



Central European Institute of Technology
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Principles of fMRI

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Educational course: NeuroImaging - Mapping the function
and structure of brain

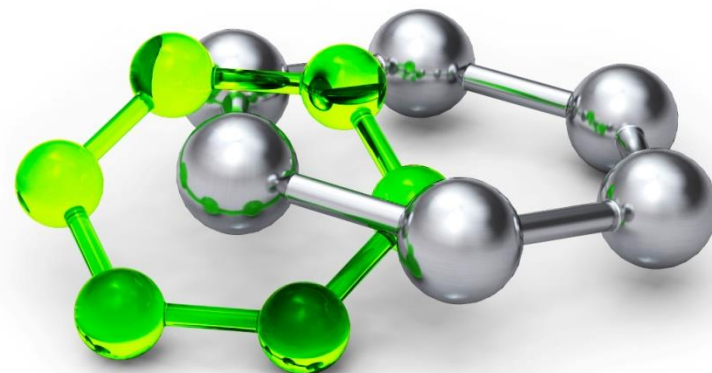
Brno, 14.-16.11.2016



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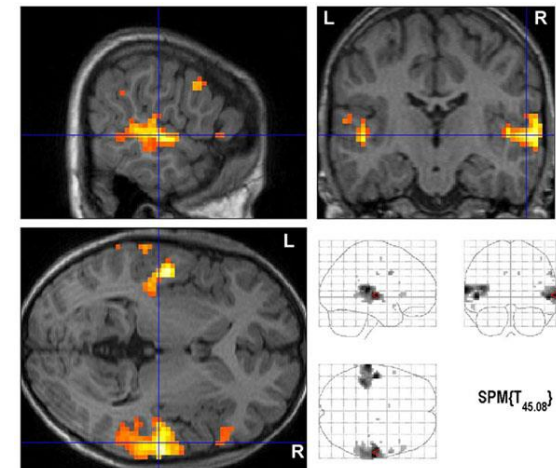
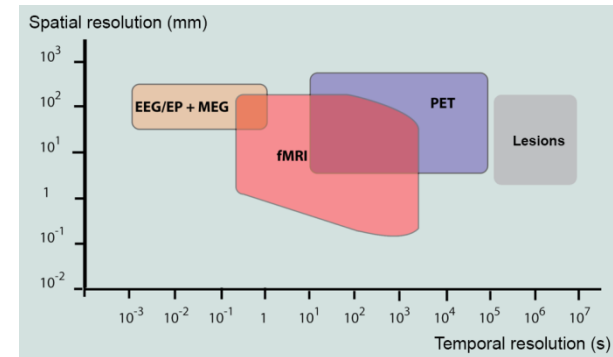


OP Research and
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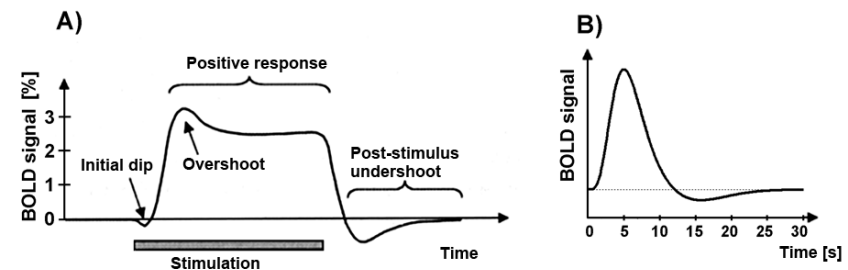
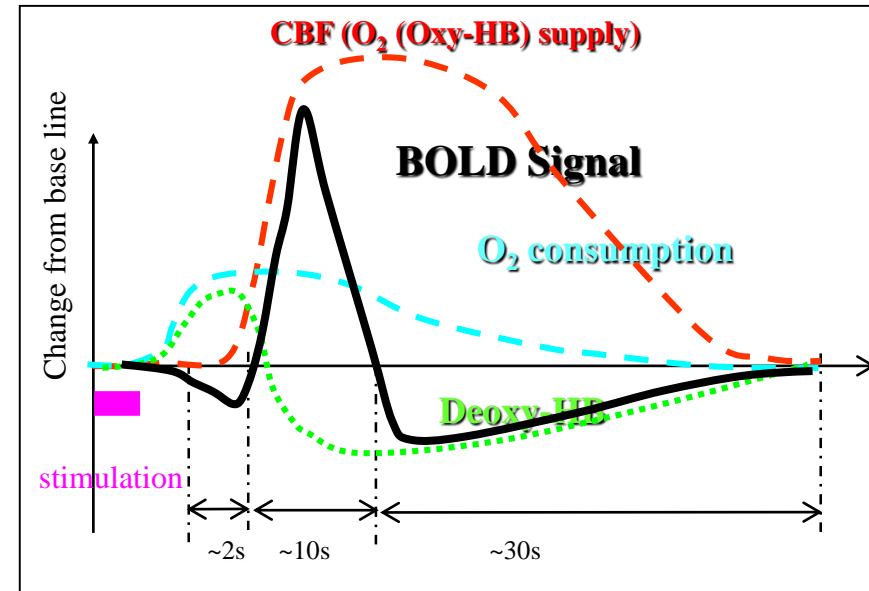
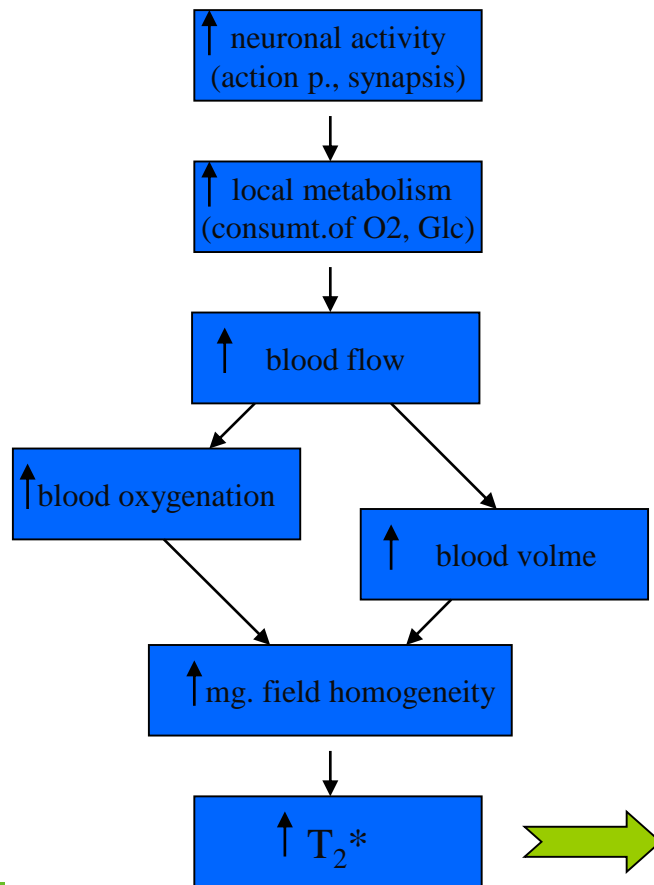
What is fMRI?

- fMRI = functional magnetic resonance imaging
- fMRI use human (clinical) MRI scanners
- **BOLD fMRI** or perfusion fMRI (e.g. ASL)
- fMRI is used mainly for neuroscience research, partially also for clinical application (e.g. pre-surgical mapping)
- fMRI enables to localize functional brain regions and to analyze relationships / dependencies between these regions (functional or effective connectivity)



BOLD effect (signal, contrast)

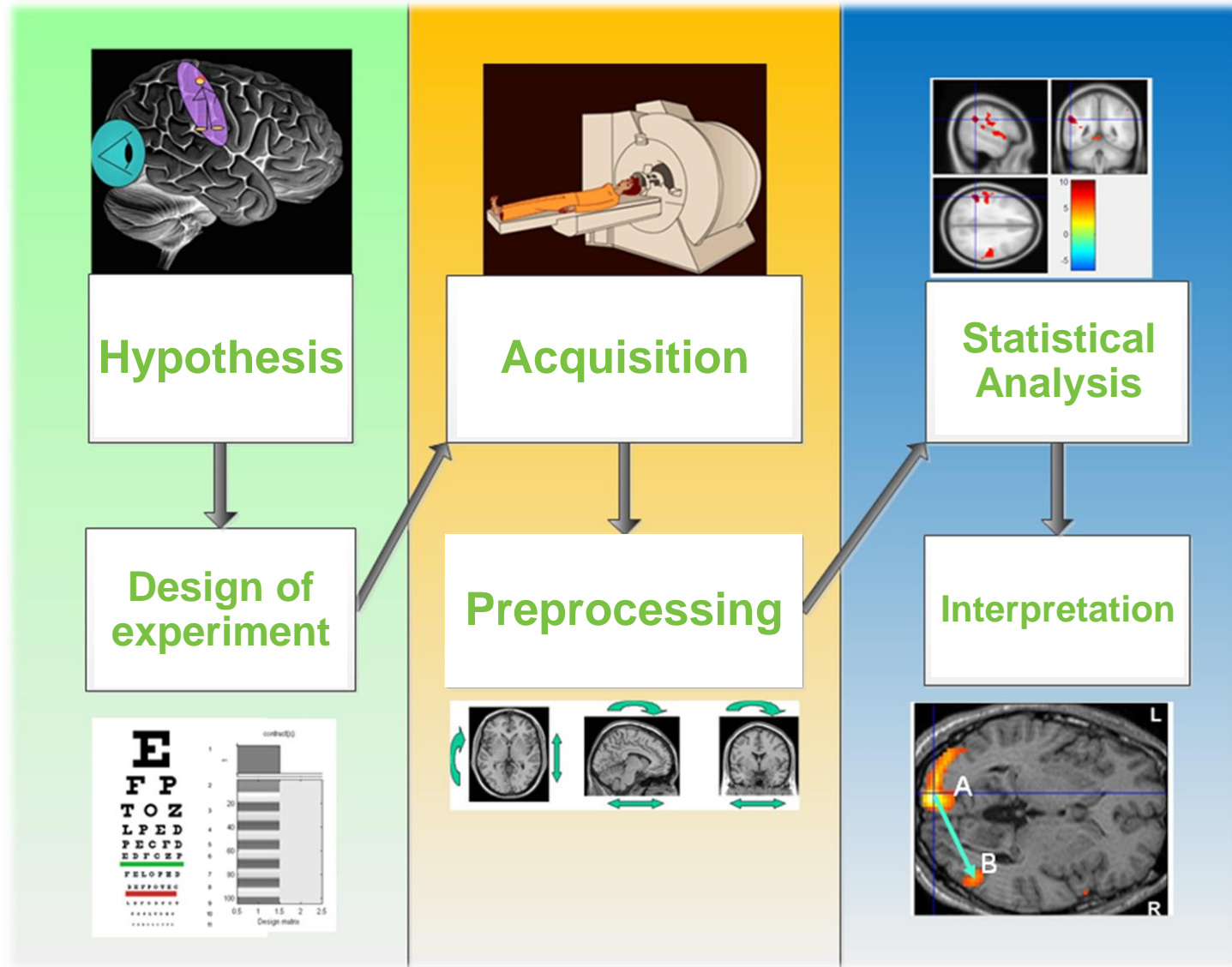
BOLD = blood oxygenation level dependent



T₂^{*} weighted images
(e.g.. GE EPI)

- Brain of scanned volunteer is measured repeatedly
 - Selection of acquisition sequence/protocol
- Periods / events with various type of experimental stimulation occurs repeatedly during fMRI measurement
 - Selection / optimization of experimental paradigm
- Measured data (MR images) are transferred, converted and preprocessed for subsequent analysis
 - Preprocessing
- Time series of measured BOLD signal are compared to time-course of experimental stimulation. Statistically significant similarity = activation
 - Statistical analysis
- Results, e.g. activation maps, can be used to localize specific brain functions; to interpret the effect of the task on brain activity
 - Interpretation of results

fMRI pipeline











fMRI experiment

We do not know any specific level of BOLD signal neither under rest nor active condition

➔ **It is necessary to measure BOLD data both for rest (or baseline) condition and for the stimuli of interest**

Percent signal change of BOLD signal is low (about 1-3%)

➔ **It is necessary to acquire many scans and to use statistics for detection of activation**

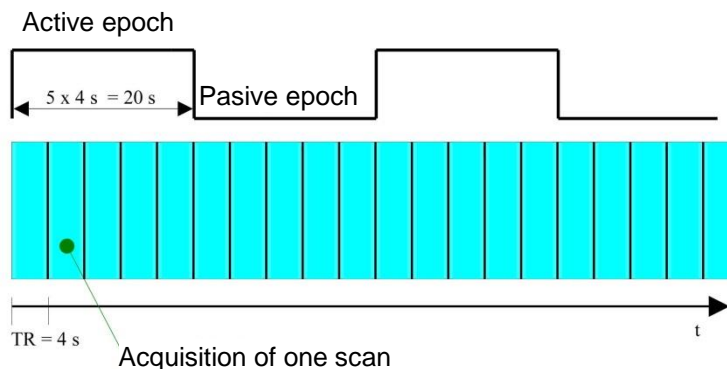
There are low frequency fluctuations and drift of BOLD signal

➔ **It is necessary to alternate experimental conditions**

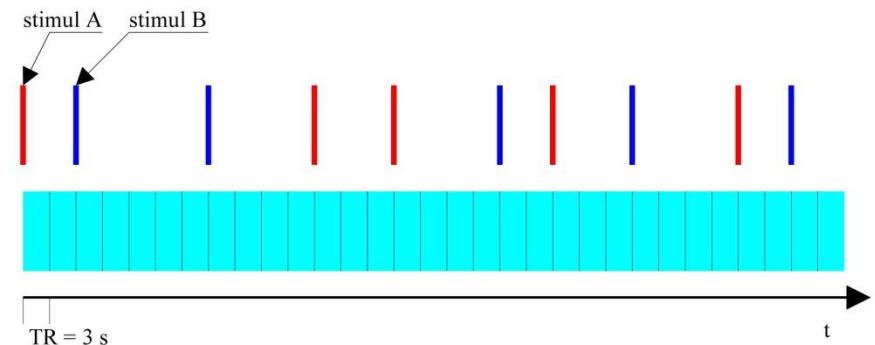
fMRI experiment

- types of experiment

- Block (epoch-related)
 - Continuous series of the same stimuli (e.g. 16 - 60 s)
 - High statistical power of detection
 - We are limited to look at relative changes between different blocks / epochs



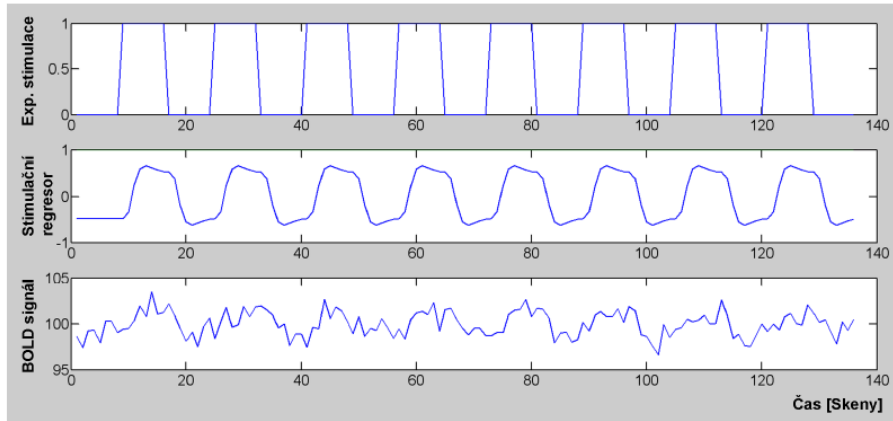
- Event-related
 - Measurement of response to individual stimulus (stimuli are intermixed across the experimental run)
 - Lower statistical power
 - We are able to estimate shape of HRF
 - Longer measurement, more complicated processing of the data



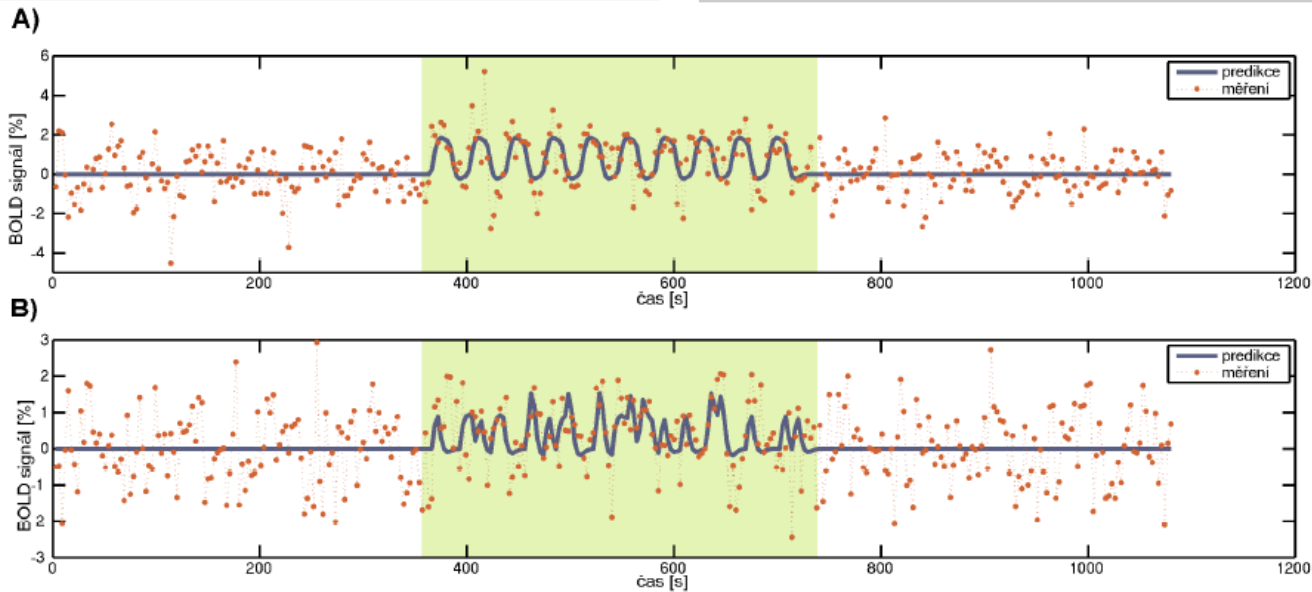
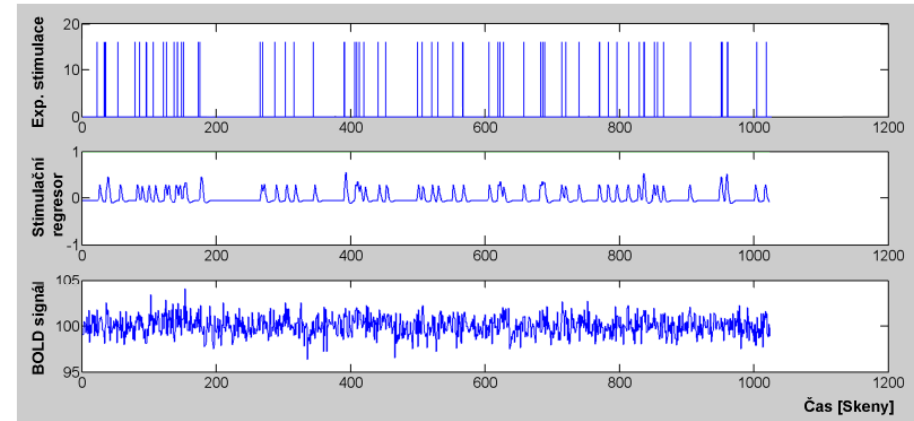
fMRI experiment

- types of experiment

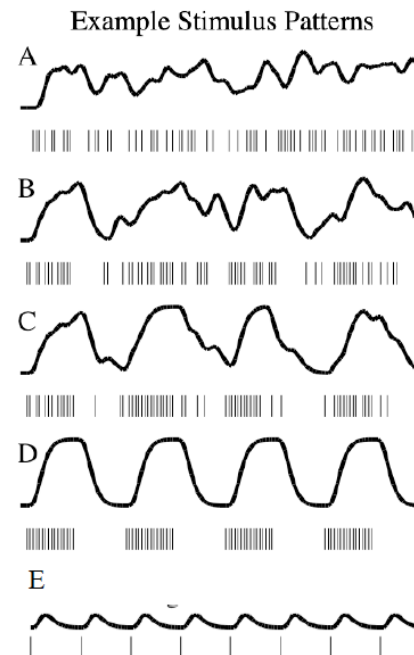
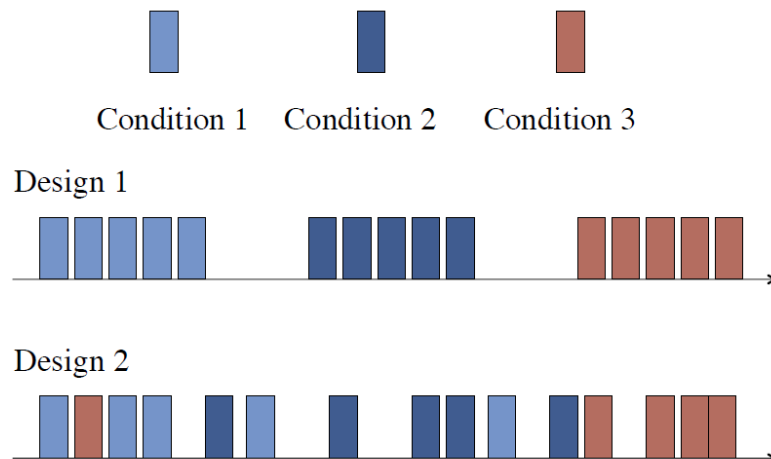
Block



Event-related



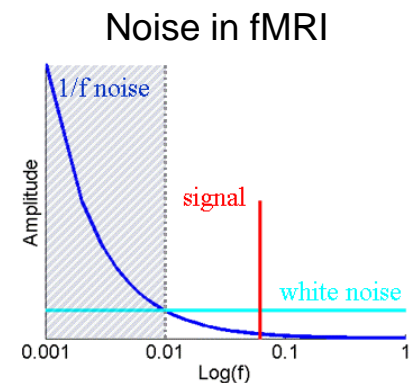
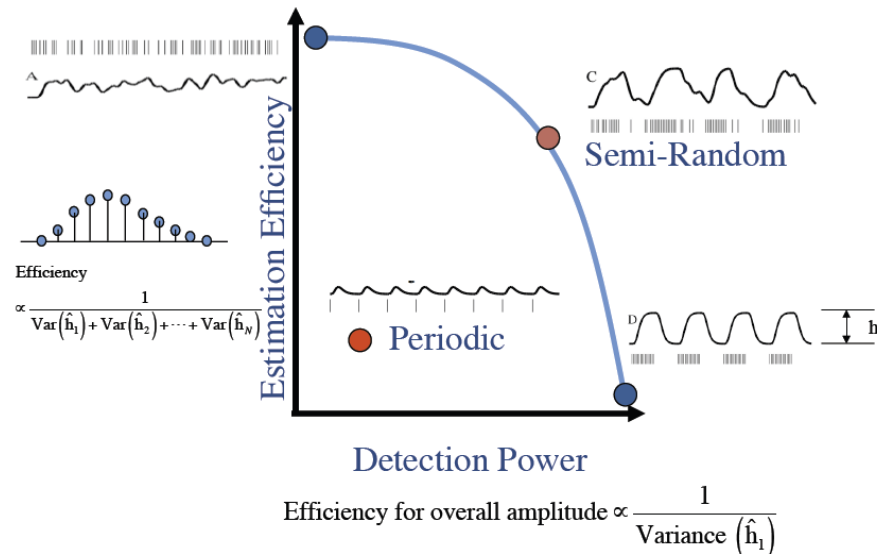
- Considerations
 - fMRI measurements are expensive
 - Subjects can be difficult to find
 - fMRI data are noisy
 - A badly designed experiment is unlikely to yield publishable results



Selection of best desing depends on experimental question

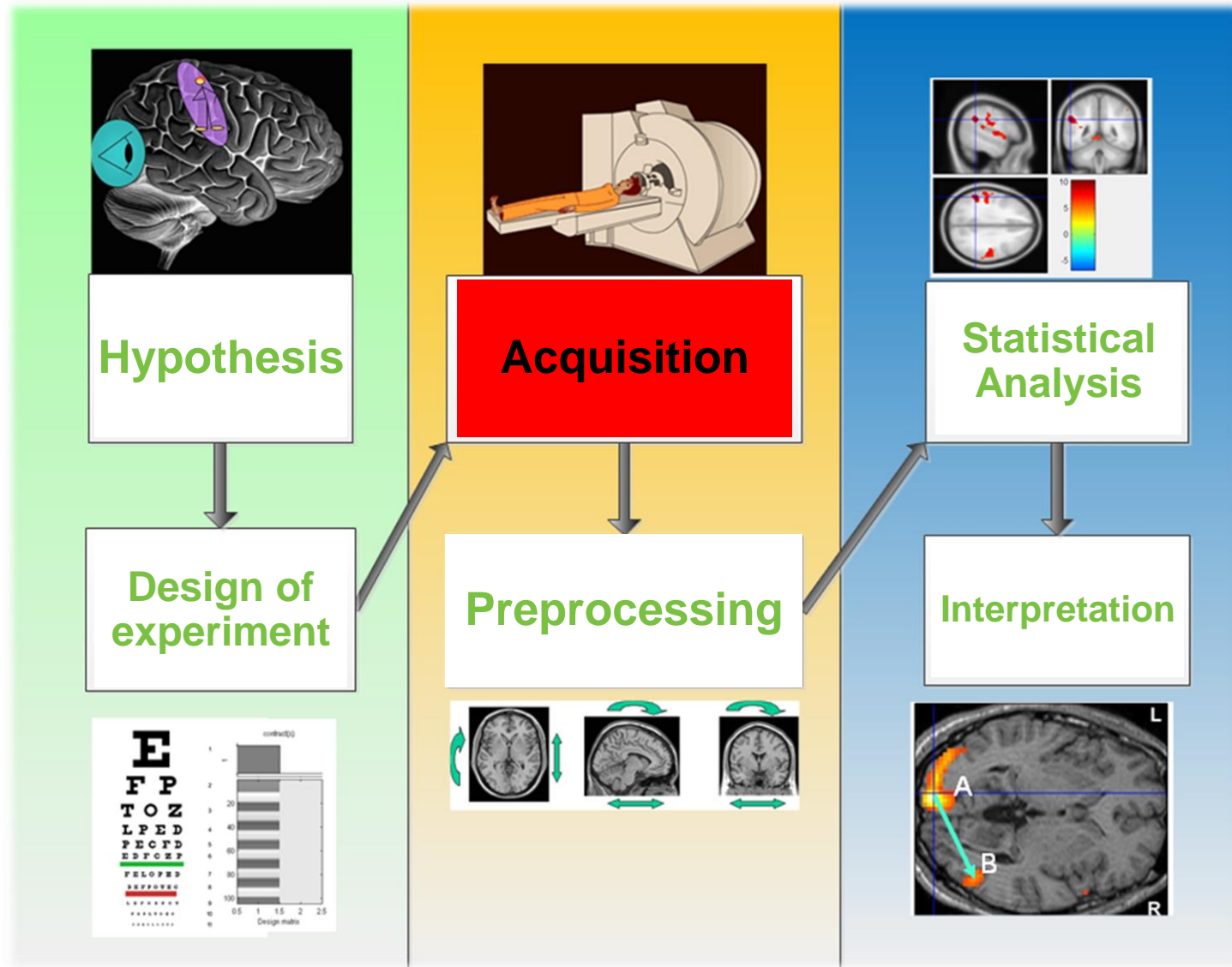
Optimization of fMRI experiments

- Statistical perspective:
 - Detection power or Estimation efficiency
 - maximize contrast of interest vs. noise
- Psychological perspective:
 - Predictability, Entropy, and other psychological factors
 - minimize anticipation, habituation, boredom, ...
- Signal processing perspective:
 - Correlation between regressors, Noise vs task power spectrum



- General hints (*from Rik Henson, <http://imaging.mrc-cbu.cam.ac.uk/imaging/DesignEfficiency>*)
- Measure as long as possible
 - Always consider the ability of participants
 - More scans / time points = increase of statistical power
- More subjects in the study is better than more time points per subject
- Use randomization
- Do not contrast distant conditions

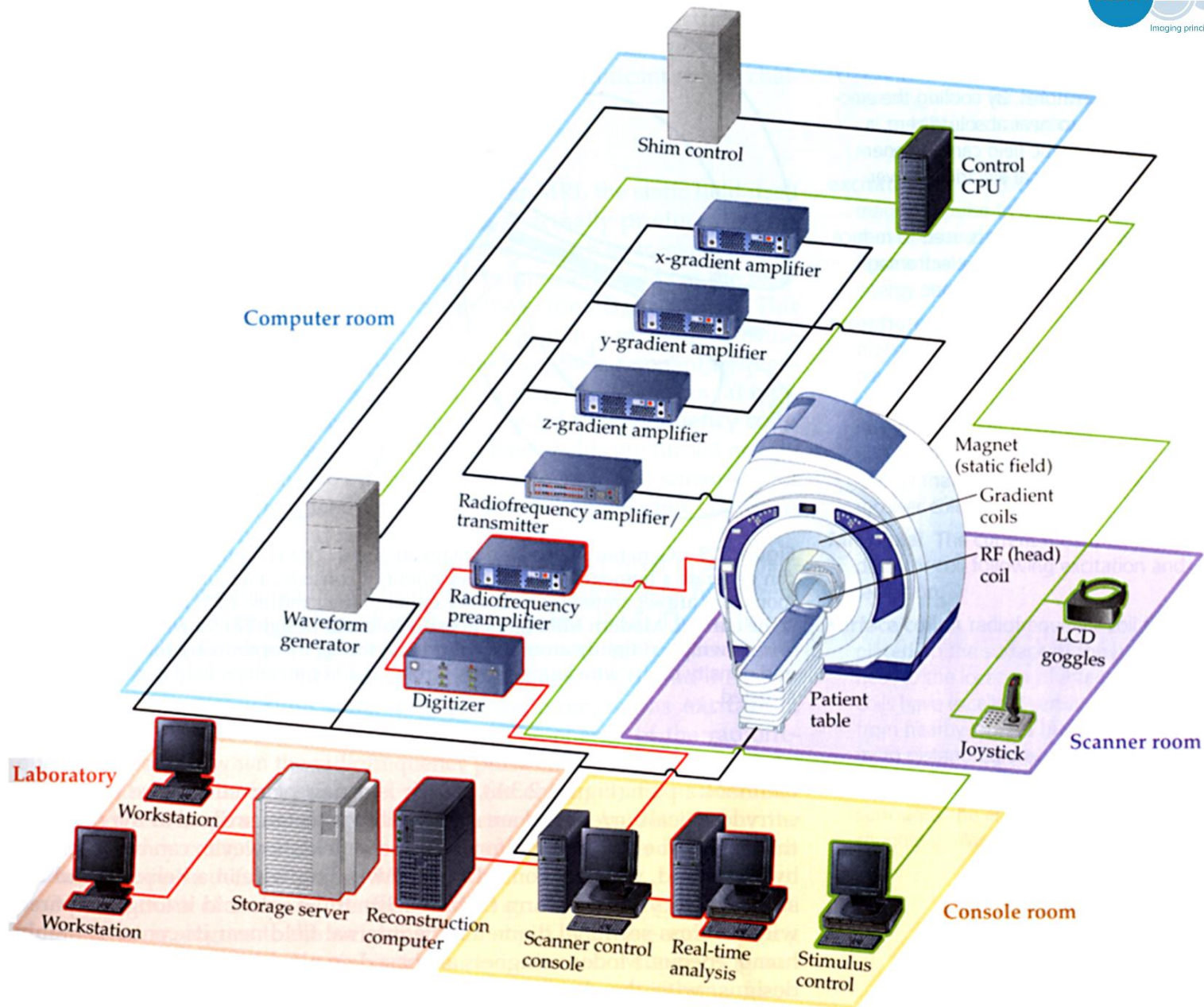
fMRI pipeline



How to present our stimuli?

- Software
 - E-prime, Presentation, Cogent + Matlab, PsychoPy, ...
- Stimuli
 - Video clips, sounds, pictures, ...
- Hardware
 - MR compatible LCD, video projector, glasses, mirror, buttons, joystick, keyboard, ...
- Connections, interfaces
 - Synchronization from scanner, signal conversion from electrical to optical or vice versa





- Typically we use GE EPI (gradient echo echo-planar imaging) – fast method sensitive to changes in local field inhomogeneity ($T2^*$ contrast)
- Matrix from 64x64 to 128x128 voxels
- Voxel size typically between 2x2x2 – 4x4x4 mm
- Larger voxel = better signal to noise ratio (SNR)
- Typical TR (scan repeat time) is about 1.5 – 3 s; hundreds of milliseconds using techniques for acceleration or parallel imaging (e.g. multiband EPI)
- Whole functional run lasts about 5 – 30 minutes
- Whole measurement of one subject lasts typically about 45-60 minutes
- Typically, we measure structural MRI data together with functional data.

- Selection criteria
 - Contraindications (peacemaker, metal parts in body)
 - Homogeneity of population (age, gender, IQ or education, mother language, handedness, type of disease for patient population)
 - Balance within group and between groups
- Before measurement
 - Ethics and safety (informed consent, safety form, data protection police, ...)
 - Careful instructions (subject has to understand the task very well and has to be motivated to do it properly and to lay without movement)
 - Check all necessary hardware and software items to be set up properly
- During measurements
 - Do it all time in the same way (e.g. use some printed measurement protocol with checklist)
 - Remember instruction to participant before each part of measurement
 - Check quality of data (from acquisition console)
 - Check subject's responses and correct running of stimulation
 - Write all notes about measurement to measurement form

- Careful usage of personal data about subjects
- Anonymous MRI data has to be used for transfer outside MR facility
- Data format and conversion issues (e.g. DICOM to NIFTI) – depends on software used for data processing
- Software:
 - SPM
 - FSL
 - Brain Voyager
 - other tools and scripts

Thank you for your attention



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