GHENT UNIVERSITY

FACULTY OF PSYCHOLOGY AND EDUCATIONAL SCIENCES

Retrieving the HRF at rest:

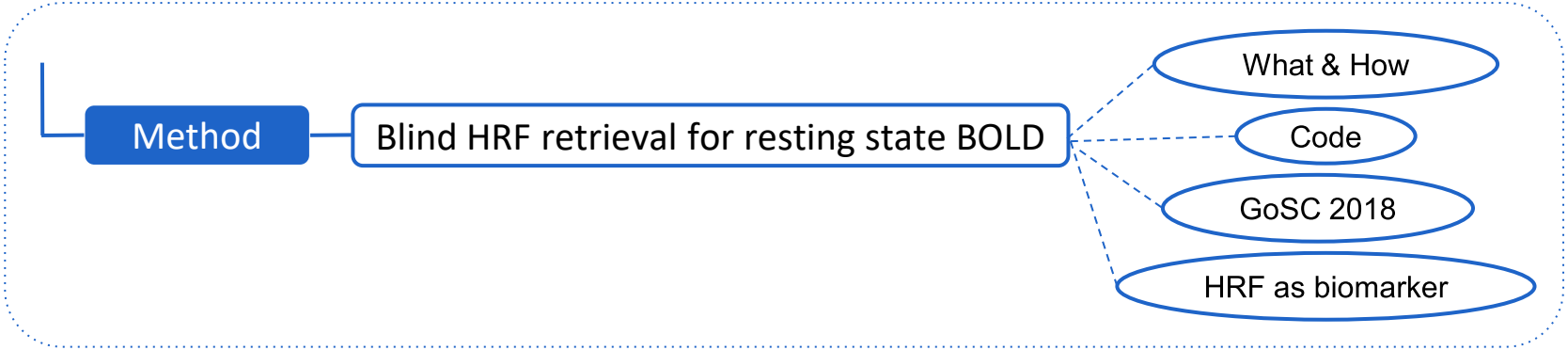
An application to brain tumor fMRI scans

Sofie Van Den Bossche - Promotor: Prof. dr. Daniele Marinazzo
In collaboration with: Hannelore Aerts

Ghent University, Belgium; ENBIT workshop; 31 May 2018

fwo

Structure:



Data set > Hannelore Aerts

fMRI - BOLD signal - General Linear Model (GLM)

Linear Time Invariant model

$$y(t) = s(t) \otimes h(t) + c + \varepsilon(t)$$

The processed BOLD signal at time *t*, *y(t)*, is modeled as the convolution of:

- neural state ***s(t)*** and
- a hemodynamic response function ***h(t)***,

where ⊗ denotes convolution, *ε(t)* is the unexplained error and *c* indicates the baseline magnitude

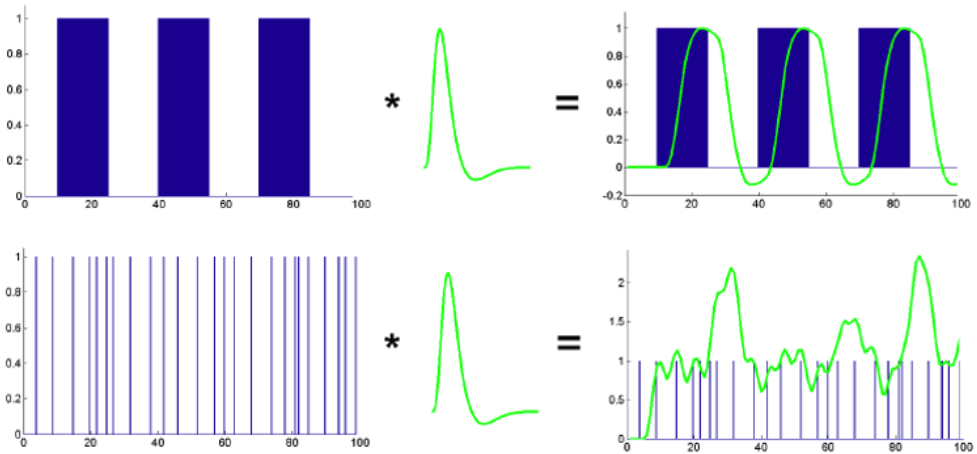


Figure: Cartoon of the BOLD signal resulting from blocked and event-related stimuli, without noise.

fMRI - BOLD signal - General Linear Model (GLM)

Linear Time Invariant model

$$y(t) = s(t) \otimes h(t) + c + \varepsilon(t)$$

AIM: solve the equation for *h(t)*

Task fMRI

s(t) could be substituted with a hypothetical model of the neural activation for *s(t)*, i.e. stimulus function

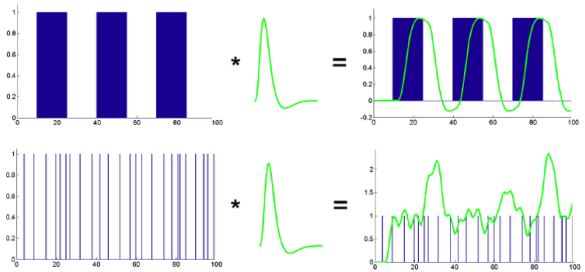


Figure: Cartoon of the BOLD signal resulting from blocked and event-related stimuli, without noise.

Resting-state fMRI

no explicit stimulus and timing for HRF onset

Point Process

Discrete BOLD events govern the brain dynamic at rest (e.g. Tagliazucchi et al. 2012)

- Reflected by relatively large amplitude BOLD signal peaks
- Identified when the stand. BOLD signal crosses a given threshold (1 SD)
- Corresponding to point process neural events

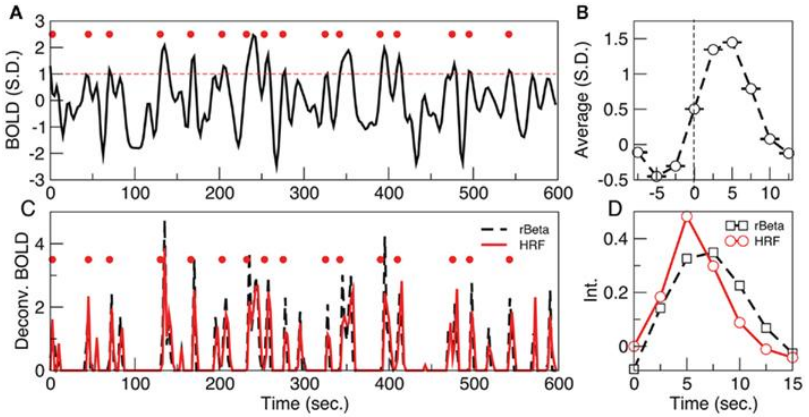


Figure: From Tagliazucchi et al. (2012) BOLD point process: $S_b(t)$

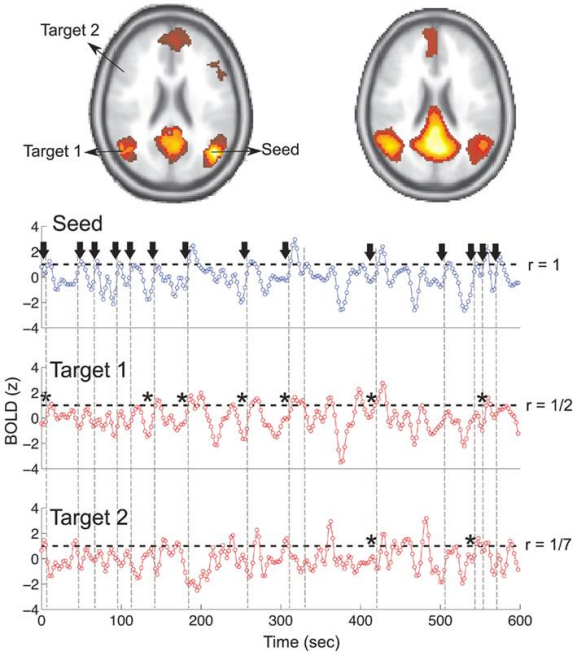


Figure: Simultaneous BOLD peaks reproduce whole series FC pattern.

Extract the HRF from those pseudo-events: from neuronal pseudo-events to BOLD peaks

Assumption: Peak of the BOLD signal lags (*L*) behind the peak of the spontaneous point process event ($L = \kappa \cdot TR/N$ seconds; 0 < *L* < *PST*).

In order to **obtain the time lag *k***, search all integer values in the interval $[0, PST \cdot N/TR]$, where *PST* is the peristimulus time, choosing the one for which the noise squared error is the smallest, $\min_{\forall 0<L<PST} \mid y(t) - s_b(t-L) \otimes h(t)|^2$, indicating the spontaneous event onset.

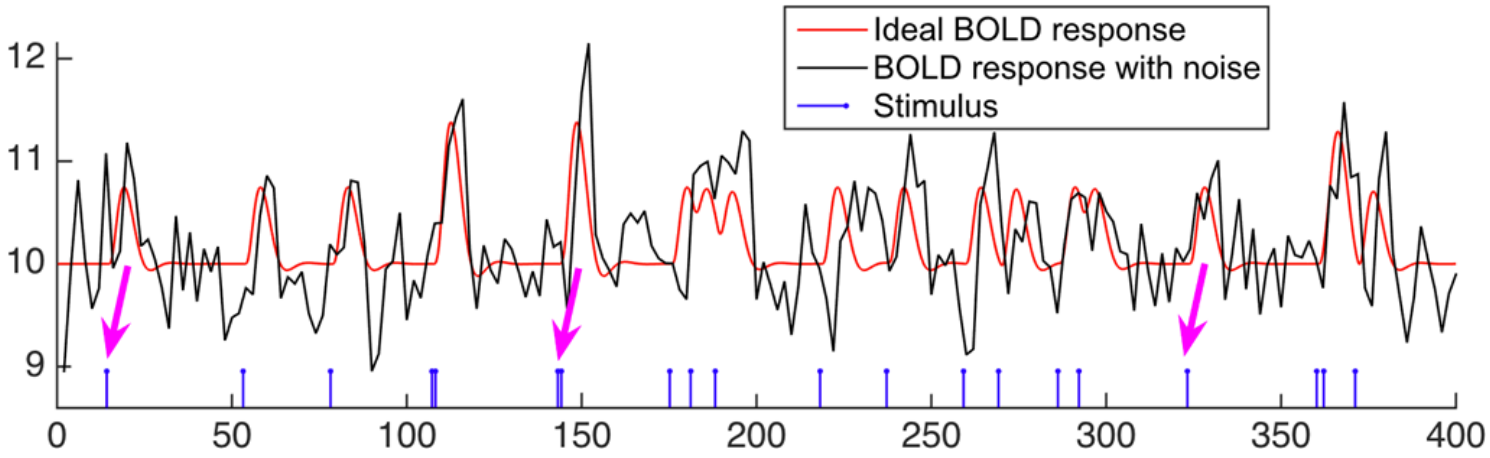
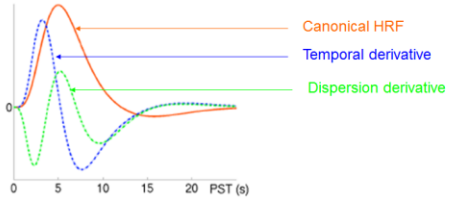


Figure: Time lag from stimulus to BOLD peak.

HRF basis vectors

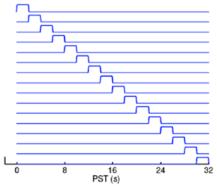
We assume that the hemodynamic responses for all resting state spontaneous point process events and at all locations in the brain are fully contained in an *d*-dimensional linear subspace *H* of R^d.
Then, any hemodynamic response *h* can be represented uniquely as the linear combination of the corresponding basis vectors, such as:

- (a) **Canonical** HRF with its (b) delay/dispersion derivatives (canon2dd)



(a) two gamma functions
(b) allow variations about the canonical form

- (smoothed) Finite Impulse Response (s**FIR**): makes minimal assumptions about the shape of the response



Three HRF parameters

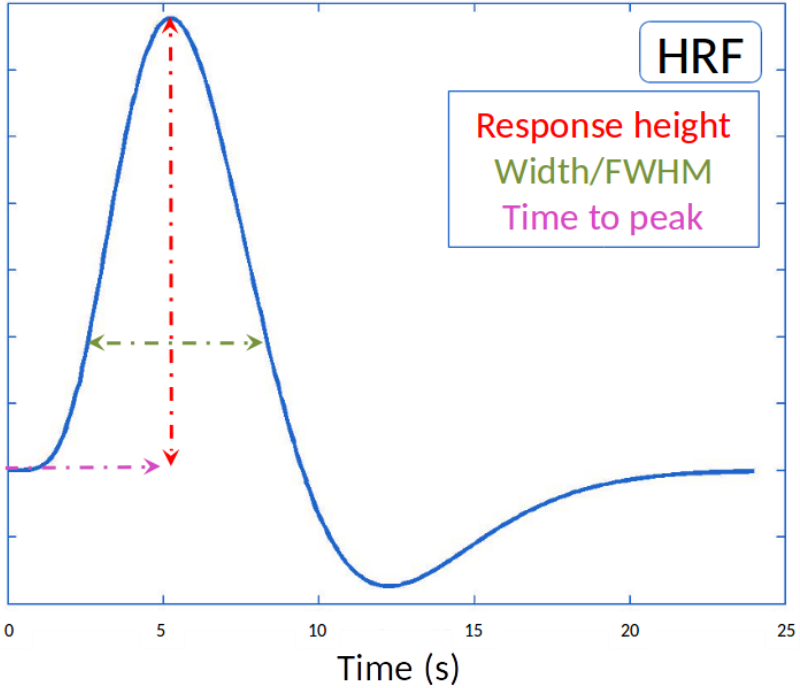


Figure: Schematic display of a typical HRF with its three characteristic parameters as potential measures of **response magnitude, latency, and response duration**.

Flow chart: quick recap

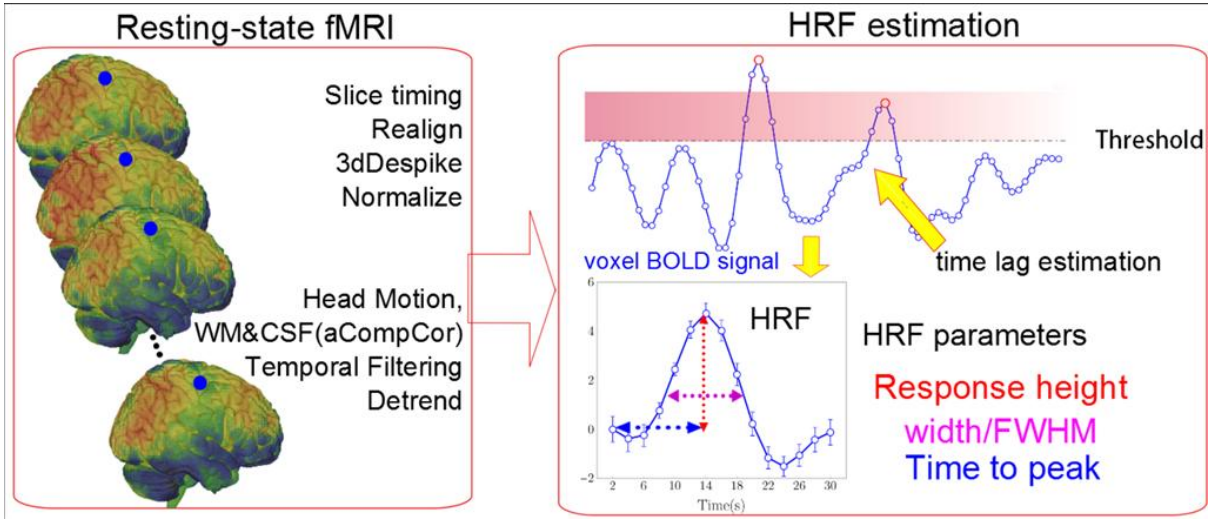


Figure: Flowchart of the blind HRF retrieval method in rfMRI.

- rsfMRI = non-invasive
- single voxel level

Method: Blind HRF retrieval for resting state BOLD

Code - GoSC 2018

1 guorongwu / **rsHRF**

Watch 5 | Star 12 | Fork 6

Code | Issues 4 | Pull requests 0 | Projects 1 | Wiki | Insights

Resting state HRF estimation from BOLD-fMRI signal http://guorongwu.github.io/HRF

42 commits | 2 2 branches | 0 releases | 4 contributors

Branch: master | New pull request | Create new file | Upload files | Find file | Clone or download

sofievdbos Update demo_main_deconvolution_FIR.m — Latest commit 5447907 2 days ago

docs	rsHRF	2 years ago
.DS_Store	rsHRF	2 years ago
README.md	add demo	a year ago
data_structure_example	Rename data_structure_example.txt to data_structure_example	a year ago
data_structure_example.txt	Add files via upload	a year ago
demo_4d_rsHRF.m → canonical	temporal resolution	4 months ago
demo_main_deconvolution_FIR.m	Update demo_main_deconvolution_FIR.m	2 days ago
→ rbeta, canonical, FIR hrf_retrieval_and_deconvolution_para.m	Add files via upload	5 months ago
wgr_get_parameters.m	rsHRF	2 years ago
wgr_rshrf_estimation_canonhrf2dd_par…	FGLS iteration	2 years ago

13,000+ STUDENTS, 108 COUNTRIES
13 YEARS, 608 OPEN SOURCE ORGANIZATIONS

33,000,000+
LINES OF CODE

Google Summer of Code is a global program focused on bringing more student developers into open source software development. Students work with an open source organization on a 3 month programming project during their break from school.

2 branches:
- master (MATLAB)
- python (**GSoC 2018**) 3
  => BIDSapp

Madhur Tandon

Building a portable open pipeline (Python) to detect the hemodynamic response function at rest

Q&A: Daniele Marinazzo, Asier Erramuzpe Aliaga, Nigel Colenbier, Sofie Van Den Bossche

Flow chart: quick recap

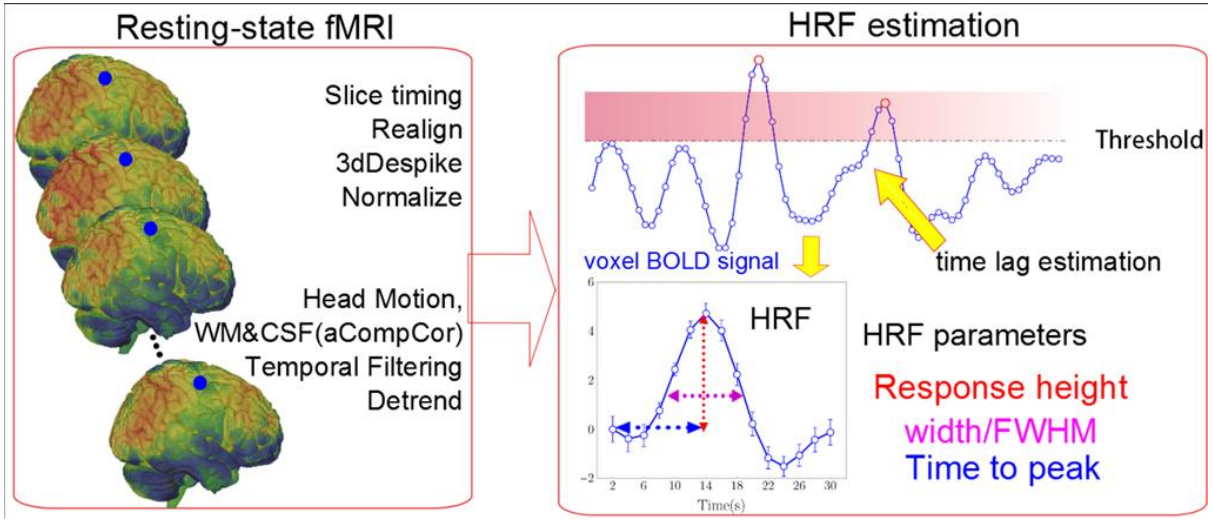


Figure: Flowchart of the blind HRF retrieval method in rfMRI.

- rsfMRI = non-invasive
- single voxel level

Once the rsHRF is retrieved it can be used to:

- deconvolve BOLD data in order to eliminate confounders on temporal precedence
- **map it onto the brain surface and look at its variability**

HRFs vary across brain regions and individuals

intra-subject spatial variability:
e.g. variations in the vasculature

inter-subject variability: psycho-physiological factors
→ HRF as a pathophysiological indicator

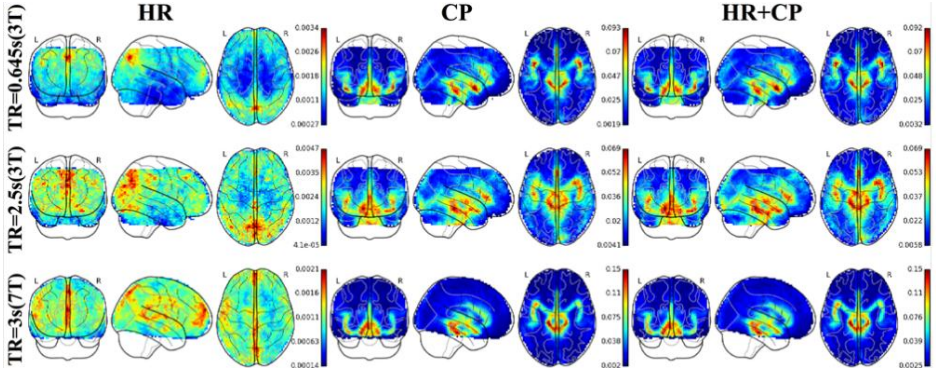
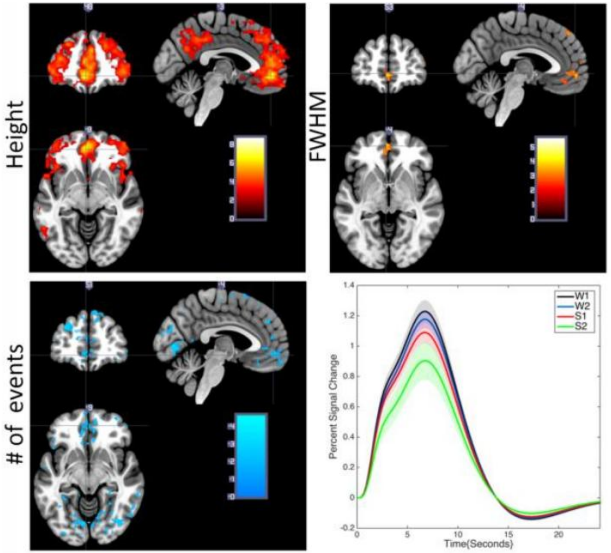


Figure: Quasi-periodic and non-periodic cardiac fluctuation regressors.

HRF modulated by several psycho-physiological factors

Loss of **consciousness** (Wu et al., 2015)



W1: Awake
W2: Recovery of consciousness
S1: Mild sedation
S2: Deep sedation

To identify regions which showed significant activation differences among four clinical states, a linear T contrast was computed, searching for a linear relationship between HRF and the level of consciousness of the subjects across the four conditions.

Contrast (W1 W2 S1 S2) [1.5 0.5 –1.5 -0.5]

Statistical differences in all the three HRF parameters, as well as in the number of spontaneous events, mainly in frontal areas

HRF modulated by several psycho-physiological factors

e.g. **ASD**, **post-traumatic stress disorder**

Aberrant hemodynamic responses in autism: Implications for resting state fMRI functional connectivity studies

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[c] Department of Psychology, Auburn University, Auburn, AL, USA
[d] Center for Health Ecology and Equity Research, Auburn University, Auburn, AL, USA
[e] Alabama Advanced Imaging Consortium, Auburn University and University of Alabama Birmingham, AL, USA

Hemodynamic variability in soldiers with trauma: Implications for functional MRI connectivity studies

D. Rangaprakash[a,b], Michael N. Dretsch[c,d], Wenjing Yan[a], Jeffrey S. Katz[a,e,f], Thomas S. Denney Jr.[a,e,f], Gopikrishna Deshpande[a,e,f,*]

Neurovascular uncoupling

Cancer cells display remarkable phenotypic variability, including ability to induce **angiogenesis**, seed metastases, and survive therapy.

" ...the abnormal neovasculature in glioblastomas (GBM's) may not be able to dilate normally in response to increased neuronal activity." (Hou et al., 2006)

1. Loss of ability to autoregulate
2. Neurovaculature already maximally dilated due to the presence of ischemia

Data and ideas

11 glioma patients

> arise from brain tissue

- Extract rsHRF (FIR) for tumor regions and contralateral control regions
- Look at HRF maps: Differences? Peritumoral regions?
- MVPA
- ...

All your ideas are welcome!