

# rsHRF: retrieving the hemodynamic response function in resting state fMRI

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<https://github.com/guorongwu/rsHRF>

# Statistical analysis of fMRI data

## Two main objectives

- ▶ Establishing the link between neural activity and the measured signal
- ▶ Determining distributed brain networks that correspond to brain function

## Statistical analysis of fMRI data

- ▶ General linear model (GLM)
- ▶ Functional and effective connectivity

# BOLD Signal: General linear model (GLM)

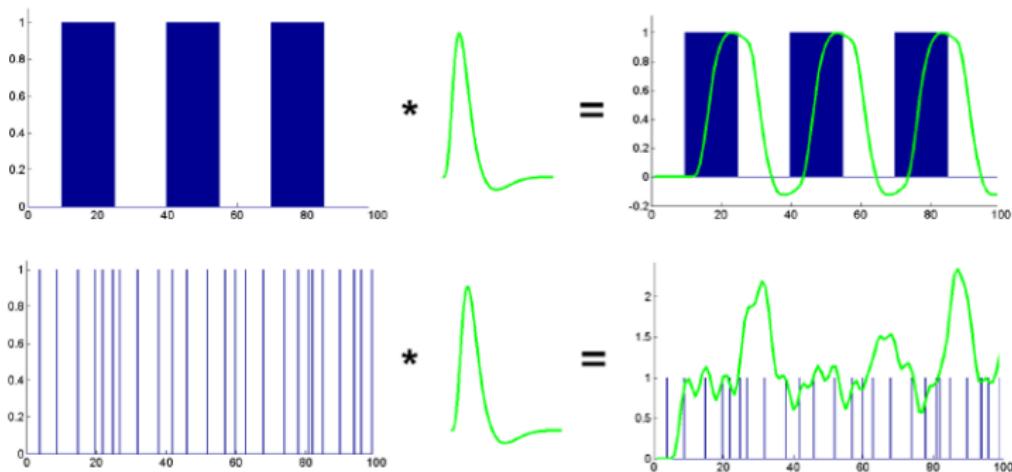


Figure: cartoon of the BOLD signal resulting from blocked and event-related stimuli, without noise

## BOLD Signal: General linear model (GLM)

### Linear Time Invariant model

The processed BOLD signal at time  $t$ ,  $y(t)$  (partial out confounds: motion parameters etc.), is modeled as the convolution of neural state  $s(t)$  and hemodynamic response function  $h(t)$ , i.e.

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

where  $c$  indicates the baseline magnitude.

- ▶  $\epsilon(t)$  can be modelled by  $AR(p)$  to account for the temporal correlation.
- ▶ in task-related fMRI,  $s(t)$  could be substituted by stimulus function  $\hat{s}(t) = \sum_{i=1}^K \alpha_i \delta(t - t^i)$
- ▶ in resting-state fMRI there is no explicit stimulus and timing for HRF onset

# Point Process

Specific BOLD events govern the dynamics of the brain at rest  
(Tagliazucchi et al. 2012, Petridou et al. 2013)

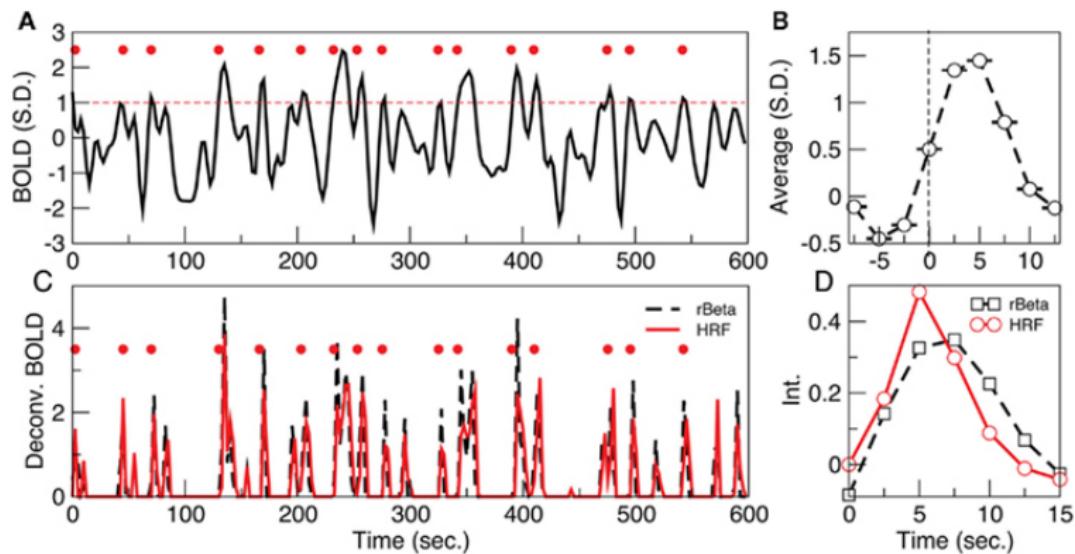


Figure: from Tagliazucchi et al. 2012. **BOLD point process:**  $S_b(t)$

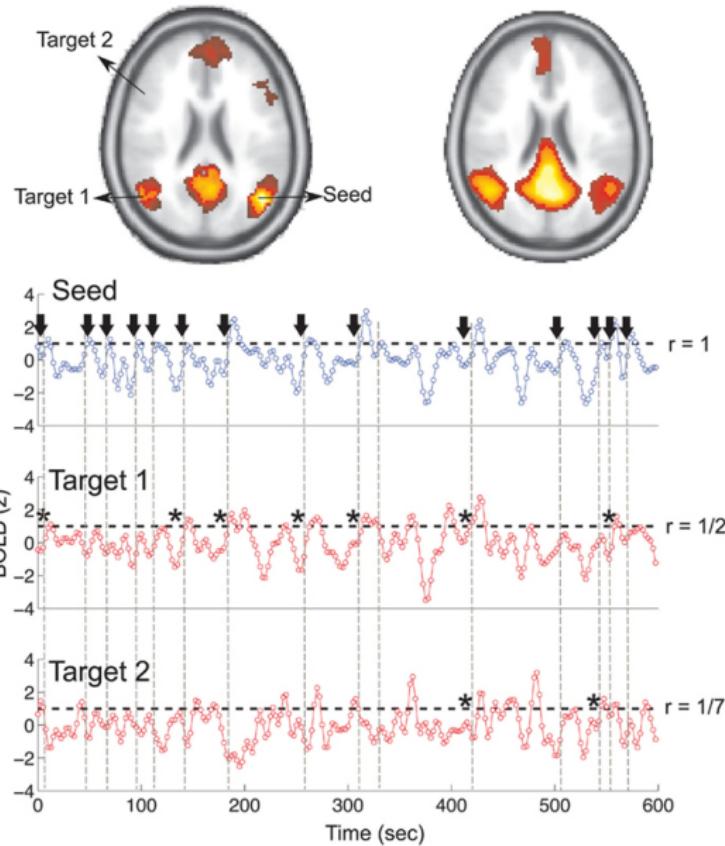
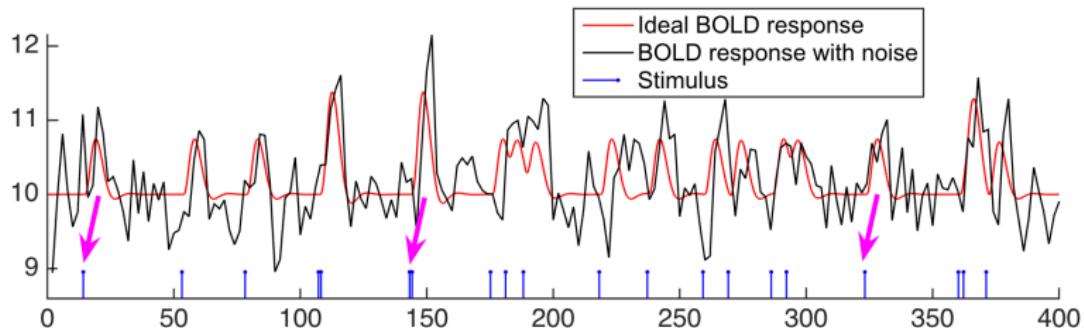


Figure: Simultaneous BOLD peaks reproduce whole series FC patterns, see also Logothetis 2012, Liu and Duyn 2013, Logothetis 2015

## From neuronal pseudo-events to BOLD peaks

we assume the peak of BOLD response lags behind the peak of spontaneous point process event is  $L = \kappa \cdot TR/N$  seconds ( $0 < L < PST$ ).



**Figure:** Time lag from stimulus to BOLD peak. To obtain the time lag  $\kappa$ , we 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 smallest (i.e.  $\min_{\forall 0 < L < PST} |y(t) - s_b(t - L) \otimes h(t)|^2$ ), indicating the spontaneous event onset.

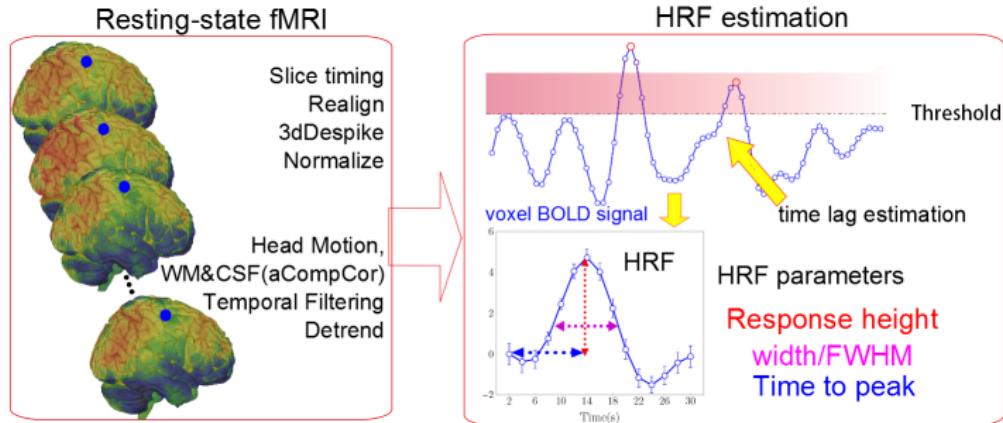
## HRF basis vectors

- ▶ Reduce the bias in the linear estimation framework especially for the low signal noise ratio dataset.
- ▶ Decrease computational cost.

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:

- ▶ Canonical HRF with its delay/dispersion derivatives (canon2dd),
- ▶ (smoothed) Finite Impulse Response (sFIR)

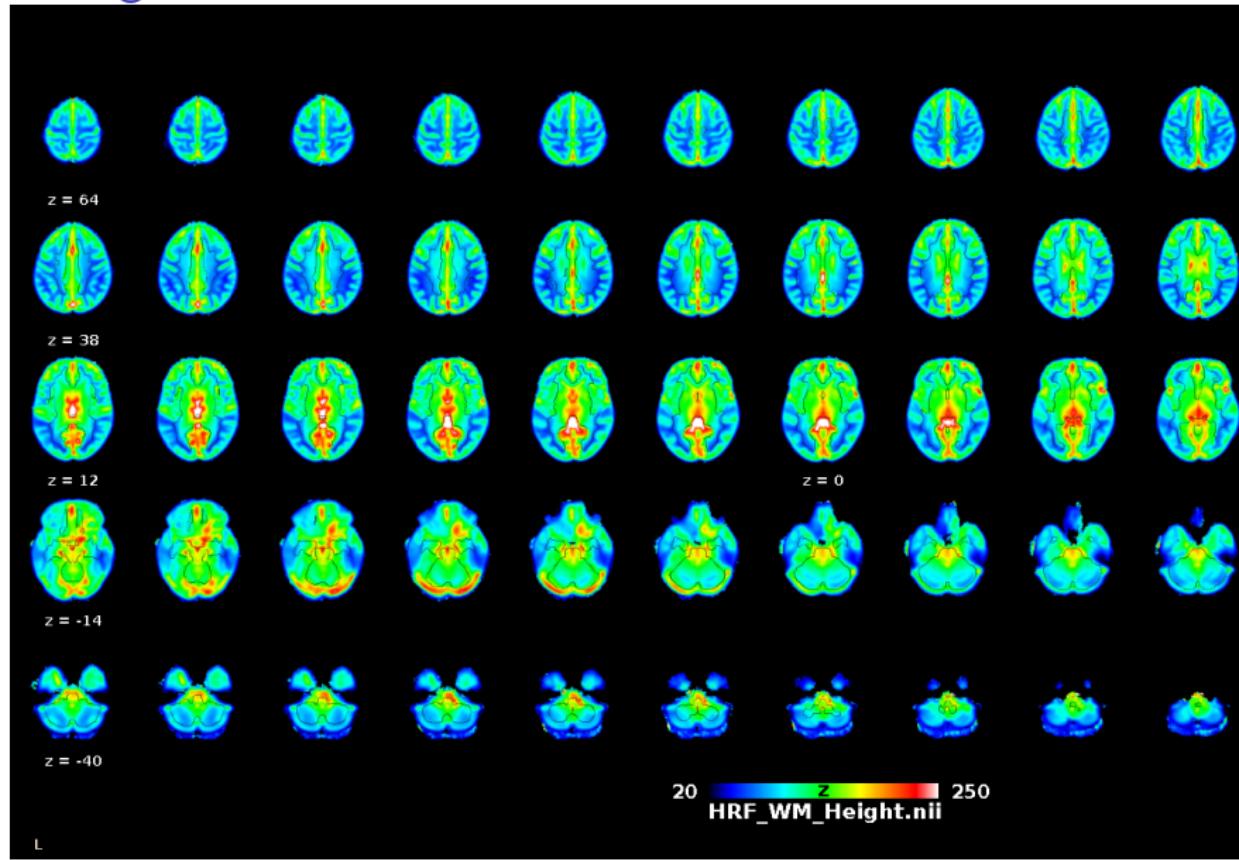
# Recap of the procedure



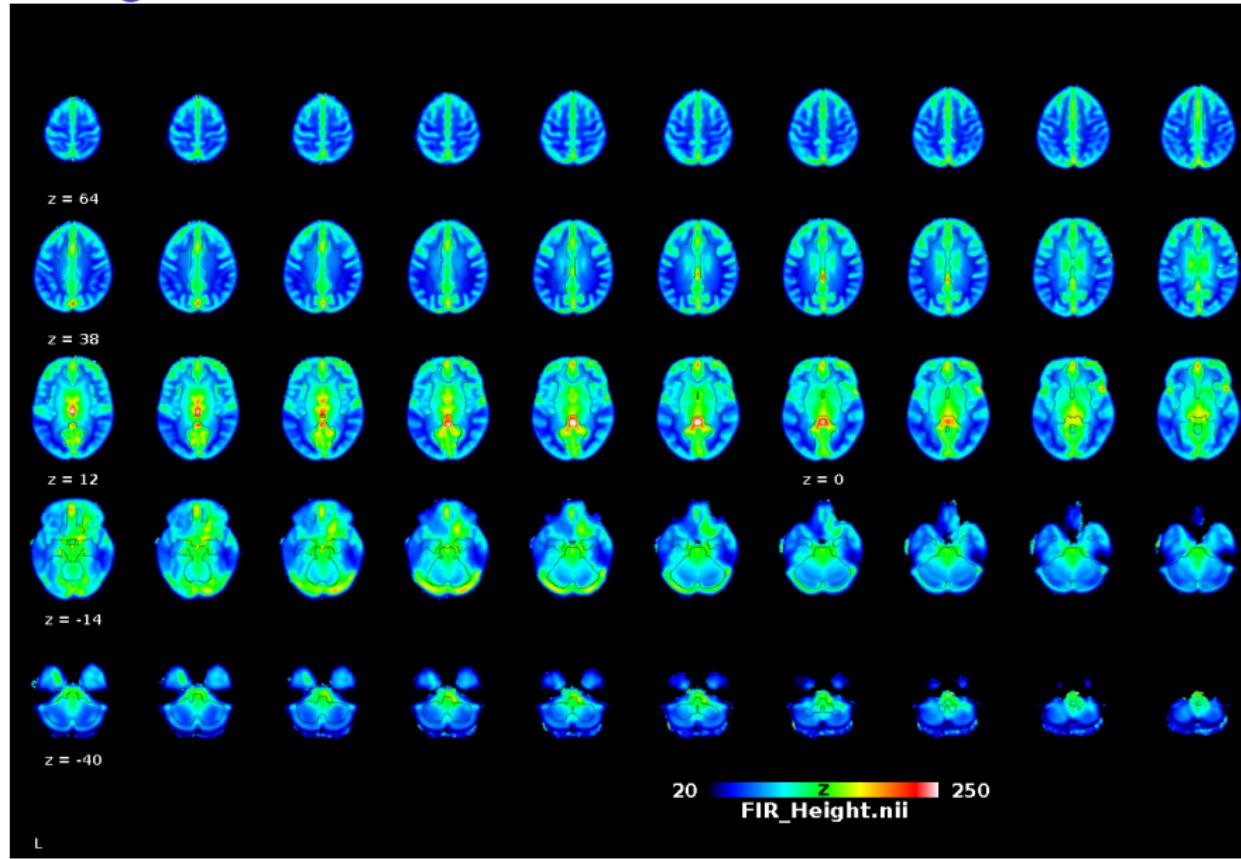
Once the RS-HRF is retrieved it can be used to:

- ▶ deconvolve BOLD data in order to eliminate confounders on temporal precedence
- ▶ map it onto the brain surface and use it as a pathophysiological indicator

# HRF height - Canonical-2DD

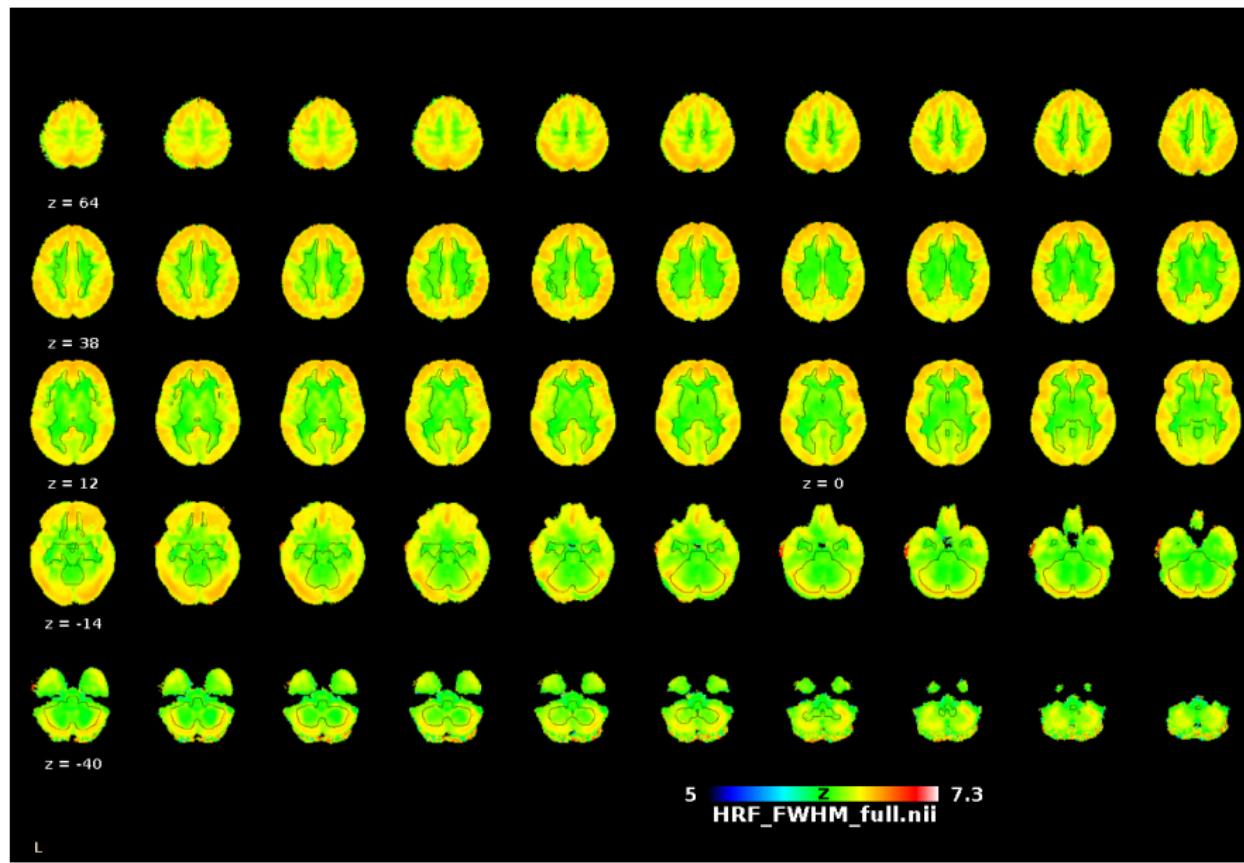


# HRF height - FIR

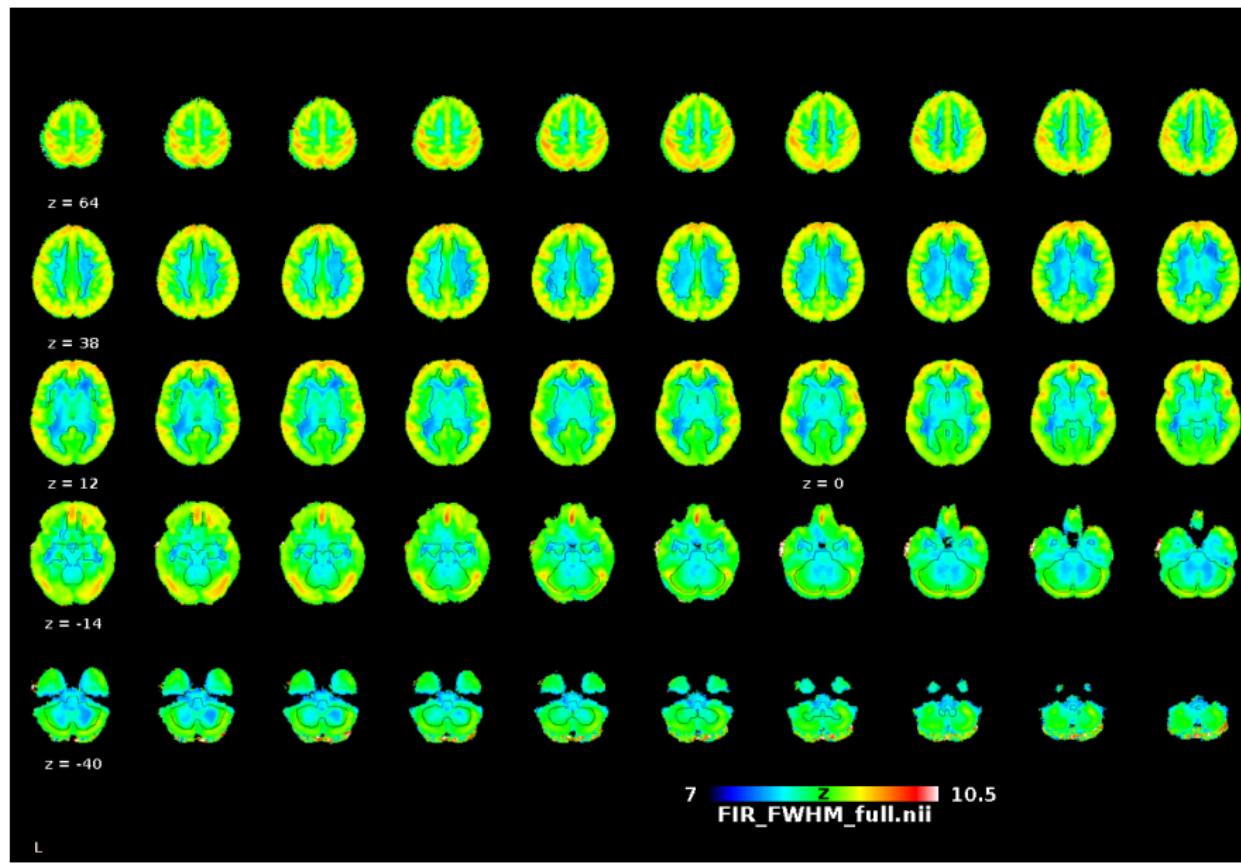


<https://neurovault.org/collections/3584/>

# HRF FWHM - Canonical-2DD

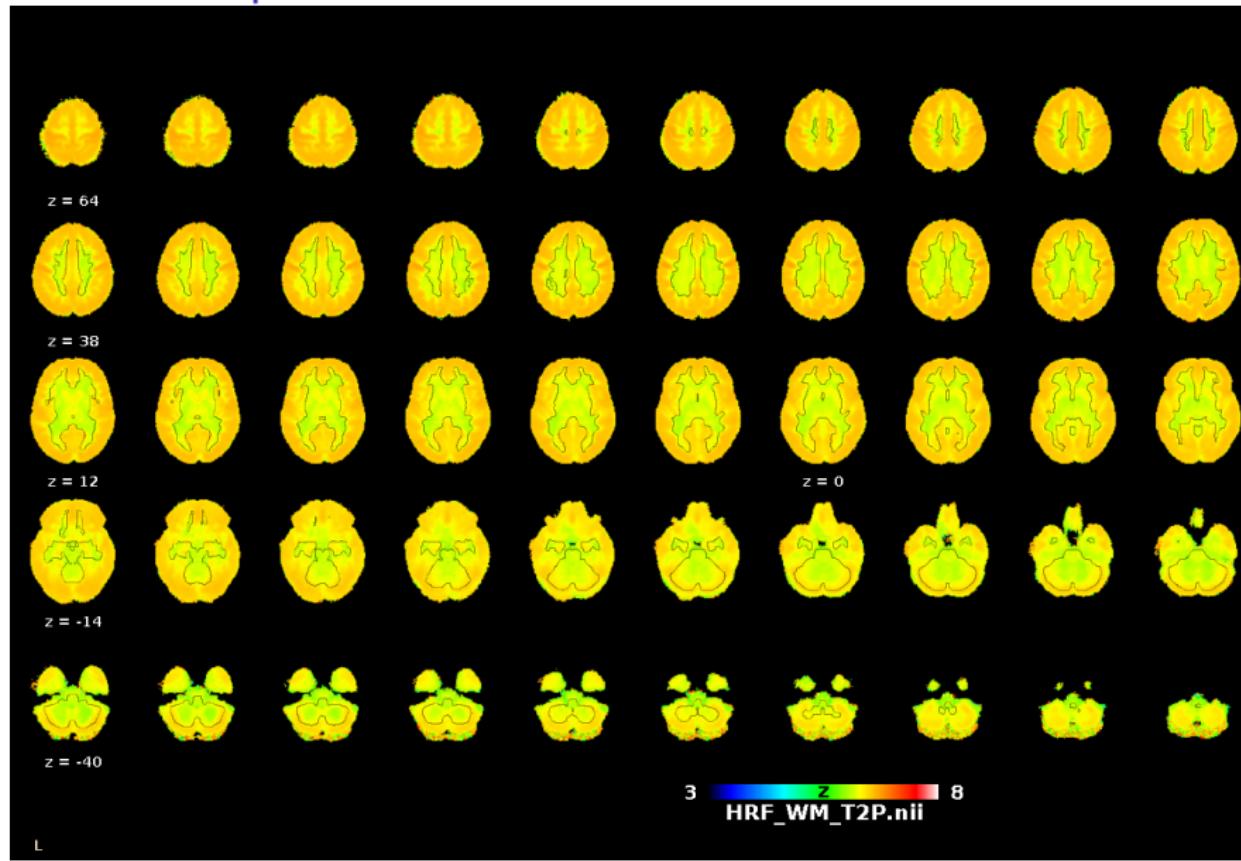


# HRF FWHM - FIR



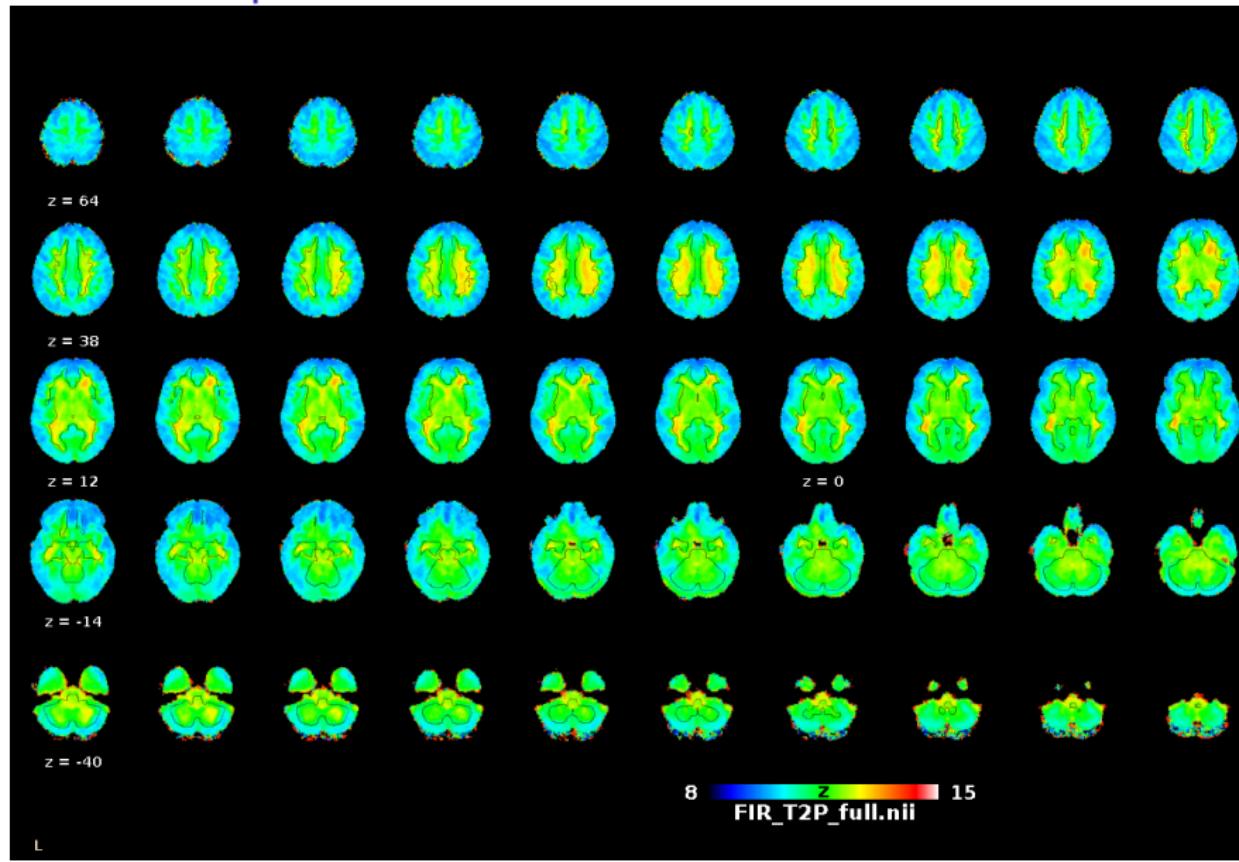
<https://neurovault.org/collections/3584/>

# HRF Time to peak - Canonical-2DD



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# HRF Time to peak - FIR



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- Lead Software Developer, University of Pennsylvania

## Resting State Hemodynamic Response Function Retrieval and Deconvolution (RS-HRF)

[Visit Website](#) ↗



This toolbox is aimed to retrieve the onsets of pseudo-events triggering an hemodynamic response from resting state fMRI BOLD voxel-wise signal. It is based on point process theory, and fits a model to retrieve the optimal lag between the events and the HRF onset, as well as the HRF shape, using either the canonical shape with two derivatives, or a (smoothed) Finite Impulse Response.

Once that the HRF has been retrieved for each voxel, it can be deconvolved from the time series (for example to improve lag-based connectivity estimates), or one can map the shape parameters everywhere in the brain (including white matter), and use it as a pathophysiological indicator.

<https://www.nitrc.org/projects/rshrf>