

Package ‘hrf’

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Type Package

Title Hemodynamic Response Function

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Description Computes the hemodynamic response function (HRF) for task functional magnetic resonance imaging (fMRI) data. Also includes functions for constructing a design matrix from task fMRI event timings, and for comparing multiple design matrices in a general linear model (GLM). A wrapper function is provided for GLM analysis of CIFTI-format data. Lastly, there are supporting functions which provide visual summaries of the HRFs and design matrices.

License GPL-3

URL <https://github.com/mandymejia/hrf>

BugReports <https://github.com/mandymejia/hrf/issues>

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Contents

aic_Param	2
ar_order_Param	3
ar_smooth_Param	3
BOLD_Param_BayesGLM	3
brainstructures_Param_BayesGLM	4
cderiv	4
Connectome_Workbench_Description	5
design_Param_BayesGLM	5
do_QC	5
faces_Param	6
field_names_Param	6
hpf_Param_BayesGLM	7
HRF96	7
HRF_calc	8
HRF_main	9
make_design	9
mask_Param_vertices	11
mean_var_Tol_Param	12
multiGLM	12
multiGLM_fun	14
nuisance_Param_BayesGLM	15
plot.BfMRI_design	15
plot_design	16
resamp_res_Param_BayesGLM	17
scale_BOLD_Param	17
scrub_Param_BayesGLM	17
session_names_Param	18
summary.BfMRI_design	18
surfaces_Param_BayesGLM	19
TR_Param_BayesGLM	19
verbose_Param	19
Index	20

aic_Param

aic

Description

aic

Arguments

aic

(For prewhitening) Use the Akaike information criterion (AIC) to select AR model orders between 0 and ar_order? Default: FALSE.

ar_order_Param	<i>ar_order</i>
----------------	-----------------

Description

ar_order

Arguments

ar_order	(For prewhitening) The order of the autoregressive (AR) model to use for prewhitening. If 0, do not prewhiten. Default: 6. For multi-session modeling, note that a single AR model is used; its coefficients will be the average estimate from each session.
----------	---

ar_smooth_Param	<i>ar_smooth</i>
-----------------	------------------

Description

ar_smooth

Arguments

ar_smooth	(For prewhitening) The FWHM parameter for spatially smoothing the coefficient estimates for the AR model to use for prewhitening. Recall that $\sigma = \frac{FWHM}{2 \cdot \sqrt{2 \cdot \log(2)}}$. Set to 0 to not smooth the estimates. Default: 5.
-----------	--

BOLD_Param_BayesGLM	<i>BOLD</i>
---------------------	-------------

Description

BOLD

Arguments

BOLD	fMRI timeseries data in CIFTI format ("*.dtseries.nii"). For single-session analysis this can be a file path to a CIFTI file or a "xifti" object from the <code>ciftiTools</code> package. For multi-session analysis this can be a vector of file paths or a list of "xifti" objects. If BOLD is a "xifti" object(s), the surfaces, if any, will be used for the spatial model. However, if <code>surfL</code> and <code>surfR</code> are provided, they will override any surfaces in BOLD.
------	--

brainstructures_Param_BayesGLM
brainstructures

Description

brainstructures

Arguments

brainstructures

Character vector indicating which brain structure(s) of BOLD to analyze: "left" cortex; "right" cortex; and/or "subcortical" structures. Or "all" to model all three. Default: c("left", "right") (cortex only).

cderiv *Central derivative*

Description

Take the central derivative of numeric vectors by averaging the forward and backward differences.

Usage

cderiv(x)

Arguments

x A numeric matrix, or a vector which will be converted to a single-column matrix.

Value

A matrix or vector the same dimensions as x, with the derivative taken for each column of x. The first and last rows may need to be deleted, depending on the application.

Examples

```
x <- cderiv(seq(5))
stopifnot(all(x == c(.5, 1, 1, 1, .5)))
```

Connectome_Workbench_Description
Connectome Workbench

Description

Connectome Workbench

Connectome Workbench Requirement

This function uses a system wrapper for the 'wb_command' executable. The user must first download and install the Connectome Workbench, available from <https://www.humanconnectome.org/software/get-connectome-workbench>.

design_Param_BayesGLM *design*

Description

design

Arguments

design A numeric matrix or data.frame, or a "BayesfMRI_design" object from make_design. Can also be an array where the third dimension is the same length as the number of data locations, to model each location with its own design.

do_QC *Mask out invalid data*

Description

Mask out data locations that are invalid (missing data, low mean, or low variance) for any session.

Usage

```
do_QC(BOLD, meanTol = 1e-06, varTol = 1e-06, verbose = TRUE)
```

Arguments

BOLD A session-length list of $T \times V$ numeric BOLD data.
meanTol, varTol Tolerance for mean and variance of each data location. Locations which do not meet these thresholds are masked out of the analysis. Defaults: 1e-6.
verbose Print messages counting how many locations are removed? Default: TRUE.

Value

A logical vector indicating locations that are valid across all sessions.

Examples

```
nT <- 30
nV <- 400
BOLD1 <- matrix(rnorm(nT*nV), nrow=nT)
BOLD1[,seq(30,50)] <- NA
BOLD2 <- matrix(rnorm(nT*nV), nrow=nT)
BOLD2[,65] <- BOLD2[,65] / 1e10
BOLD <- list(sess1=BOLD1, sess2=BOLD2)
do_QC(BOLD)
```

faces_Param	<i>faces</i>
-------------	--------------

Description

faces

Arguments

faces An $F \times 3$ matrix, where each row contains the vertex indices for a given triangular face in the mesh. F is the number of faces in the mesh.

field_names_Param	<i>field_names</i>
-------------------	--------------------

Description

field_names

Arguments

field_names (Optional) Names of fields represented in design matrix.

hpf_Param_BayesGLM *hpf*

Description

hpf

Arguments

hpf Add DCT bases to nuisance to apply a temporal high-pass filter to the data, for detrending? hpf is the filter frequency. Use NULL to skip detrending. Detrending is strongly recommended for fMRI data, to help reduce the autocorrelation in the residuals, so NULL will induce a warning. Use "already" to disable the warning while skipping highpass filtering.

Using at least two DCT bases is as sufficient for detrending as using linear and quadratic drift terms in the nuisance matrix. So if DCT detrending is being used here, there is no need to add linear and quadratic drift terms to nuisance.

HRF96

Canonical (double-gamma) HRF (old one from SPM96, Glover)

Description

Calculate the HRF from a time vector and parameters. Optionally compute the first or second derivative of the HRF instead.

Usage

HRF96(t, deriv = 0, a1 = 6, b1 = 0.9, a2 = 12, b2 = 0.9, c = 0.35)

Arguments

t	time vector
deriv	0 (default) for the HRF, 1 for the first derivative of the HRF, or 2 for the second derivative of the HRF.
a1	delay of response. Default: 6
b1	response dispersion. Default: 0.9
a2	delay of undershoot. Default: 12
b2	dispersion of undershoot. Default: 0.9
c	scale of undershoot. Default: 0.35

Value

HRF vector (or dHRF, or d2HRF) corresponding to time

Examples

```
upsample <- 100
HRF96(seq(0, 30, by=1/upsample))
```

HRF_calc

*Canonical HRF and Derivatives***Description**

Calculate the HRF from a time vector and parameters, or its derivative with respect to delay or dispersion.

Usage

```
HRF_calc(
  t,
  deriv = 0,
  a1 = 6,
  b1 = 1,
  a2 = 16/6 * a1 * sqrt(b1),
  b2 = b1,
  c = 1/6,
  o = 0
)
```

Arguments

t	time vector (in units of seconds)
deriv	0 (default) for the HRF, 1 for the delay derivative of the HRF, or 2 for the dispersion derivative of the HRF.
a1	delay of response. Default: 6
b1	response dispersion. Default: 1
a2	delay of undershoot. Default: $16/6 * a1 * \sqrt{b1} = 16$
b2	dispersion of undershoot. Default: $b1 = 1$
c	scale of undershoot. Default: $1/6$
o	onset of response. Default: 0

Value

HRF vector (or dHRF, or d2HRF) corresponding to time vector t

Examples

```
samples_per_sec <- 200
nsec <- 50
HRF_calc(seq(nsec*samples_per_sec)/samples_per_sec)
```

HRF_main	<i>Canonical (double-gamma) HRF</i>
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Description

Calculate the HRF from a time vector and parameters. Optionally compute the first or second derivative of the HRF instead. Form of HRF is similar to SPM but here the response and undershoot are scaled so the difference of the HRFs peaks at 1 and -c

Usage

```
HRF_main(t, a1 = 6, b1 = 1, a2 = NULL, b2 = NULL, c = 1/6, o = 0)
```

Arguments

t	time vector (in seconds). Must be equally spaced.
a1	delay of response. Default: 6
b1	response dispersion. Default: 1
a2	delay of undershoot. Default: $16/6 * a1 = 16$
b2	dispersion of undershoot. Default: $b1 = 1$
c	scale of undershoot. Default: $1/6$
o	onset of response (in seconds). Default: 0

Value

HRF vector corresponding to time vector t

Examples

```
upsample <- 100
HRF_main(seq(0, 30, by=1/upsample))
```

make_design	<i>Make design matrix</i>
-------------	---------------------------

Description

Make the design matrix for the GLM, from the task information.

Usage

```

make_design(
  EVs,
  nTime,
  TR,
  dHRF = 0,
  upsample = 100,
  onset = NULL,
  offset = NULL,
  scale_design = TRUE,
  onsets_sep = FALSE,
  offsets_sep = FALSE,
  verbose = TRUE,
  ...
)

```

Arguments

EVs	<p>The explanatory variables i.e. the task stimulus information, from which a design matrix will be constructed. This is a list where each entry represents a task as a matrix of onsets (first column) and durations (second column) for each stimuli (each row) of the task, in seconds. List names should be the task names. nTime and TR are required.</p> <p>An example of a properly-formatted EVs is: <code>on_s1 <- list(taskA=cbind(on=c(1, 9, 17), dr=rep(1, 3)), taskB=cbind(on=c(3, 27), dr=rep(5, 2)))</code>. In this example, there are two tasks: the first has three 1s-long stimuli, while the second has two 5s-long stimuli.</p>
nTime	the number of timepoints (volumes) in the task fMRI data.
TR	the temporal resolution of the data, in seconds.
dHRF	<p>Controls the extent of HRF derivatives modeling.</p> <p>Set to 0 to only model the main HRF regressor (default), and not include its derivatives; set to 1 to model the temporal derivative too; or, set to 2 to model both the temporal and dispersion derivatives. If <code>dHRF==0</code>, there is one design column (field) per task. If <code>dHRF==1</code>, there are two fields per task. And if <code>dHRF==2</code>, there are three fields per task.</p> <p>If there are several tasks and <code>dHRF>0</code>, the total number of design matrix columns may exceed five, which may require large computation times with INLA. The analysis can be adjusted by modeling the derivatives as nuisance signals rather than as fields. To do so, move the corresponding columns from the design matrix to the nuisance argument for BayesGLM.</p>
upsample	Upsample factor for convolving stimulus boxcar or stick function with canonical HRF. Default: 100.
onset, offset	Add task regressors indicating the onset and/or offset of each event block? Provide the names of the tasks as a character vector. All onsets (or offsets) across the specified tasks will be represented by one additional column in the design matrix. The task names must match the names of EVs. Can also be "all" to use all tasks.

Onsets/offset modeling is only compatible with a block design experiment. An error will be raised if the events in EVs do not have duration greater than one second.

scale_design Scale the columns of the design matrix? Default: TRUE.
 onsets_sep, offsets_sep
 Model the onsets (onsets_sep) or offsets (offsets_sep) separately for each task? Default: FALSE, to model all onsets together, or all offsets together, as a single field in the design.
 verbose Print diagnostic messages? Default: TRUE.
 ... Additional arguments to [HRF_calc](#).

Value

A "BfMRI_design" object: a list with elements

design The volumes by fields design matrix. Column names are field names.

field_names The name of each task from the provided onsets.

dHRF The input dHRF parameter.

HRF_info Additional HRF modeling results.

Examples

```
EVs <- list(taskA=cbind(on=c(1,9,17), dr=rep(1,3)), taskB=cbind(on=c(3,27), dr=rep(5,2)))
TR <- .72
nTime <- ceiling(65/TR)
make_design(EVs, nTime, TR)
```

mask_Param_vertices *mask: vertices*

Description

mask: vertices

Arguments

mask A length V logical vector indicating if each vertex is within the input mask.

mean_var_Tol_Param	<i>mean and variance tolerance</i>
--------------------	------------------------------------

Description

mean and variance tolerance

Arguments

meanTol, varTol Tolerance for mean and variance of each data location. Locations which do not meet these thresholds are masked out of the analysis. Default: 1e-6 for both.

multiGLM	<i>multiGLM for CIFTI</i>
----------	---------------------------

Description

Performs classical Bayesian GLM for task fMRI activation with CIFTI-format data, evaluating multiple design matrices. Includes the pre-processing steps of nuisance regression. Supports single-session analysis only.

Usage

```
multiGLM(
  BOLD,
  design,
  brainstructures = c("left", "right"),
  TR = NULL,
  resamp_res = 10000,
  hpf = NULL,
  nuisance = NULL,
  design_canonical = NULL,
  verbose = 1,
  meanTol = 1e-06,
  varTol = 1e-06
)
```

Arguments

BOLD fMRI timeseries data in CIFTI format ("*.dtseries.nii"). For single-session analysis this can be a file path to a CIFTI file or a "xiffti" object from the `ciftiTools` package. For multi-session analysis this can be a vector of file paths or a list of "xiffti" objects.

If BOLD is a "xiffti" object(s), the surfaces, if any, will be used for the spatial model. However, if `surfL` and `surfR` are provided, they will override any surfaces in BOLD.

design	A 3D numeric array that is locations by fields by designs.
brainstructures	Character vector indicating which brain structure(s) of BOLD to analyze: "left" cortex; "right" cortex; and/or "subcortical" structures. Or "all" to model all three. Default: c("left", "right") (cortex only).
TR	Temporal resolution of the data, in seconds.
resamp_res	For cortex spatial model. The number of vertices to which each cortical surface should be resampled, or NULL to not resample. For computational feasibility, a value of 10000 (default) or lower is recommended for Bayesian spatial modeling. If Bayes=FALSE, resamp_res can be set to NULL for full-resolution classical modeling.
hpf	Add DCT bases to nuisance to apply a temporal high-pass filter to the data, for detrending? hpf is the filter frequency. Use NULL to skip detrending. Detrending is strongly recommended for fMRI data, to help reduce the autocorrelation in the residuals, so NULL will induce a warning. Use "already" to disable the warning while skipping highpass filtering. Using at least two DCT bases is as sufficient for detrending as using linear and quadratic drift terms in the nuisance matrix. So if DCT detrending is being used here, there is no need to add linear and quadratic drift terms to nuisance.
nuisance	(Optional) A $T \times N_{nuis}$ matrix of nuisance signals, where T is the number of timepoints and N is the number of nuisance signals, or a list of these for multi-session analysis. Nuisance signals are regressed from the fMRI data and design matrix prior to GLM computation. Nuisance signals can include motion regressors, HRF derivatives not being modeled as tasks, and other sources of noise. Detrending/high-pass filtering is accomplished by adding DCT bases to the nuisance matrix; see the parameters hpf and DCT. Do not add spike regressors for scrubbing to the nuisance matrix. Rather, provide these in scrub so that their corresponding timepoints are also removed from the BOLD data after nuisance regression.
design_canonical	TO DO
verbose	1 (default) to print occasional updates during model computation; 2 for occasional updates as well as running INLA in verbose mode (if Bayes), or 0 for no printed updates.
meanTol, varTol	Tolerance for mean and variance of each data location. Locations which do not meet these thresholds are masked out of the analysis. Default: 1e-6 for both.

Value

An object of class "mGLM": a list with elements

brainstructures data.frame summarizing the spatial features of each brain structure modeled.

fields data.frame with the name, related task, and HRF_order of each field.

Connectome Workbench Requirement

This function uses a system wrapper for the 'wb_command' executable. The user must first download and install the Connectome Workbench, available from <https://www.humanconnectome.org/software/get-connectome-workbench>.

 multiGLM_fun

multiGLM0

Description

Performs classical GLM for task fMRI activation, comparing multiple designs

Usage

```
multiGLM_fun(
  BOLD,
  design,
  nuisance = NULL,
  design_canonical = NULL,
  verbose = 1,
  meanTol = 1e-06,
  varTol = 1e-06
)
```

Arguments

BOLD, design, nuisance	Session-length list of numeric matrices/arrays, each with volumes along the first dimension.
design_canonical	TO DO
verbose	1 (default) to print occasional updates during model computation; 2 for occasional updates as well as running INLA in verbose mode (if Bayes), or 0 for no printed updates.
meanTol, varTol	Tolerance for mean, variance and SNR of each data location. Locations which do not meet these thresholds are masked out of the analysis. Default: 1e-6 for mean and variance, 50 for SNR.

Value

A list with elements

bestmodel ...

Fstat ...

pvalF ...

```
nuisance_Param_BayesGLM
      nuisance
```

Description

nuisance

Arguments

nuisance (Optional) A $T \times N_{nuis}$ matrix of nuisance signals, where T is the number of timepoints and N is the number of nuisance signals, or a list of these for multi-session analysis. Nuisance signals are regressed from the fMRI data and design matrix prior to GLM computation. Nuisance signals can include motion regressors, HRF derivatives not being modeled as tasks, and other sources of noise.

Detrending/high-pass filtering is accomplished by adding DCT bases to the nuisance matrix; see the parameters `hpf` and `DCT`.

Do not add spike regressors for scrubbing to the nuisance matrix. Rather, provide these in `scrub` so that their corresponding timepoints are also removed from the BOLD data after nuisance regression.

```
plot.BfMRI_design      S3 method: use view\_xiffti to plot a "BGLM" object
```

Description

S3 method: use [view_xiffti](#) to plot a "BGLM" object

Usage

```
## S3 method for class 'BfMRI_design'
plot(x, ...)
```

Arguments

`x` An object of class "BfMRI_design".

`...` Additional arguments to [plot_design](#).

Value

Result of the call to [plot_design](#)

plot_design	<i>Plot design matrix</i>
-------------	---------------------------

Description

Plot design matrix

Plot design with lineplot

Plot design with imageplot

Usage

```
plot_design(design, method = c("lineplot", "imageplot"), ...)
```

```
plot_design_line(
  design,
  colors = "Set1",
  linetype = "solid",
  linewidth = 0.7,
  alpha = 0.8
)
```

```
plot_design_image(design)
```

Arguments

design	The timepoints by fields design matrix or data.frame.
method	"lineplot" (default) or "imageplot".
...	Additional arguments to plot_design_line or plot_design_image.
colors	The name of a ColorBrewer palette (see RColorBrewer::brewer.pal.info and colorbrewer2.org), the name of a viridisLite palette, or a character vector of colors. Default: "Set1".
linetype, linewidth, alpha	Parameters for ggplot2::geom_line. Defaults: "solid" linetype, 0.7 linewidth and 0.8 alpha. linetype can also be a vector of options with length matching the number of fields in design.

Value

A ggplot

A ggplot

A ggplot

resamp_res_Param_BayesGLM
resamp_res

Description

resamp_res

Arguments

resamp_res For cortex spatial model. The number of vertices to which each cortical surface should be resampled, or NULL to not resample.
For computational feasibility, a value of 10000 (default) or lower is recommended for Bayesian spatial modeling. If Bayes=FALSE, resamp_res can be set to NULL for full-resolution classical modeling.

scale_BOLD_Param *scale_BOLD*

Description

scale_BOLD

Arguments

scale_BOLD Controls scaling the BOLD response at each location.
"mean": Scale the data to percent local signal change.
"sd": Scale the data by local standard deviation.
"none": Center the data but do not scale it.

scrub_Param_BayesGLM *scrub*

Description

scrub

Arguments

scrub (Optional) A $T \times N_{scrub}$ matrix of spike regressors (one 1 value at the timepoint to scrub, and 0 for all other values), or a logical vector indicating the timepoints to scrub (TRUE to scrub, and FALSE to keep). For multi-session data, a session-length list of such matrices or logical vectors.
The spike regressors will be included in the nuisance regression, and afterwards the timepoints indicated in scrub will be removed from the BOLD data and design matrix.

session_names_Param	<i>session_names</i>
---------------------	----------------------

Description

session_names

Arguments

session_names The names of the task-fMRI BOLD sessions, for multi-session analysis. If not provided here, will be inferred from names(BOLD), inferred from names(design), or generated automatically, in that order.

summary.BfMRI_design	<i>Summarize a "BfMRI_design" object</i>
----------------------	--

Description

Summary method for class "BfMRI_design"

Usage

```
## S3 method for class 'BfMRI_design'
summary(object, ...)

## S3 method for class 'summary.BfMRI_design'
print(x, ...)

## S3 method for class 'BfMRI_design'
print(x, ...)
```

Arguments

object	Object of class "BfMRI_design".
...	further arguments passed to or from other methods.
x	Object of class "summary.BfMRI_design".

Value

A "summary.BfMRI_design" object, a list summarizing the properties of object.

NULL, invisibly.

NULL, invisibly.

surfaces_Param_BayesGLM
surfaces

Description

surfaces

Arguments

surfL, surfR For cortex spatial model. Left and right cortex surface geometry in GIFTI format (*.surf.gii). These can be a file path to a GIFTI file or a "surf" object from ciftiTools.
Surfaces can alternatively be provided through the \$surf metadata in BOLD if it is "xiffti" data. If neither are provided, by default the HCP group-average fs_LR inflated surfaces included in ciftiTools will be used for the cortex spatial model.

TR_Param_BayesGLM *TR*

Description

TR

Arguments

TR Temporal resolution of the data, in seconds.

verbose_Param *verbose*

Description

verbose

Arguments

verbose 1 (default) to print occasional updates during model computation; 2 for occasional updates as well as running INLA in verbose mode (if Bayes), or 0 for no printed updates.

Index

aic_Param, 2
ar_order_Param, 3
ar_smooth_Param, 3

BOLD_Param_BayesGLM, 3
brainstructures_Param_BayesGLM, 4

cderiv, 4
Connectome_Workbench_Description, 5

design_Param_BayesGLM, 5
do_QC, 5

faces_Param, 6
field_names_Param, 6

hpf_Param_BayesGLM, 7
HRF96, 7
HRF_calc, 8, 11
HRF_main, 9

make_design, 9
mask_Param_vertices, 11
mean_var_Tol_Param, 12
multiGLM, 12
multiGLM_fun, 14

nuisance_Param_BayesGLM, 15

plot.BfMRI_design, 15
plot_design, 15, 16
plot_design_image (plot_design), 16
plot_design_line (plot_design), 16
print.BfMRI_design
 (summary.BfMRI_design), 18
print.summary.BfMRI_design
 (summary.BfMRI_design), 18

resamp_res_Param_BayesGLM, 17

scale_BOLD_Param, 17

scrub_Param_BayesGLM, 17
session_names_Param, 18
summary.BfMRI_design, 18
surfaces_Param_BayesGLM, 19

TR_Param_BayesGLM, 19

verbose_Param, 19
view_xifti, 15