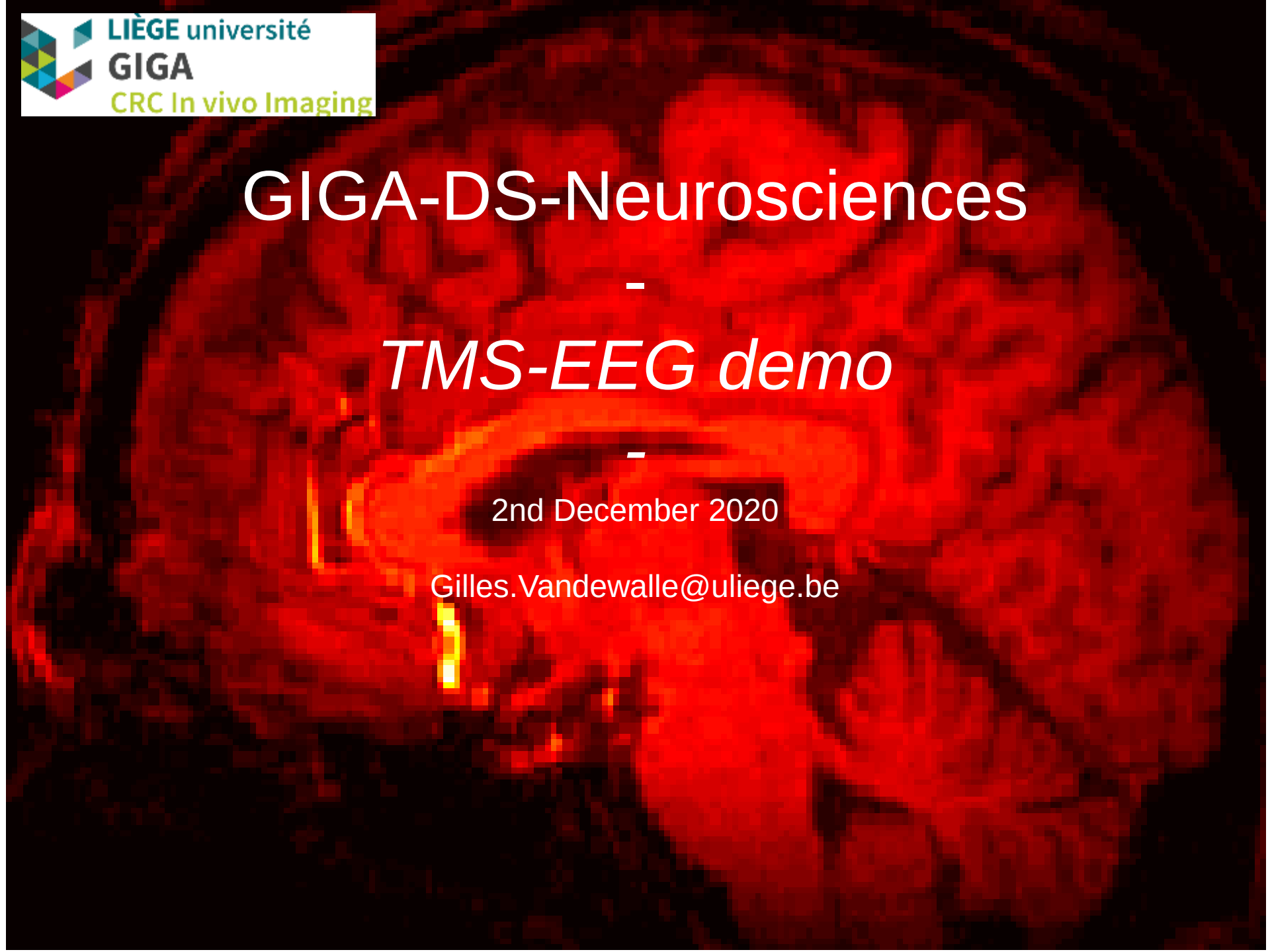

GIGA-DS-Neurosciences

-

TMS-EEG demo

-

2nd December 2020

Gilles.Vandewalle@uliege.be

TMS: Transcranial Magnetic Stimulation

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- *Neuronavigation: precise target (hotspot)*
- *TMS: magnetic perturbation of neuronal activity*

TMS: Transcranial Magnetic Stimulation

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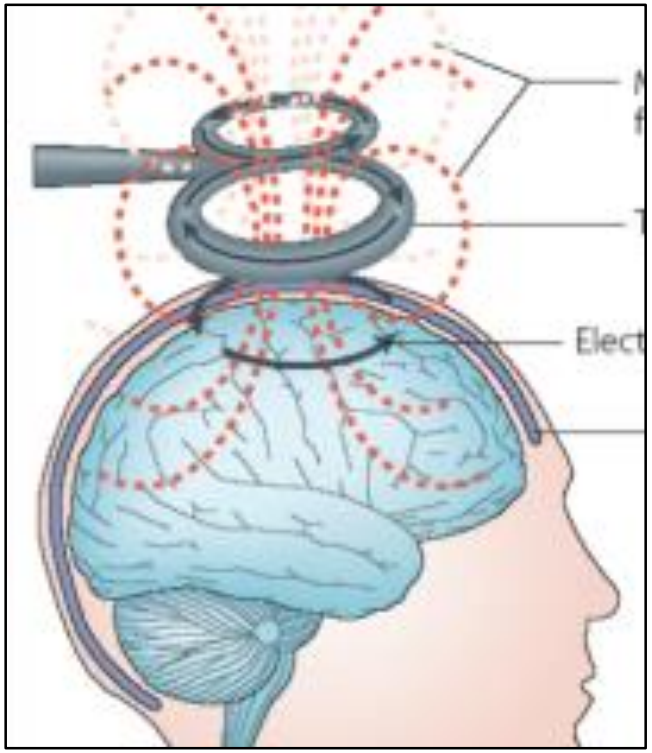
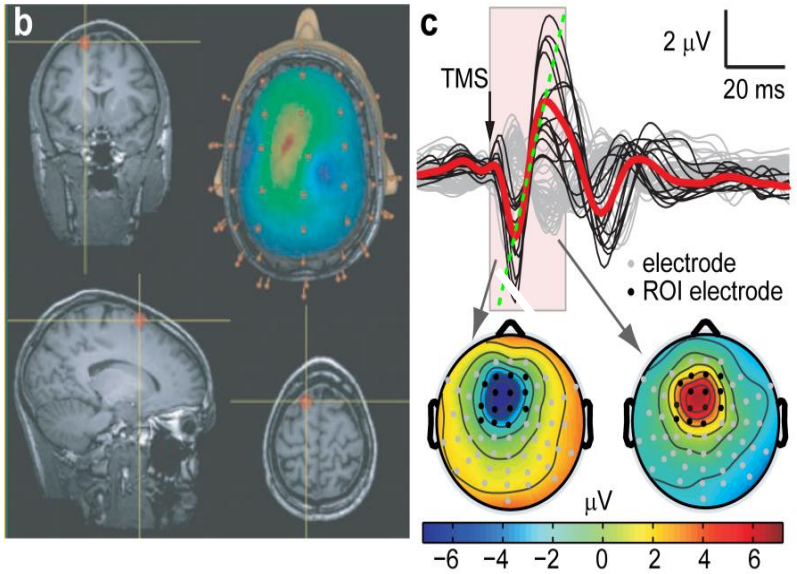
- Neuronavigation system
- Magnetic stimulation over the scalp
- Electric current in the brain
- Perturbation of neuronal activity
- Precise in time and location but does look at the entire brain
- Role in a given brain area in a given brain process
- Therapeutic applications

- *Many ongoing developments/applications*



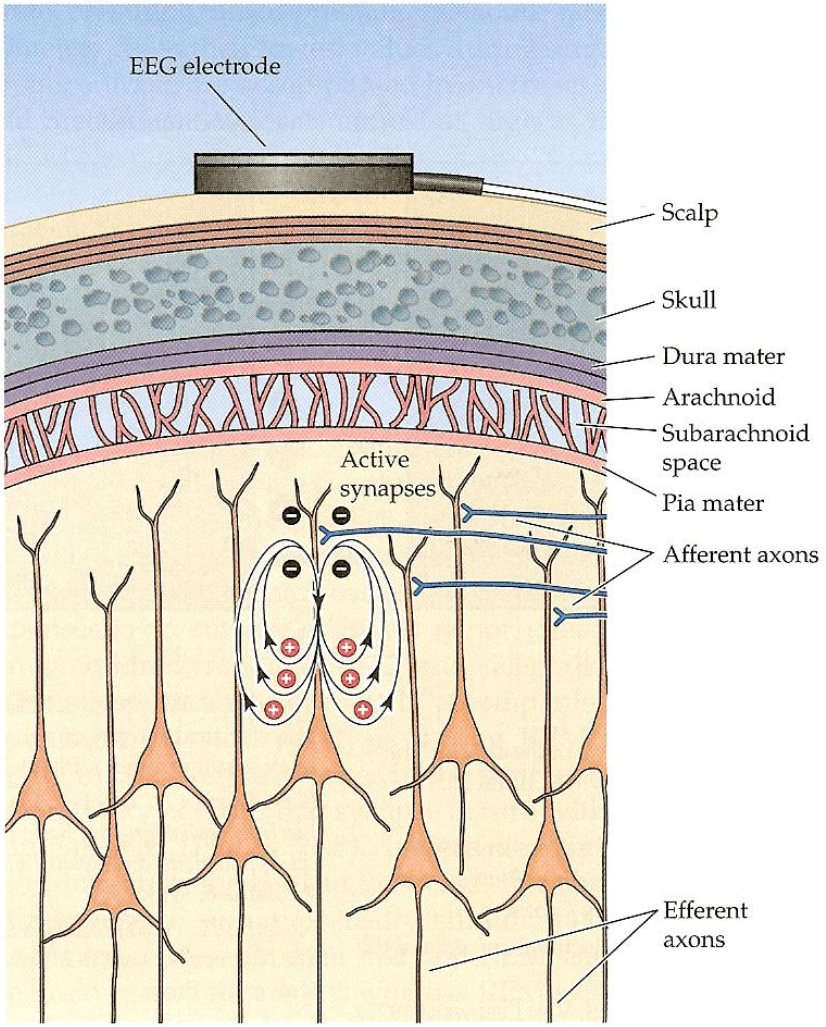
TMS/EEG: non-invasive recording of direct neuronal stimulation



- ***EEG: neuronal response recording***

Electroencephalogram - EEG

- Recording of difference in electrical potential
- More direct recording of neuronal activity
  - but from a distance
  - thousands of neurons at once
- Records mainly pyramidal cells
- With axons perpendicular to scalp



(B) An electrode on the scalp measures the activity of a very large number of neurons in the underlying regions of the brain, each of which generates a small electrical field that changes over time. This activity (which is thought to be mostly synaptic) makes the more superficial extracellular space negative with respect to deeper cortical regions. The EEG electrode measures a synchronous signal because many thousands of cells are responding in the same manner at more or less the same time. (Adapted from Bear et al., 2001.)

EEG

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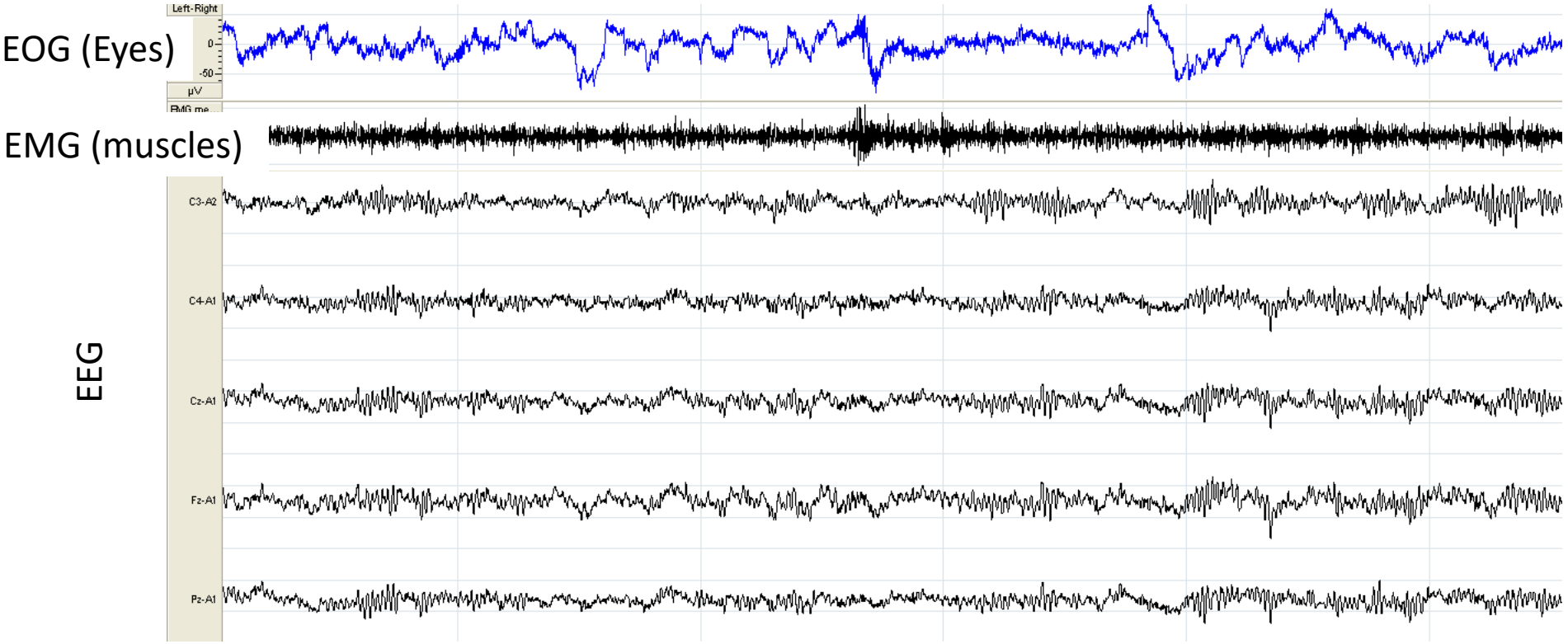
WAKEFULNESS



5 seconds

EEG

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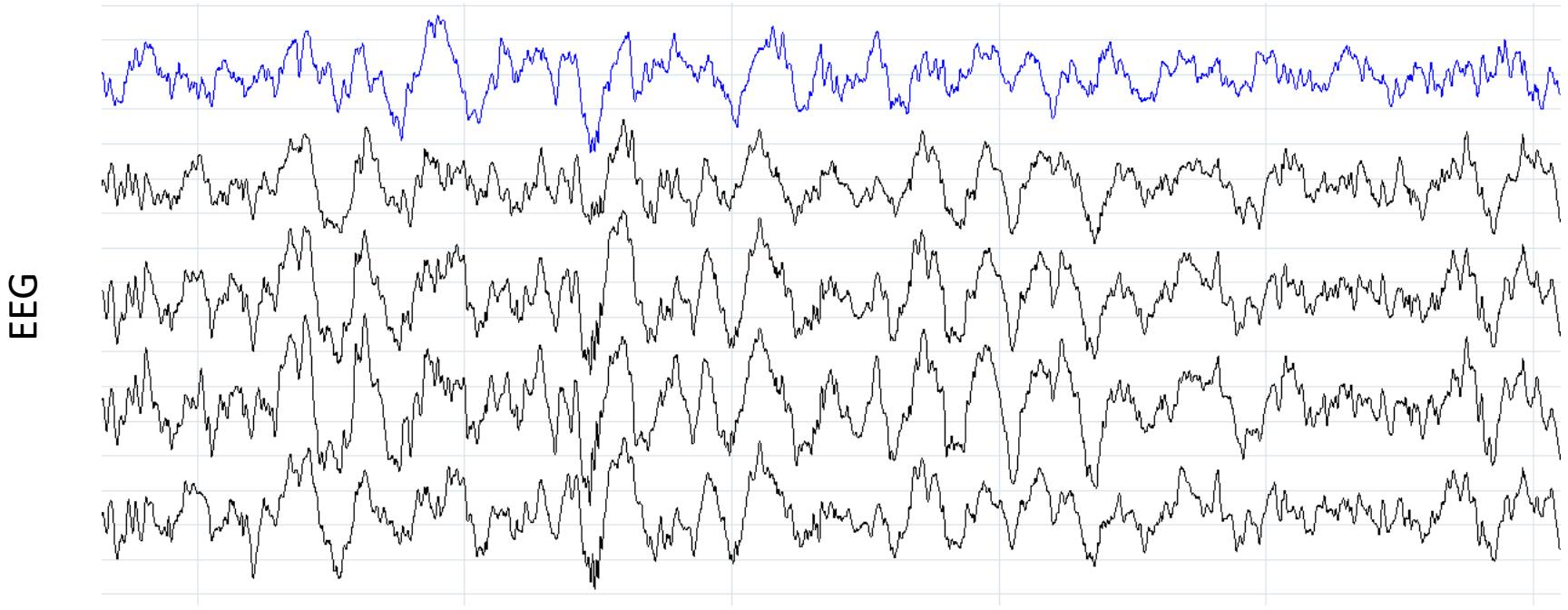
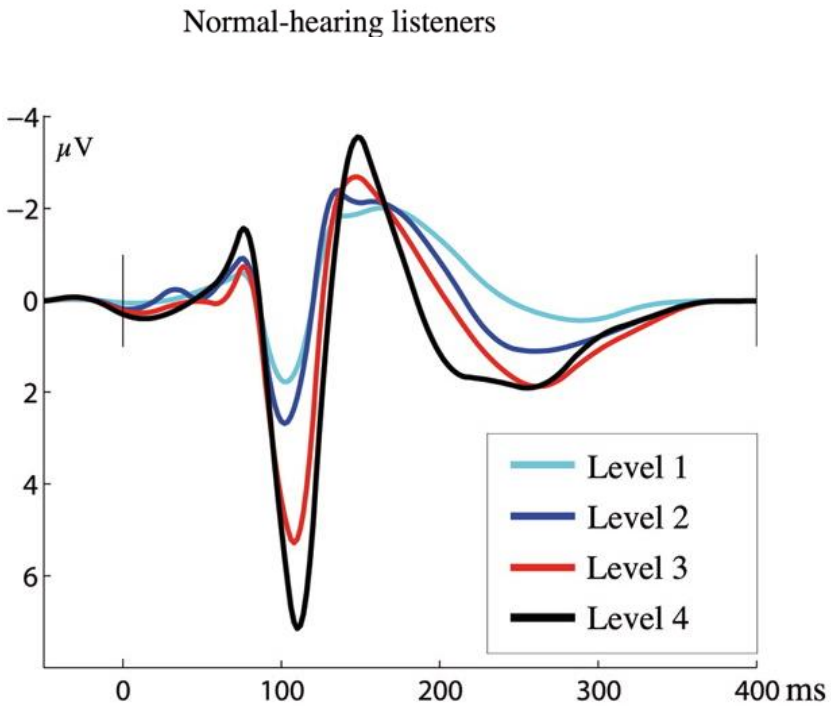
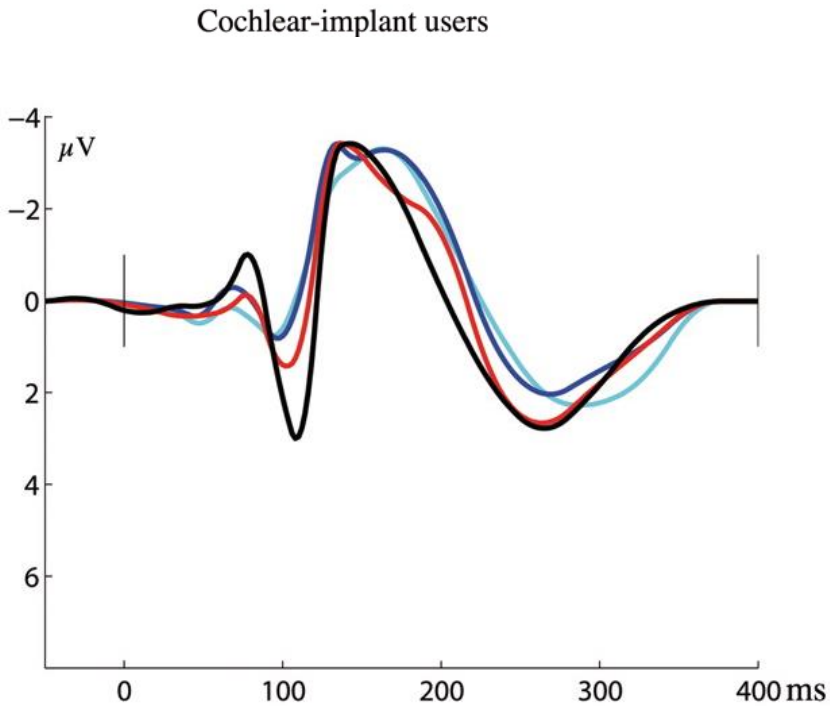
SLEEP



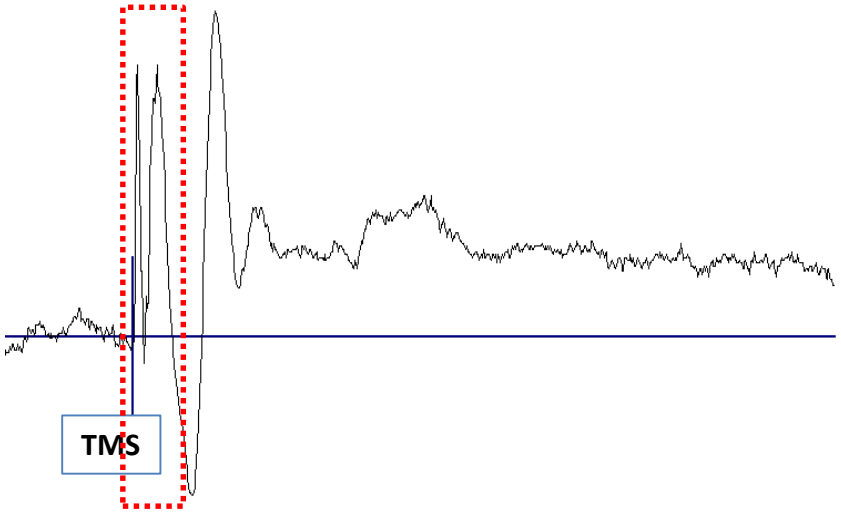
Evoked responses



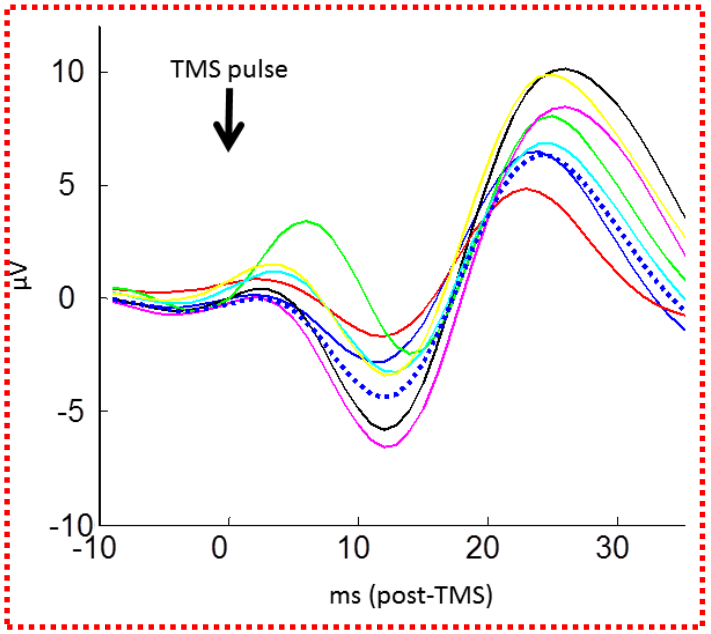


TMS-Evoked responses

Averaged raw signal



Averaged preprocessed signal



S1 ~10AM
S2 ~4PM
S3 ~8PM
S4 ~10PM
S5 ~1AM
S6 ~5AM
S7 ~7AM
S8 ~10AM

Representative subject

TMS-*compatible* EEG system

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Sample-and-hold circuit ~= turning off EEG system around TMS pulse

TMS-compatible EEG system

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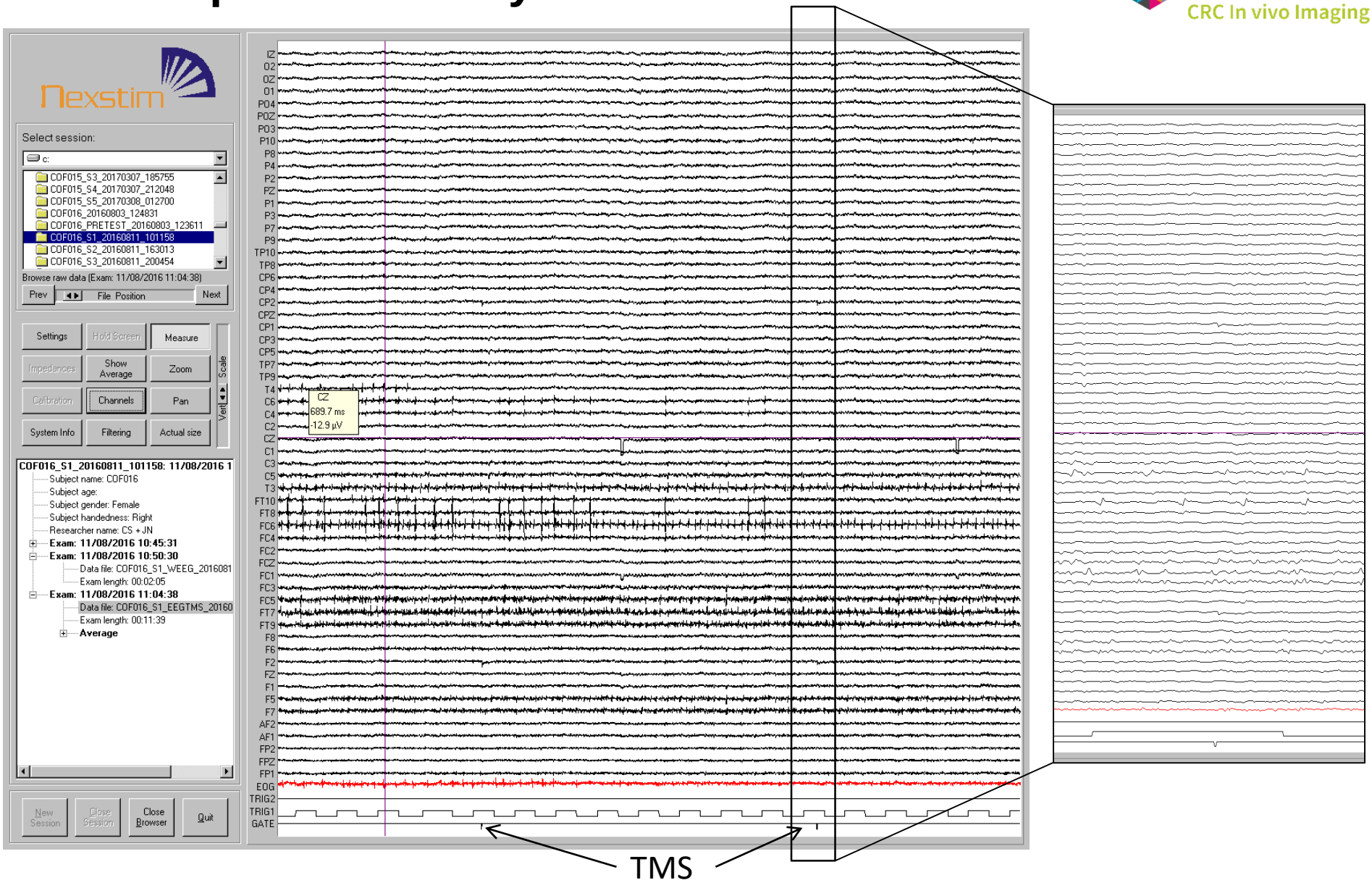

~ Artefact free EEG trace dispite the high magnetic field created by the TMS pulse

TMS-EEG – how dos it work?

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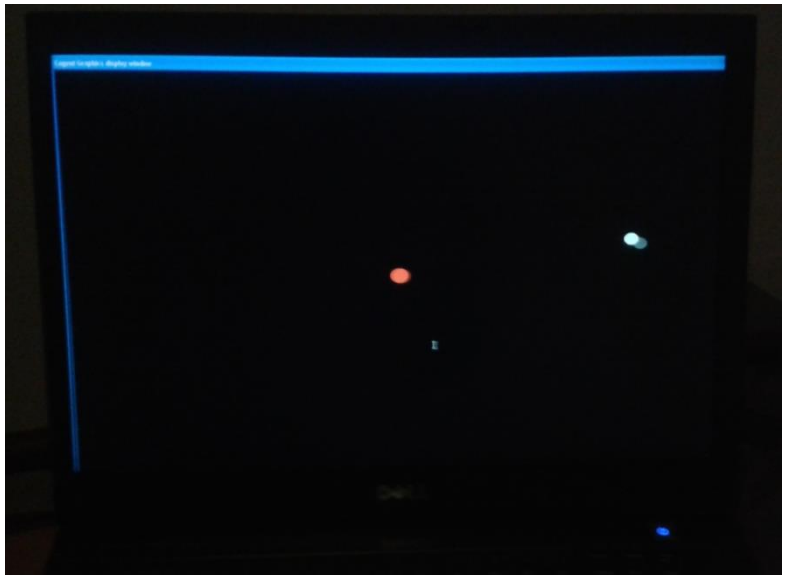
- TMS produces a “click” that triggers auditory responses if not controlled for
  >> use of a load masking noise (pink noise)

- Participants may become sleepy
  >> need to monitor vigilance to quantify sleepiness and potentialy to exclude data when sleepy



Visuomotor vigilance task: (maintan a constantly moving dot in the centre of the screen)

Processing of EEG data – the different steps

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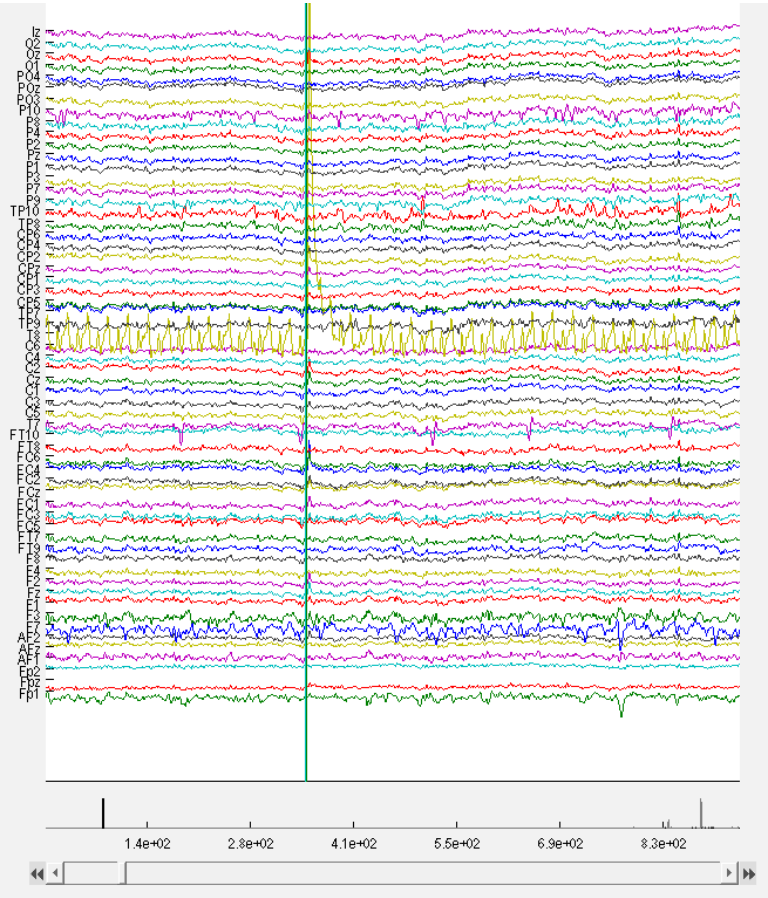
- Raw signal

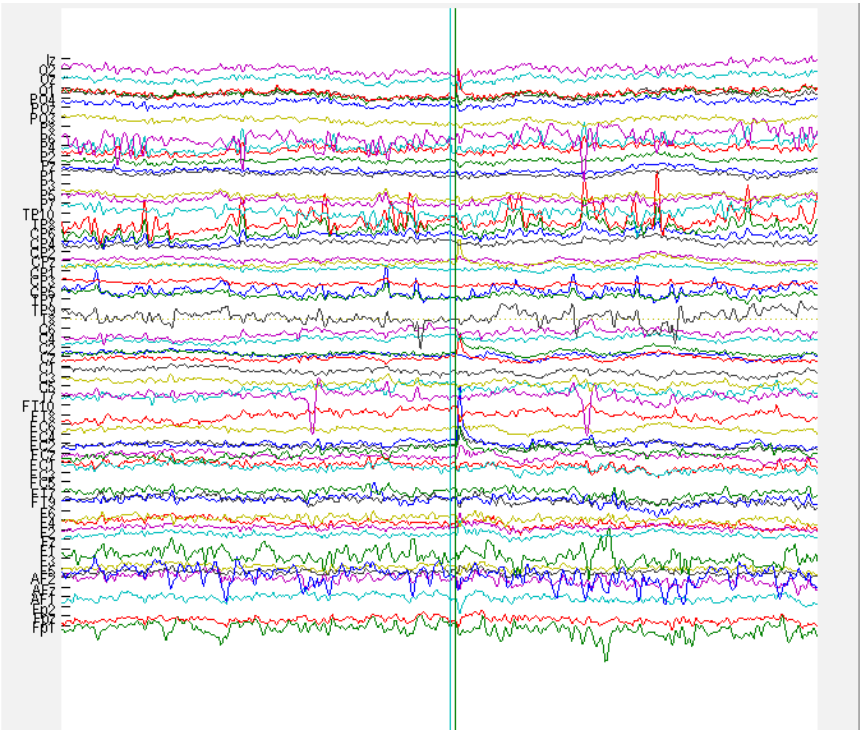
TMS



- Signal referenced to the average of all good electrode (each electrode minus mean of the other)

Bad electrodes are removed.
The average is used as a reference against which the difference in electrical field is computed
During typical recording, the reference is placed on a neutral area (e.g. mastoids)

TMS



Processing of EEG data – the different steps

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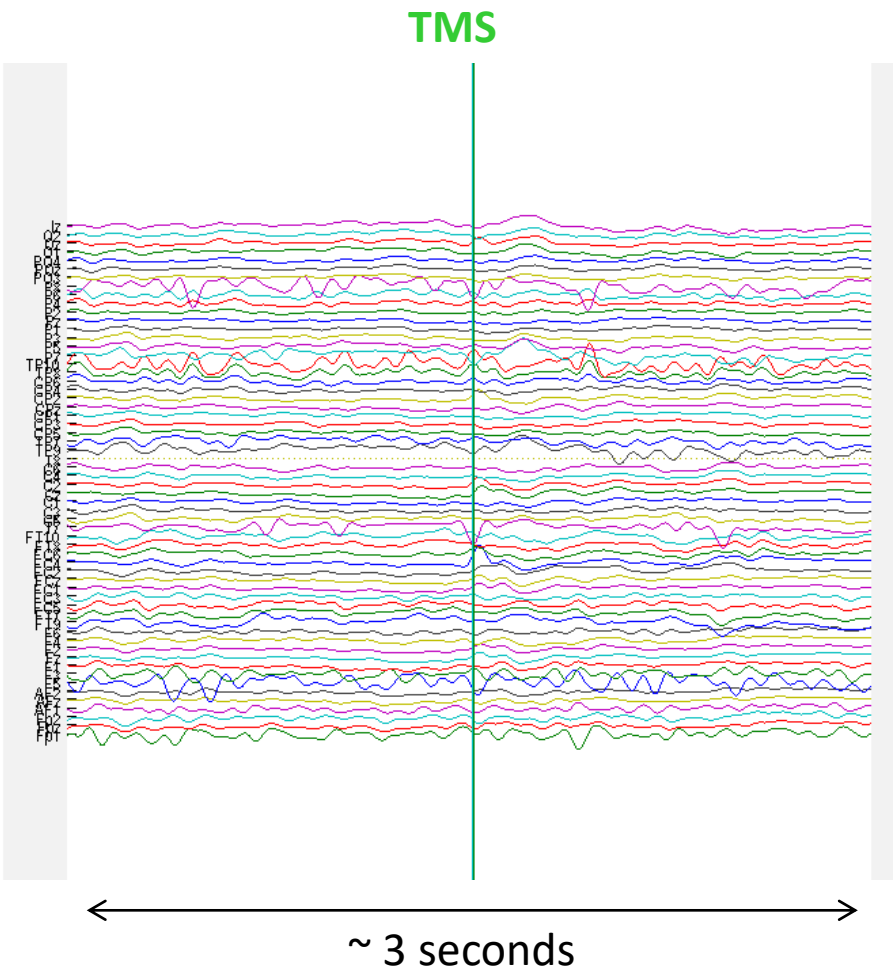
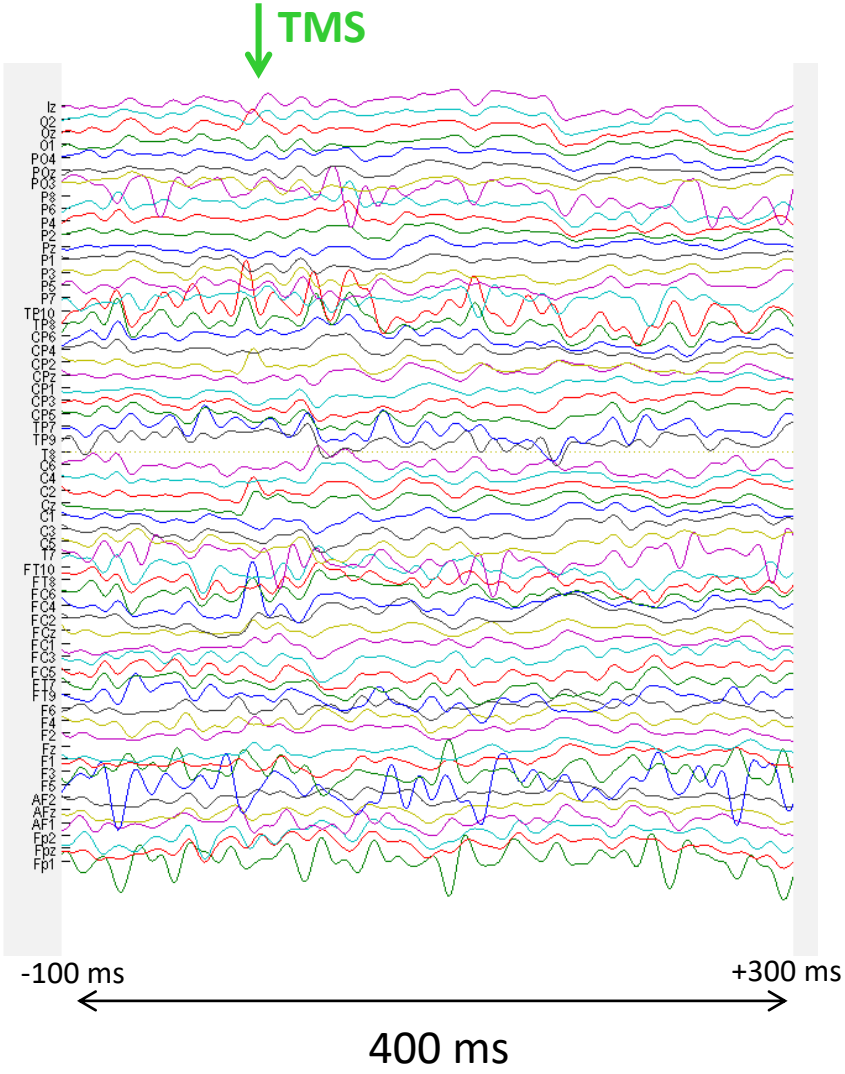
- Signal is high-pass and low-pass-filtered and downsampled



- Signal is epoched (cut around TMS pulse; -100ms > 300ms post-TMS)



Processing of EEG data – the different steps

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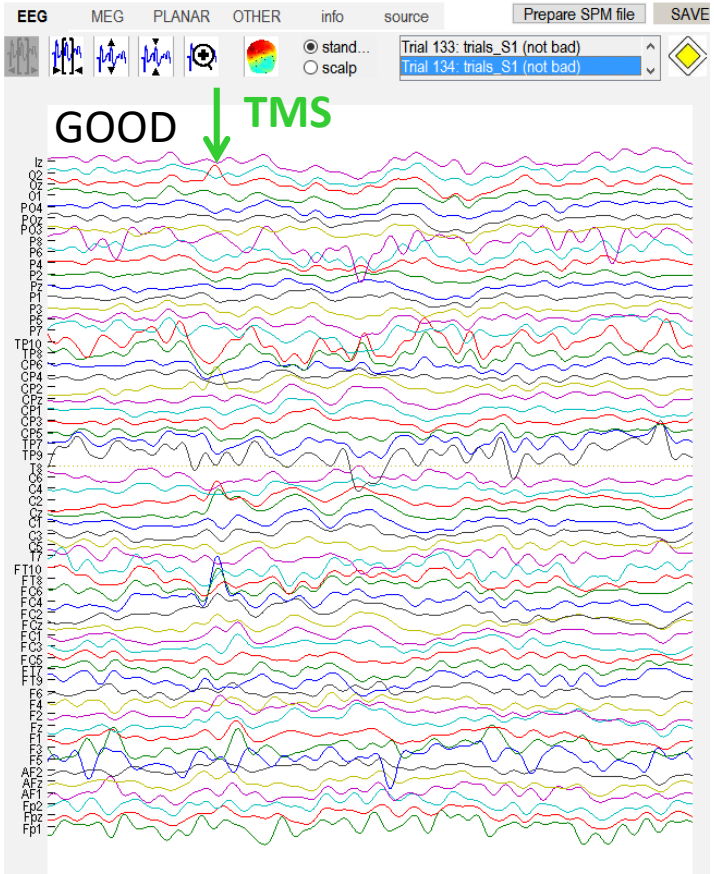
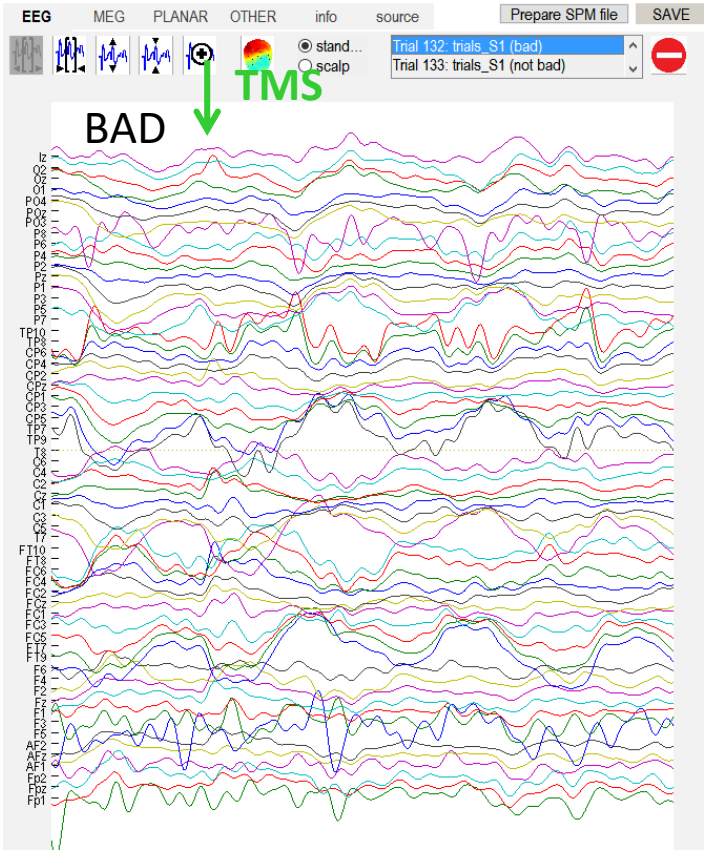
- Good and bad epochs are stamped





Processing of EEG data – the different steps

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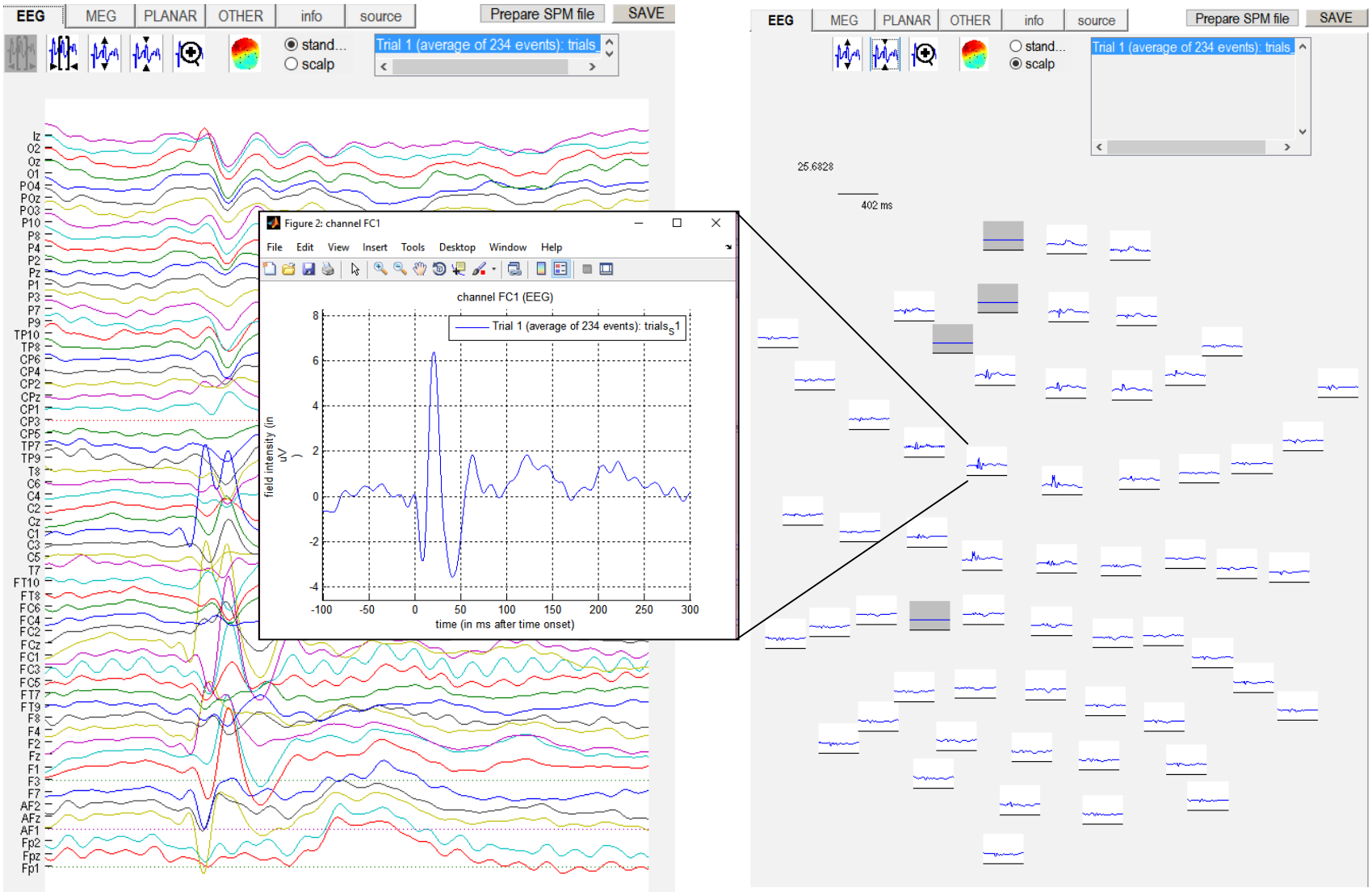
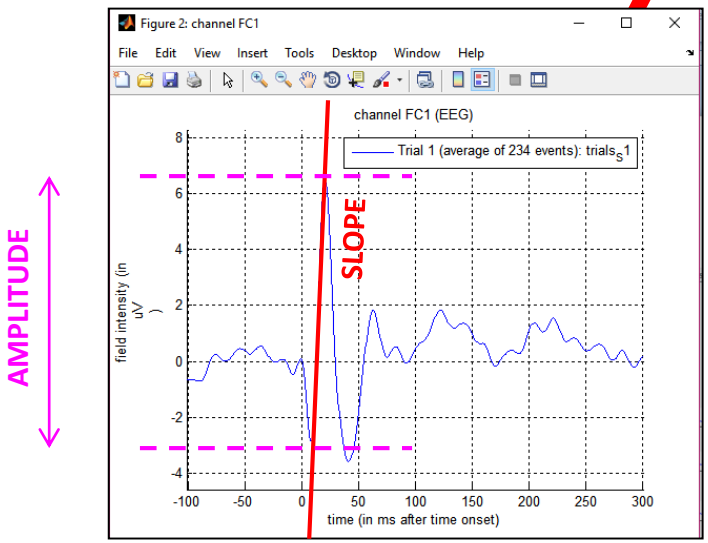
- Signal is averaged over good epochs

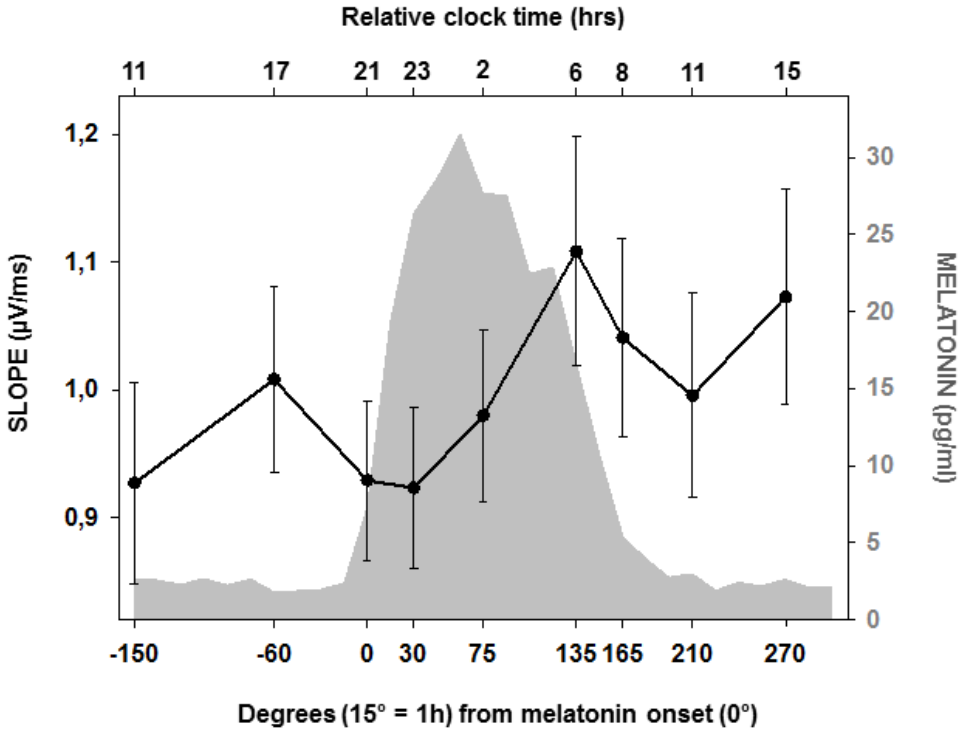


Processing of EEG data – Results

- *N = 26 (healthy)*
- *13 younger (5F; 23 y.o. ± 2.9)*
- *13 older (7F; 63 y.o. ± 3.8)*
- *35h of prolonged wakefulness (9 sessions)*



- ***Average slope of TMS-evoked EEG response (mean ± SD)***



Significant effect of time : **p = .02**

<u>Main results</u>: slope = an index of neuron excitability/reactivity

> neuron excitability varies with time awake in a non linear fashion

Why would that be useful?

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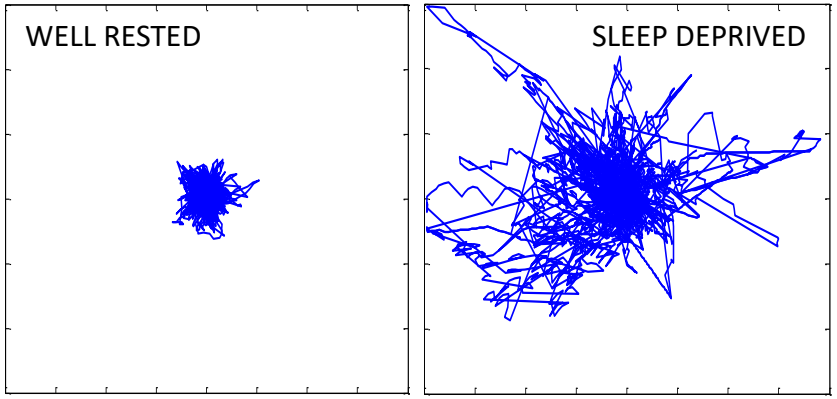
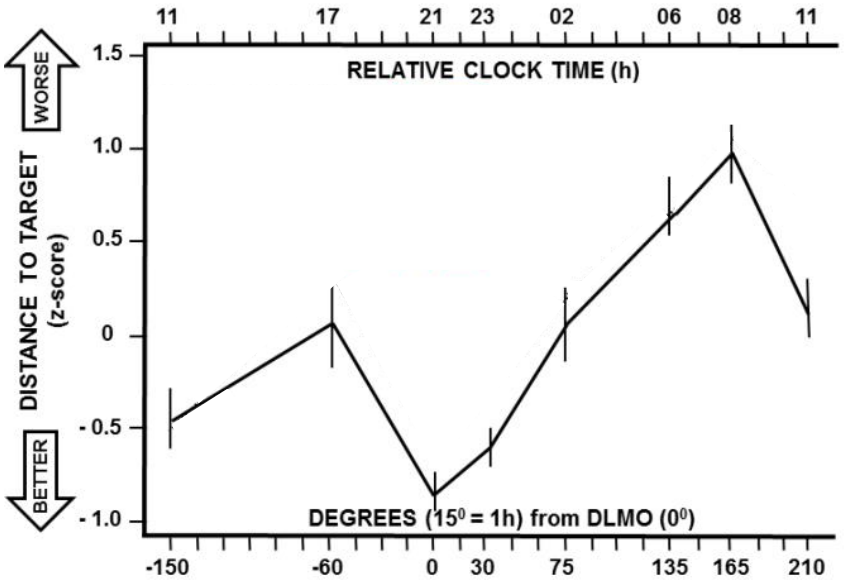
➢ *How does this relate to behavior / cognitive performance ?*

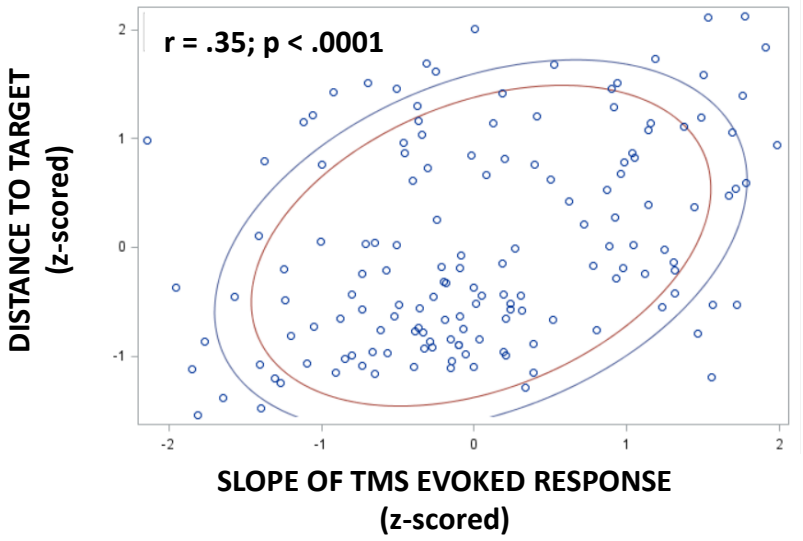
- ***Visio motor vigilance task***



Average over all subjects



PROC MIXED: circadian phase : **p < .0001**



> Excitability is correlated to performance

Ly*, Gaggioni*, Chellappa* et al. 2016 *Nat Comm*

Why would that be useful?

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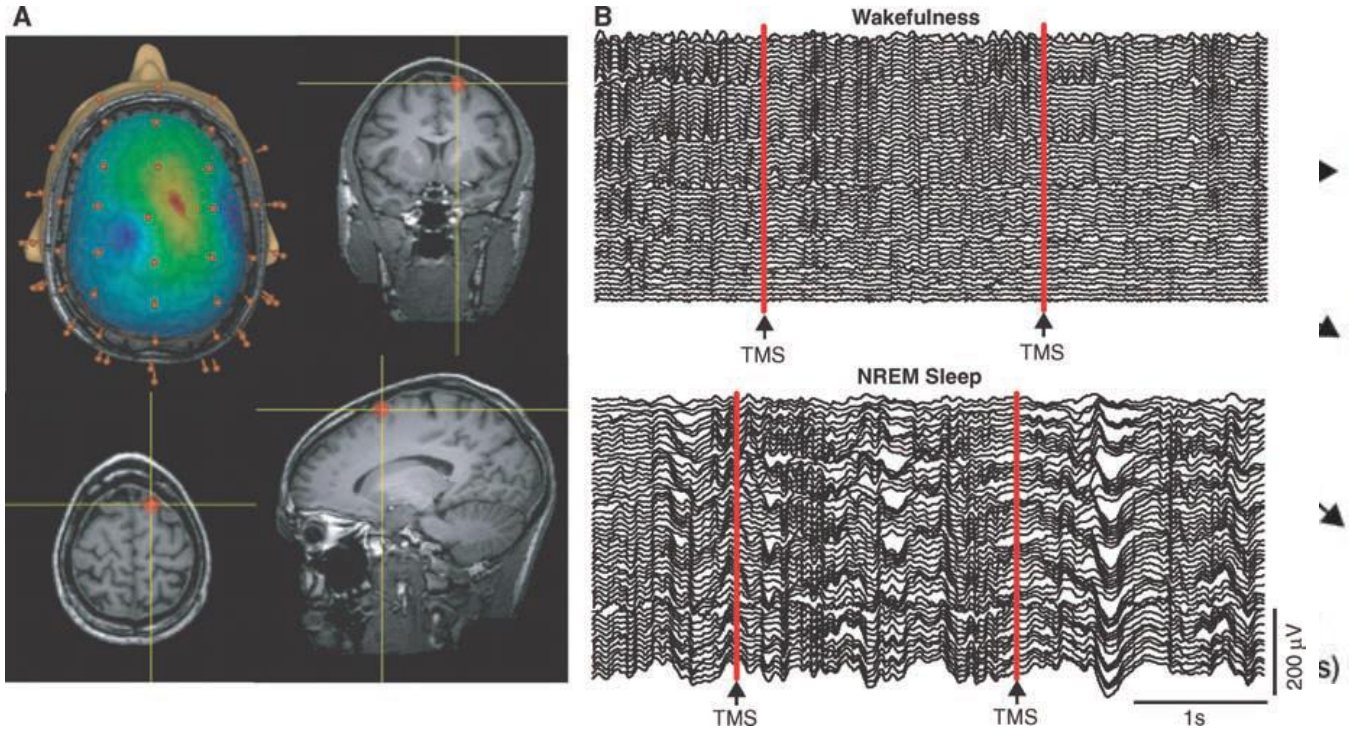
- *Better understanding of basic aspect of brain function (excitability is basic yet essential)*
- *Better understading of sleep/wake regulation*
- *Implications for neurostimulation/neurorehabilitation*

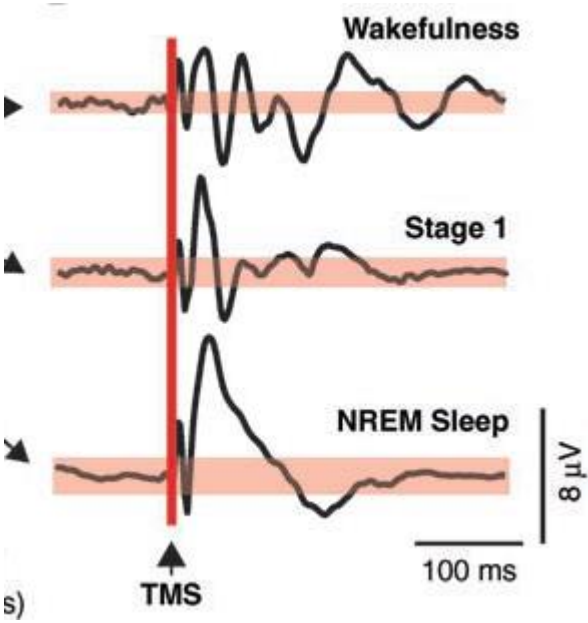
+ It is a non-invasive way to address these issues

A century ago we may have done thing otherwise….

TMS-EEG applied during sleep

TMS perturbation propagates less during sleep (even though brain structure has not changed!)





Breakdown of the dialogue (connectivity) between brain regions during sleep
>> Connectivity between regions is required for consciousness

Massimini et al. 2005

Processing of EEG data – Can we go further??

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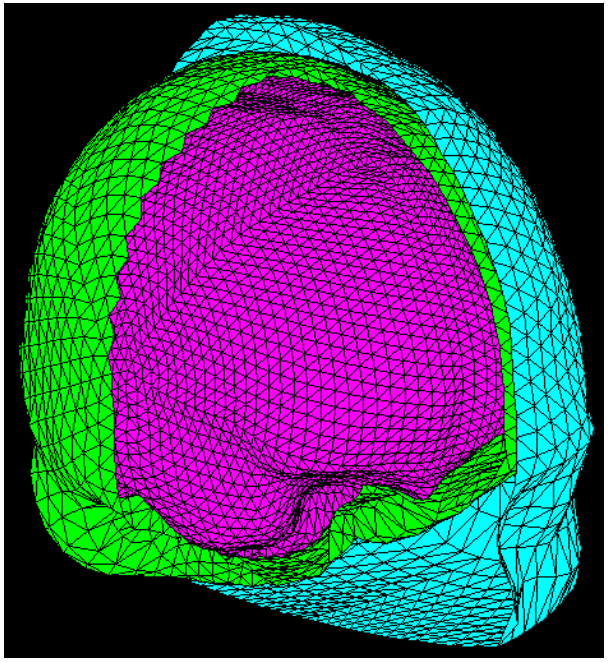
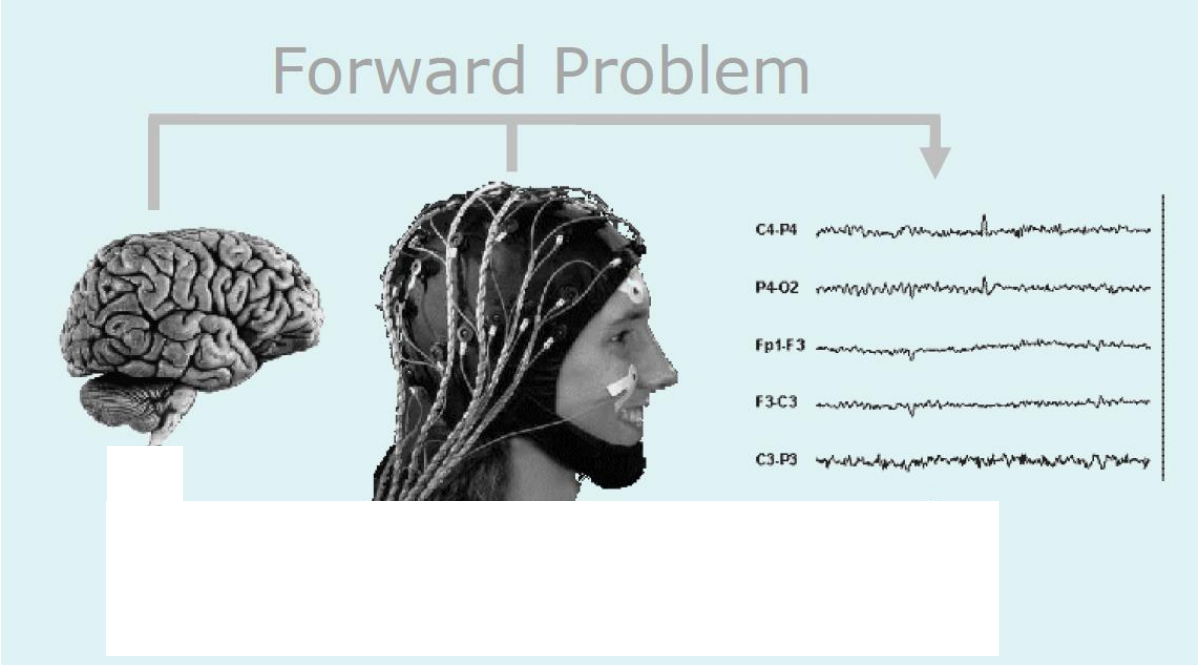
EEG source reconstruction

> based on what we know about the brain (neuroanatomy, fMRI, etc.), one can **estimate** where the signal originates from in the brain
(estimates = provide a *likely* source; the best solution which may not be reality)

Surface medialization
Dipoles on cortex surface
(from 10,000 to 40,000 dipoles)



Forward problem: how would these dipole detected on the EEG



EEG source reconstruction

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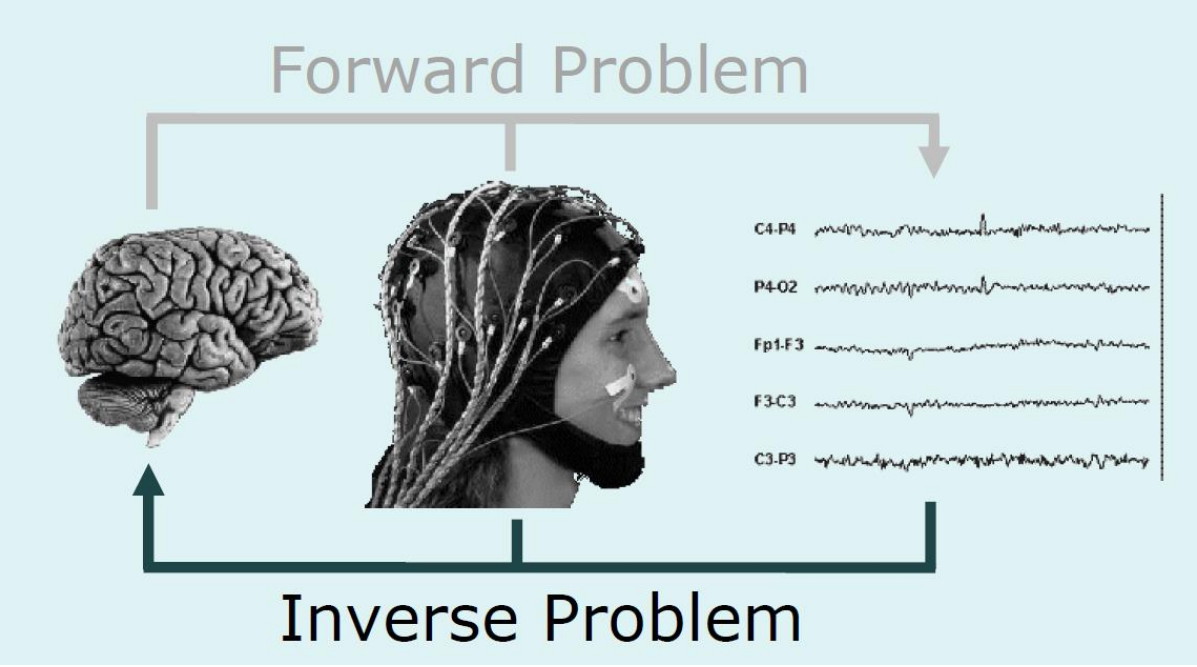
Inverse problem: knowing the forward solution, where should the EEG measured come from?



You have the shadow, what is the most probable combination of hand positions that may explain it?

EEG source reconstruction

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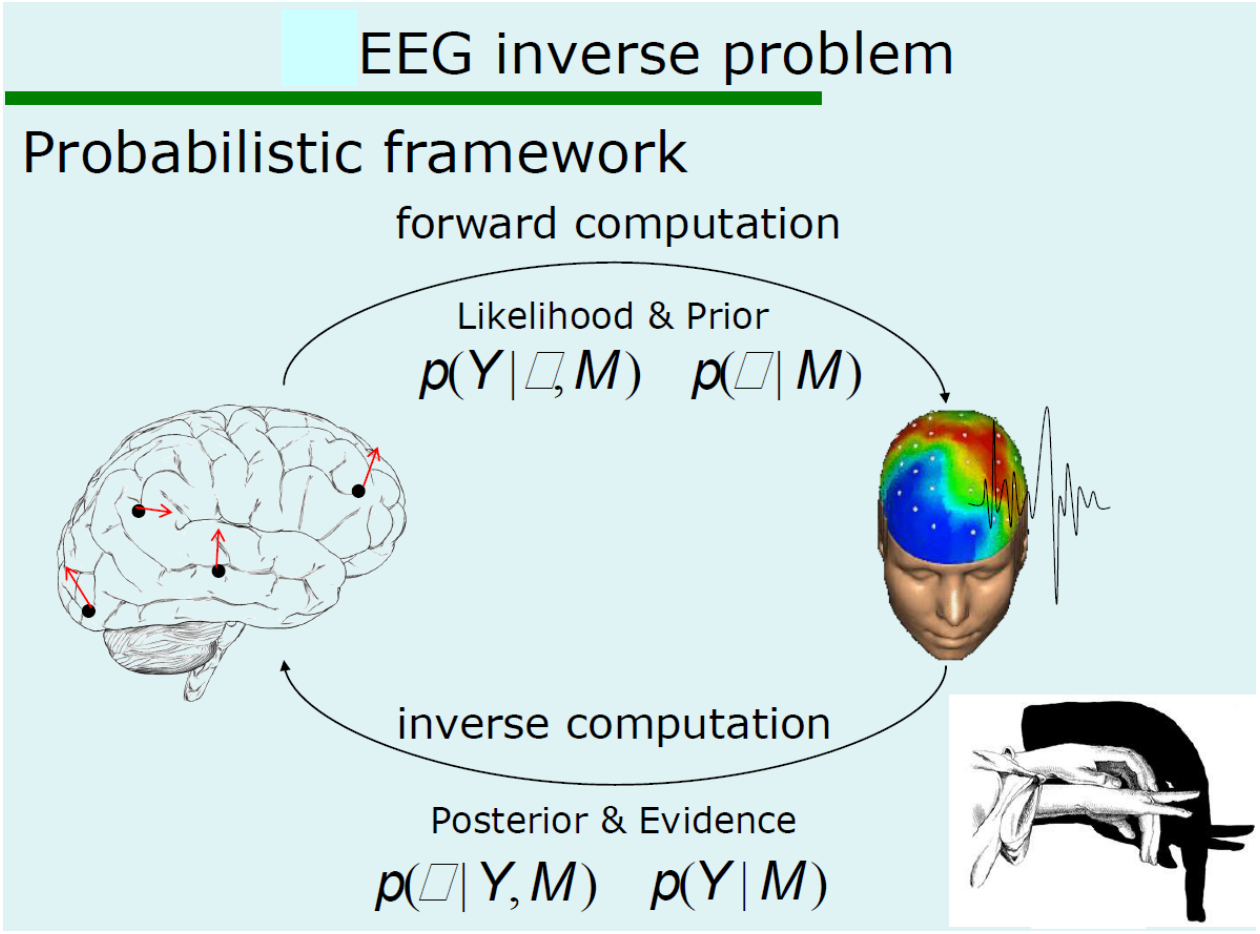
Use of differential equations and probabilistic statistics to get the most likely solution
Compuationaly demanding (e.g. 1h per subject, per session)



Lots of developments remain to be done: e.g. use of MRI brain structure, more realistic head models, etc…

EEG source reconstruction

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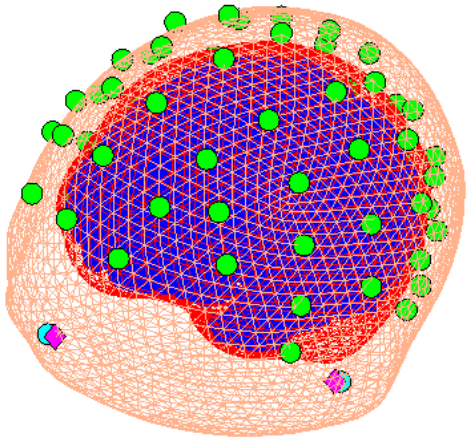
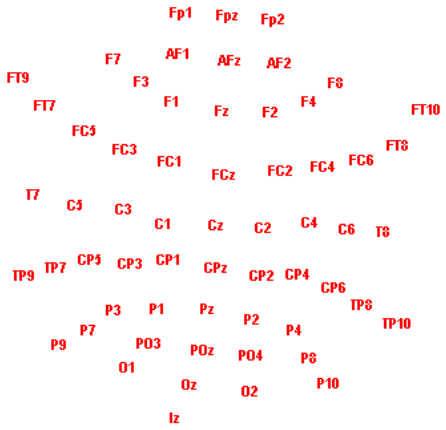
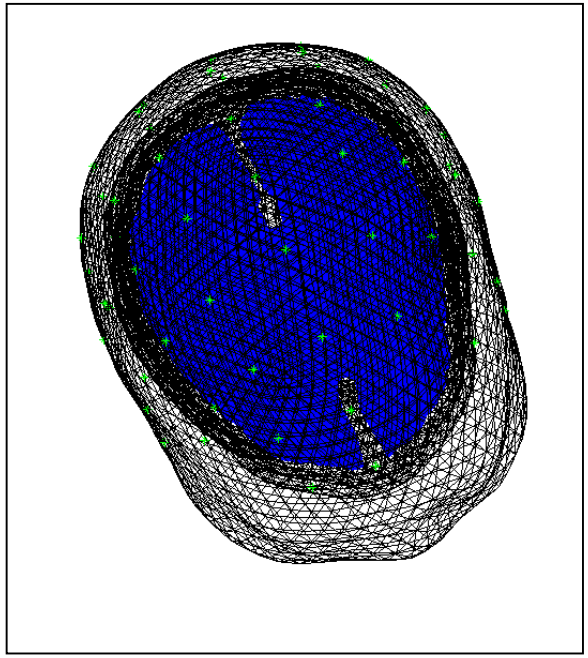
3D position of electrodes

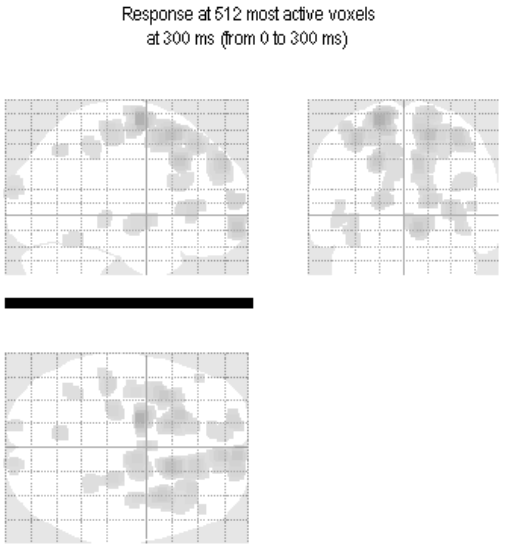


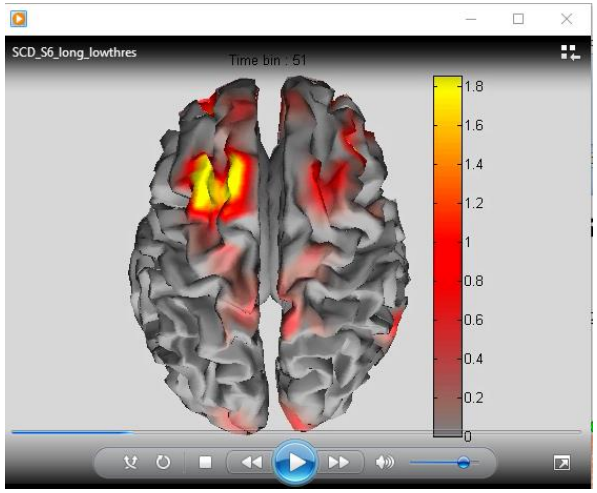


3D mesh of the brain with electrode
~ 10,000 dipoles



Solution of the EEG source reconstruction





Processing of EEG data – Can we go further??

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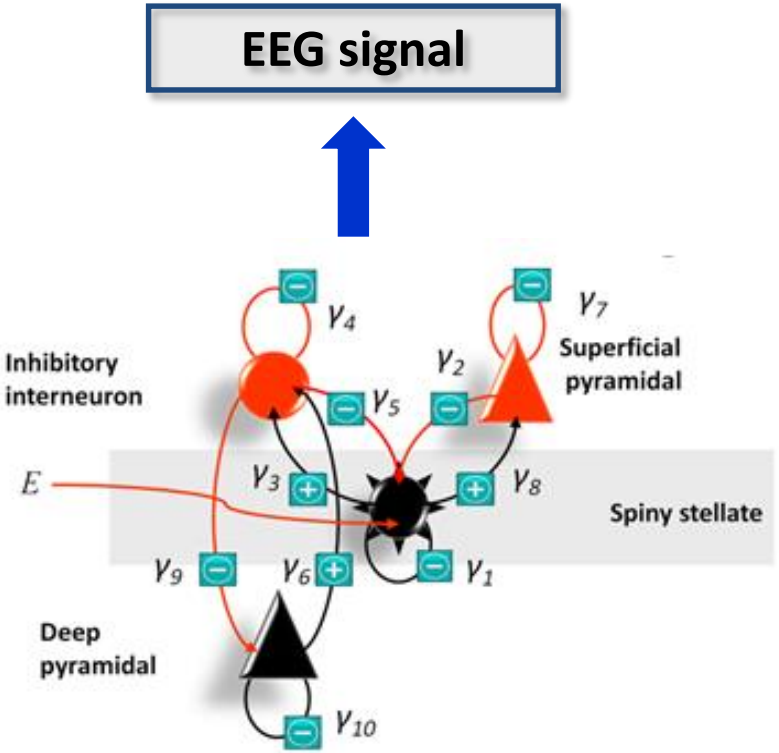
Neural Mass Models (NMM)

- Describes physiologically meaningful neuronal states within a cortical column based on EEG source reconstruction
- "Mathematical microscope" of the brain (other finer models exist)



Moran et al., 2011