



Central European Institute of Technology  
BRNO | CZECH REPUBLIC

# Simultaneous EEG-fMRI Basics

**Radek Mareček**

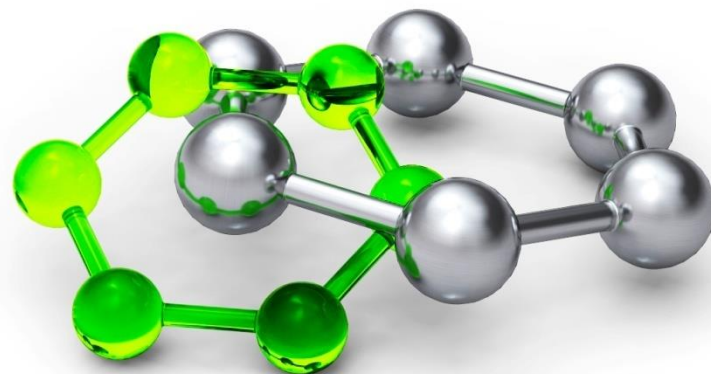
**Brno, November 15<sup>th</sup> 2016**



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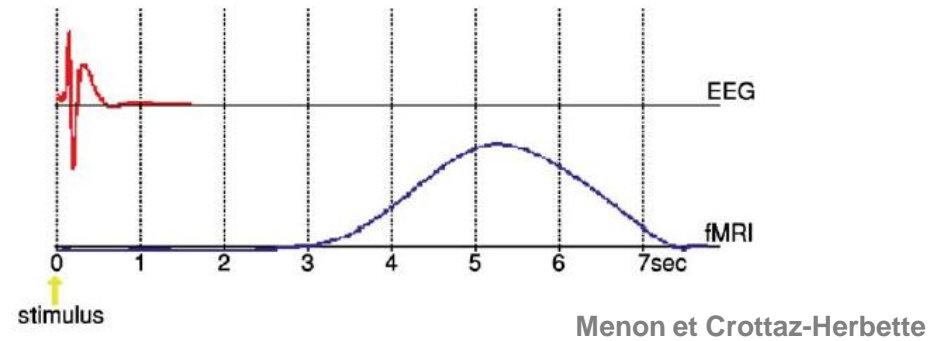
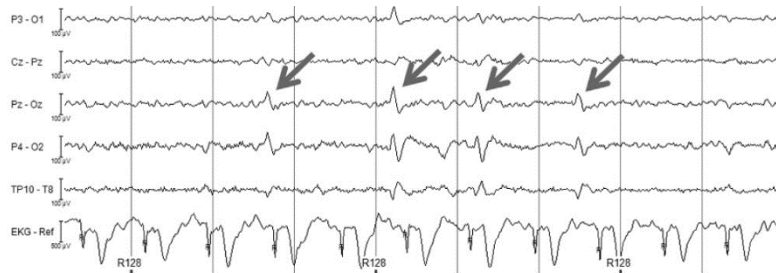
# MOTIVATION

- simultaneous observation of the brain with two independent modalities
- benefit from the combination of favorable features of both modalities (EEG – ms resolution in time domain; fMRI – mm resolution in space)
- a phenomenon is better recognized with one of the modalities, nevertheless observer is interested in information, which is contained in the other modality
- technical problems **X** potential benefit

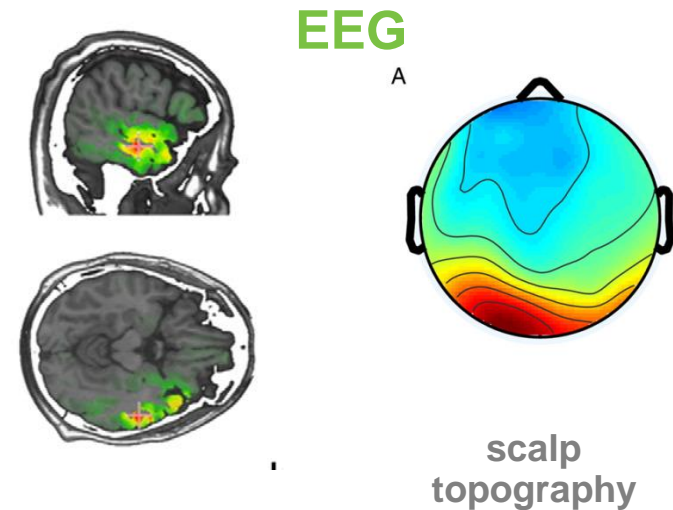
# MOTIVATION

## EPILEPSY

- looking for epileptogenic focus



fMRI



Electrical  
source imaging

De Martino et al., 2010

Vulliemoz et al., 2009

# OUTLINE

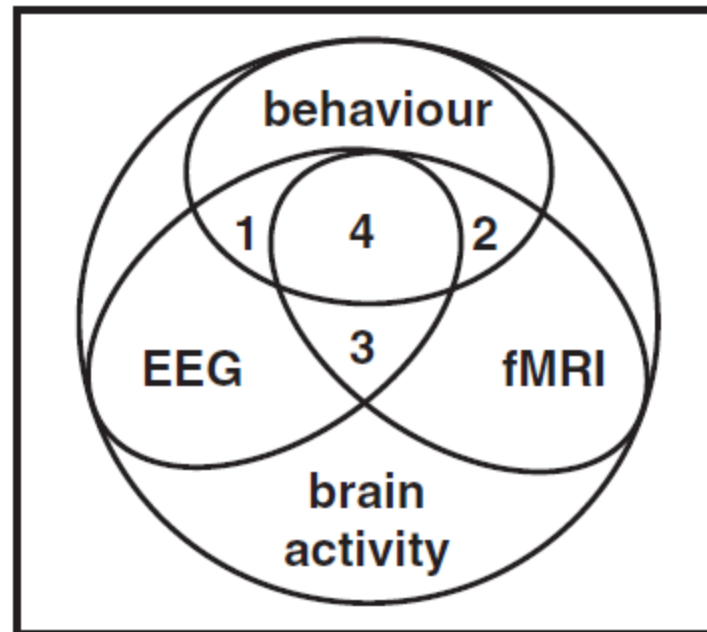
Motivation

Physiology

Strategies for data analyses

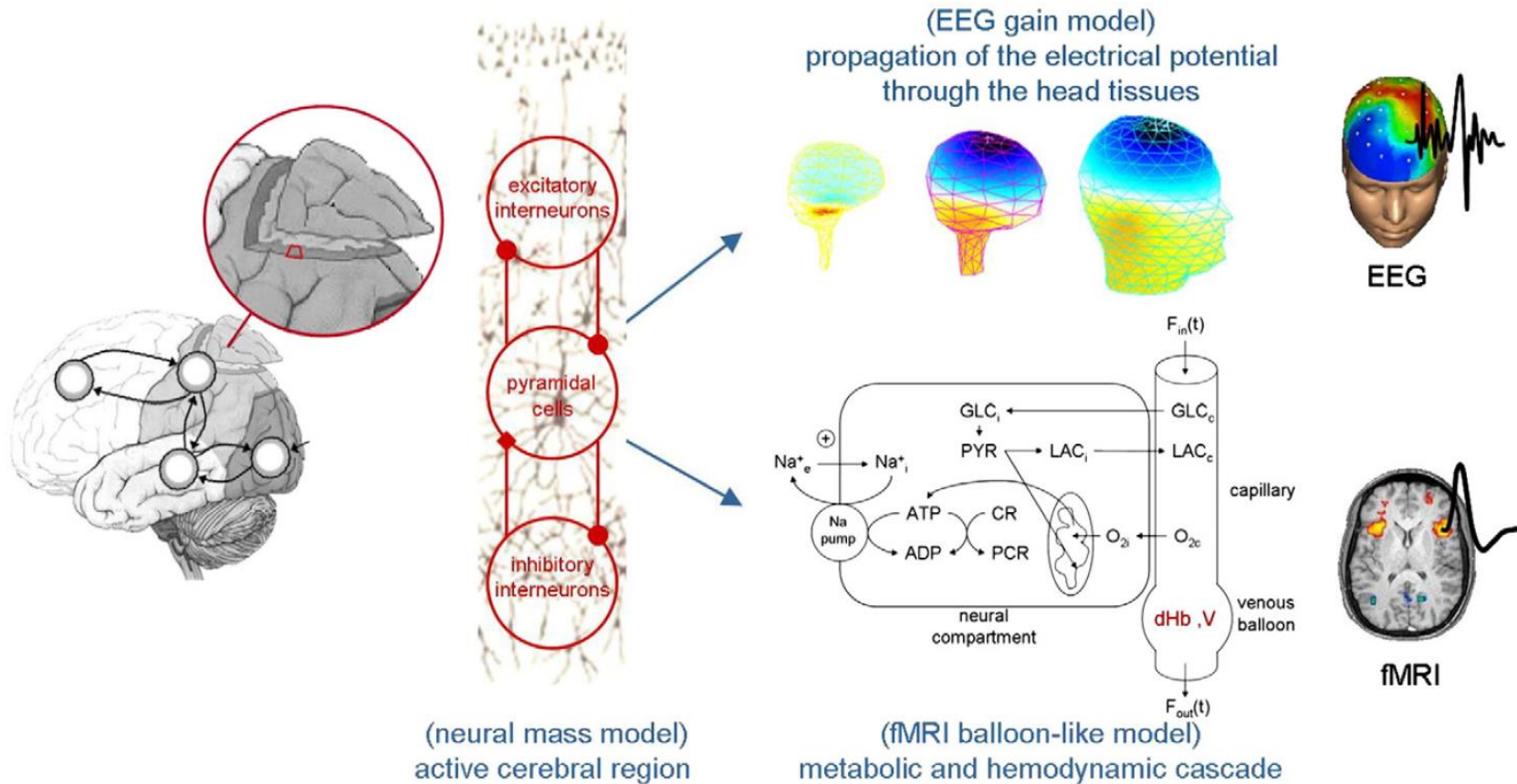
Technical issues

# PHYSIOLOGY

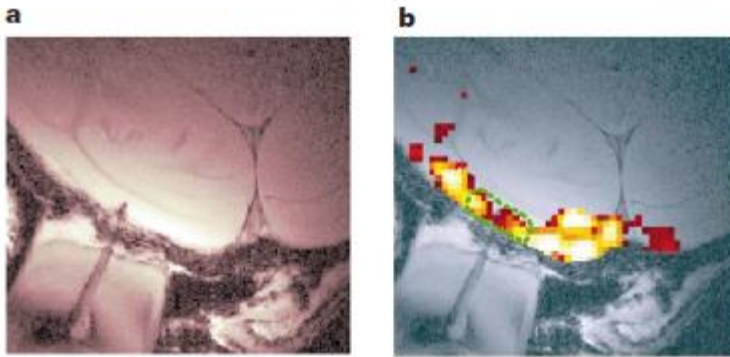


Helmut Laufs, 2012

# PHYSIOLOGY

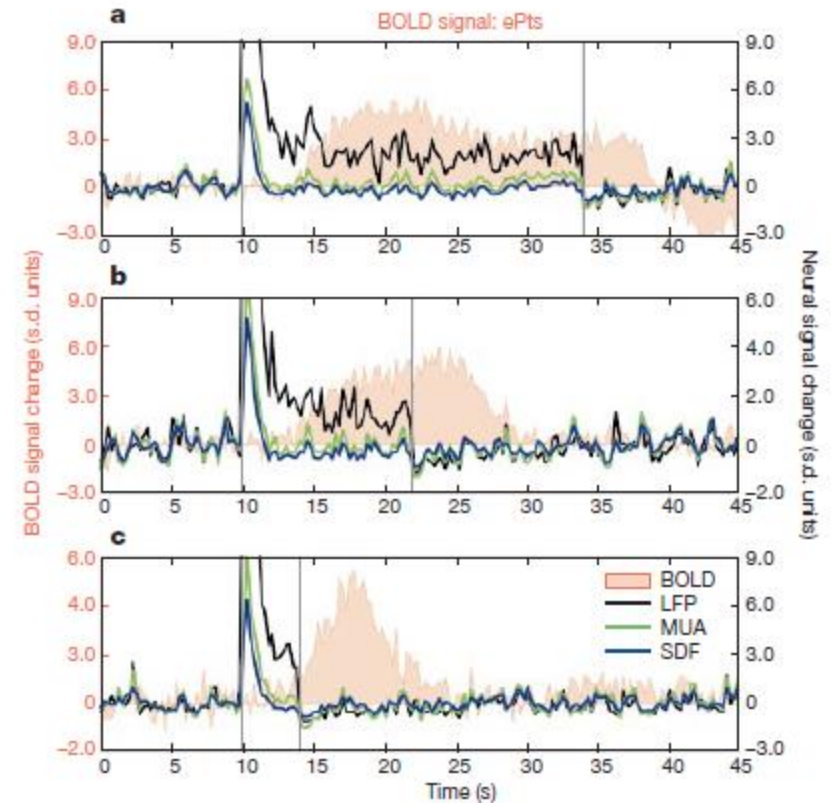


# PHYSIOLOGY



## Logothetis et al. 2001

- study with monkeys
- simultaneous depth electrode EEG recording and fMRI
- the BOLD corresponds most closely to local field potential fluctuations (frequency range up to ~100Hz)



**Figure 3** Simultaneous neural and haemodynamic recordings from a cortical site showing transient neural response. **a–c**, Responses to a pulse stimulus of 24, 12 and 4 s. Both single- and multi-unit responses adapt a couple of seconds after stimulus onset, with LFP remaining the only signal correlated with the BOLD response. SDF, spike-density function (see text); ePts, electrode ROI—positive time series.



## Goense et Logothetis 2008

- study with monkeys
- simultaneous depth electrode EEG recording and fMRI
- the BOLD corresponds most closely to local field potential fluctuations in the range between 20 and 60 Hz

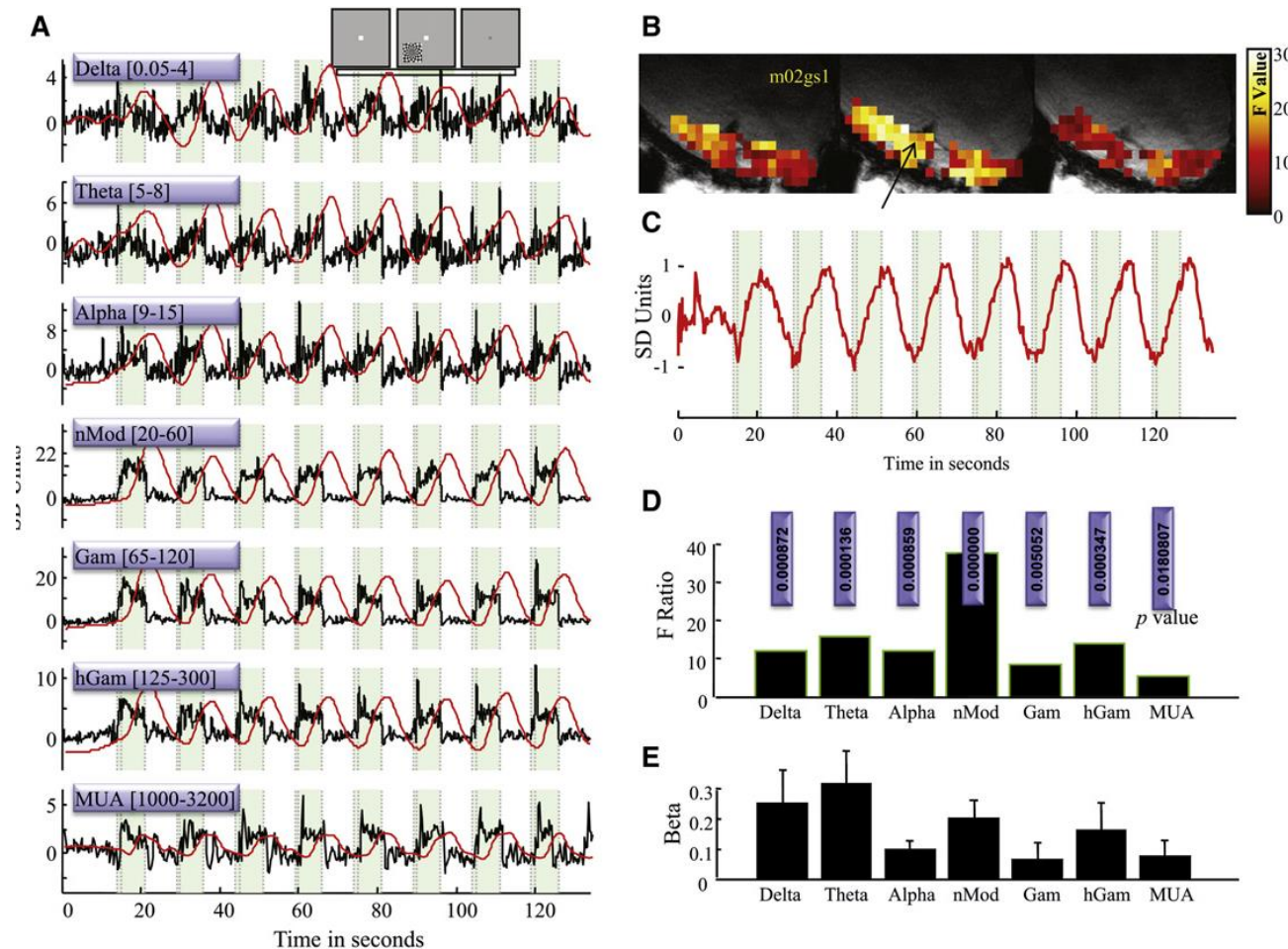


Figure 1. Example Session Showing Data Analysis Procedure and Dependencies between BOLD and Neural Signals in V1 (A) Band-separated neural signals (black) in response to a 6 visual stimulus (see inset) with the regressors for each band superimposed (red). Green shading indicates the times the stimulus was presented. The response to the stimulus is especially pronounced in the neuromodulatory and gamma bands. (B) Functional activation map superimposed on GE-anatomical images. The location of the electrode is indicated by the arrow. (C) The BOLD time course acquired at a temporal resolution of 250 ms shows obvious modulation to the stimulus. The output of the GLM analysis and F-test for this session yielded significant p values for all bands (D), indicating that all bands contributed significantly to the BOLD response. (E) Beta values lacked dramatic differences across bands. Error bars represent SEM.



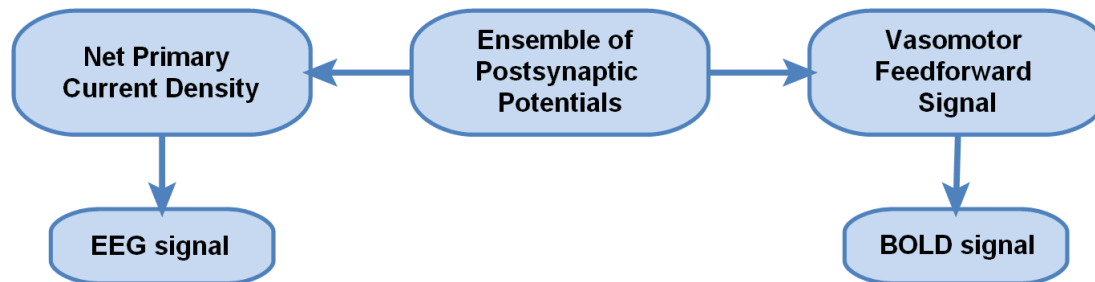
# PHYSIOLOGY

## Magri et al. 2012

- study with monkeys
- simultaneous depth electrode EEG recording and fMRI
- the most informative about **BOLD** signal is the power fluctuations in **gamma band** (40-100Hz)
- the relationship between **alpha** and gamma is informative about **amplitude of BOLD**
- the relationship between **beta** and gamma is informative **about latency of BOLD response** to gamma fluctuations

# PHYSIOLOGY

- both modalities capture neuronal activity in an indirect way
- the primary physiological parameter which gives rise both signals is a fluctuation in postsynaptic potentials
- the BOLD corresponds directly to rather high EEG frequencies (beta, gamma, high gamma)



Valdes-Sosa et al., 2009

# DATA ANALYSIS STRATEGIES

## ASYMMETRIC X SYMMETRIC

- information drawn from any modality used to process data acquired by the other modality
- e.g. spike-informed GLM, BOLD activation spatial constrain for EEG sources
- simultaneous processing of data from both modalities in single model
- typically, models estimated in iterative mode

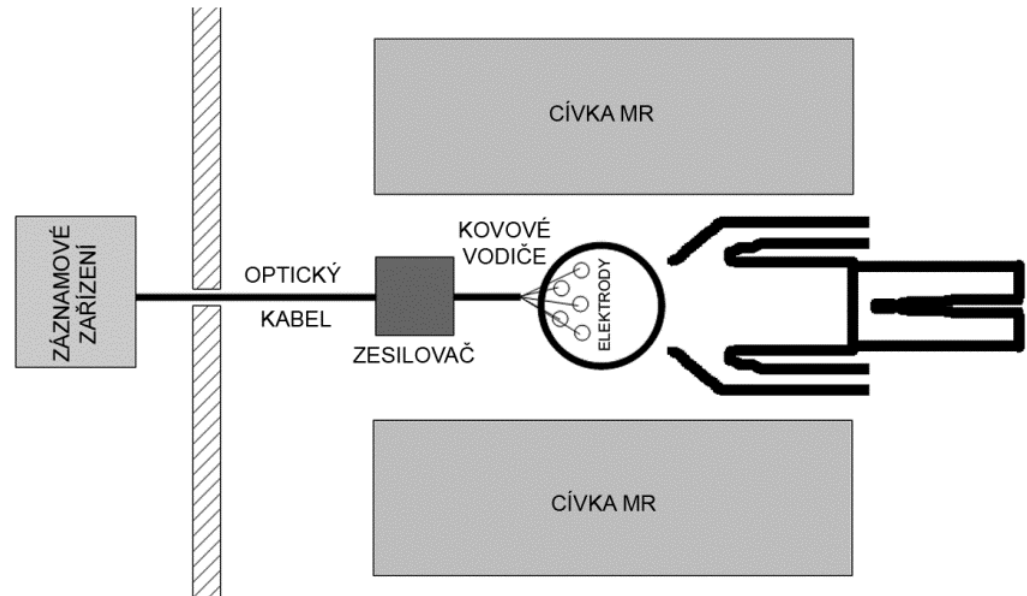
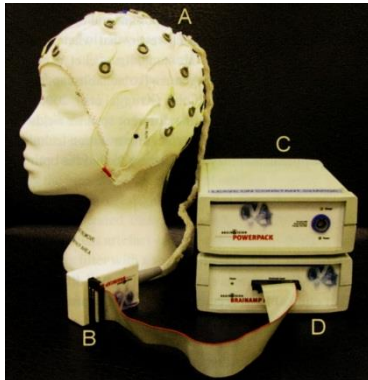
## MODEL DRIVEN X DATA DRIVEN

- examination of a system response to external stimulation
- examination of latent variables hidden in acquired

# TECHNICAL ISSUES

## MR compatible EEG system

- MR compatible cap
- MR compatible EEG amplifier
- optical connection between amplifier and data recorder
- data recorder



Mareček et al., 2011

# TECHNICAL ISSUES

## MR compatible EEG system

- 30 to 256 channels
- ECG, EOG, other polygraphic signals
- sampling frequency in kHz (typically 1-5 kHz)
- precise synchronization between EEG sampling and timing of MR acquisition
- head fixation
- fixation of cables within gantry

# ARTIFACTS IN EGG

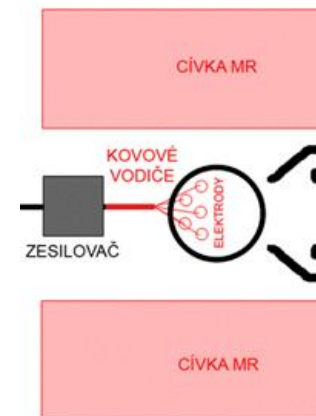
## Artifacts induced by MR environment

- gradient
- cardiobalistogram
- cooling liquid pump
- movement

interaction between changing magnetic field and metallic parts of the EEG system

## Common artifacts

- muscles
- eye movements
- fluctuations of electrode impedance





# Thank you for your attention



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