Data Processing of Resting-State fMRI: DPARSF

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DPARSF

frontiers in SYSTEMS NEUROSCIENCE

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DPARSF: a MATLAB toolbox for "pipeline" data analysis of resting-state fMRI

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Resting-state functional magnetic resonance imaging (fMRI) has attracted more and more attention because of its effectiveness, simplicity and non-invasiveness in exploration of the intrinsic functional architecture of the human brain. However, user-friendly toolbox for "pipeline" data analysis of resting-state fMRI is still lacking. Based on some functions in Statistical Parametric Mapping (SPM) and Resting-State fMRI Data Analysis Toolkit (REST), we have developed a MATLAB toolbox called Data Processing Assistant for Resting-State fMRI (DPARSF) for "pipeline" data analysis of resting-state fMRI. After the user arranges the Digital Imaging and Communications in Medicine (DICOM) files and click a few buttons to set parameters, DPARSF will then give all the preprocessed (slice timing, realign, normalize, smooth) data and results for functional connectivity, regional homogeneity, amplitude of low-frequency fluctuation (ALFF), and fractional ALFF. DPARSF can also create a report for excluding subjects with excessive head motion and generate a set of pictures for easily checking the effect of normalization. In addition, users can also use DPARSF to extract time courses from regions of interest.

Keywords: data analysis, DPARSF, REST, resting-state fMRI, SPM

(Yan and Zang, 2010)

DPARSF

Data Processing Assistant for Resting-State fMRI (DPARSF)

Yan and Zang, 2010. Front Syst Neurosci.

http://rfmri.org/DPARSF

DPABI

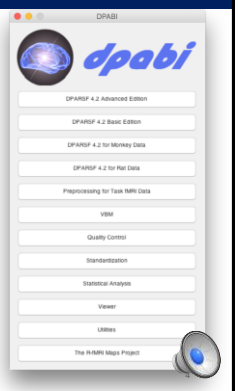
DPABI: a toolbox for Data Processing & Analysis of Brain Imaging

License: GNU GPL

Chao-Gan Yan
Programmer
Initiator

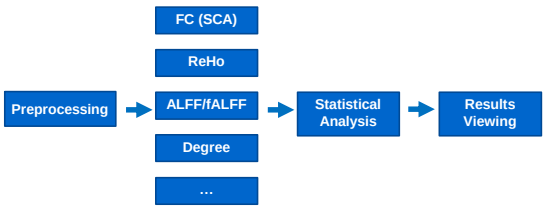
Xin-Di Wang
Programmer

http://rfmri.org/dpabi
http://dpabi.org



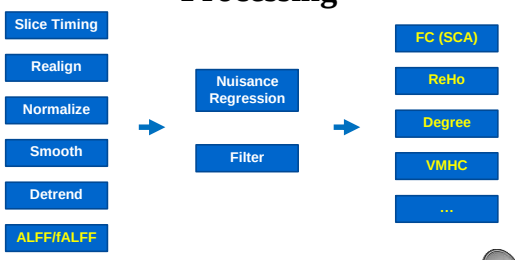
DPABI

Resting State fMRI Data Processing



DPABI

Resting State fMRI Data Processing



Calculate in MNI Space: TRADITIONAL order

DPABI

Resting State fMRI Data Processing

Slice Timing
Realign
Nuisance Regression
Normalize
Smooth
ALFF/fALFF

→ Filter →

FC (SCA)
ReHo
Degree
VMHC
…

Calculate in MNI Space: alternative order

DPABI

Resting State fMRI Data Processing

Slice Timing
Realign
Nuisance Regression
ALFF/fALFF
Filter

→

FC (SCA)
ReHo
Degree
…

→

Normalize
Smooth

Calculate in Original Space

Resting State fMRI Data Processing

Template Parameters

Data Organization

ProcessingDemoData.zip

FunRaw
- Sub_001
- Sub_002
- Sub_003

→ Functional DICOM data

T1Raw
- Sub_001
- Sub_002
- Sub_003

→ Structural DICOM data

http://rfmri.org/DemoData

Data Organization

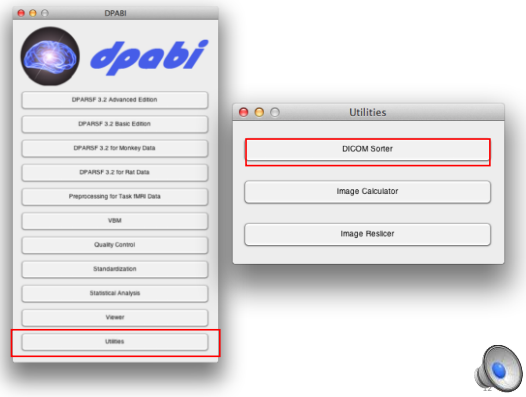
ProcessingDemoData.zip

FunImg
- Sub_001
- Sub_002
- Sub_003

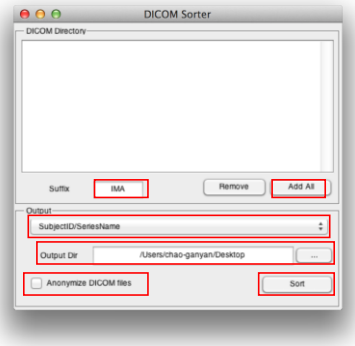
→ Functional NIfTI data (.nii.gz., .nii or .img)

T1Img
- Sub_001
- Sub_002
- Sub_003

→ Structural NIfTI data (.nii.gz., .nii or .img)

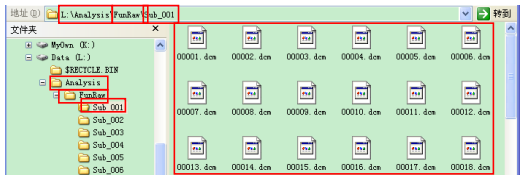


IMA
dcm
none



Data preparation

Arrange each subject's fMRI DICOM images in one directory, and then put them in "FunRaw" directory under the working directory.



SubjectSubjectDICOMfiles directory, please name as this
Working directory

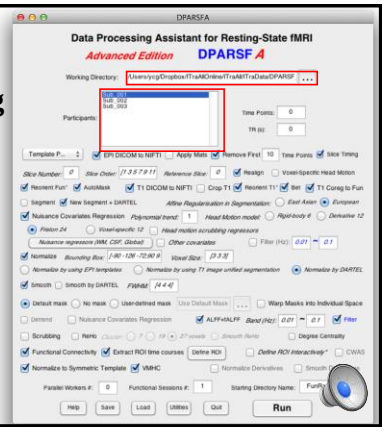
Data preparation

Arrange each subject's T1 DICOM images in one directory, and then put them in "T1Raw" directory under the working directory.

SubjectSubjectDICOMfiles directory, please name as this
Working directory

Preprocessing and R-fMRI measures Calculation

Working Dir where stored Starting Directory (e.g., FunRaw)
Detected participants



Preprocessing and R-fMRI measures Calculation

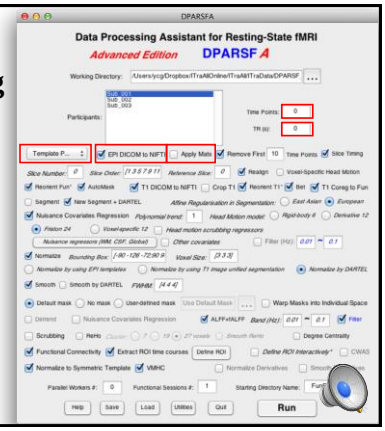
Detected participants

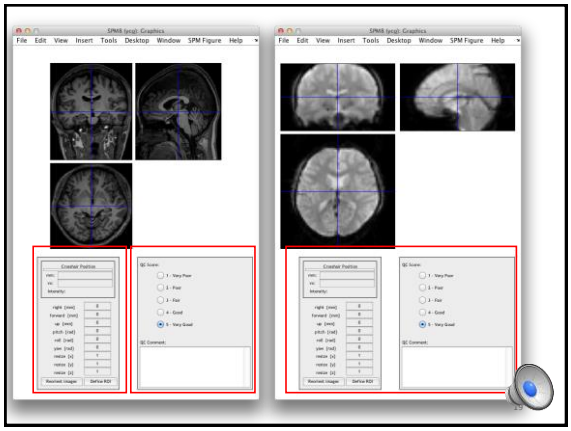
Preprocessing and R-fMRI measures Calculation

Number of time points
(if 0, detect automatically)
TR
(if 0, detect from NifTI header)

Template Parameters

DICOM to NifTI, based on MRIcroN's dcm2nii
Apply reorientation matrices





Preprocessing and R-fMRI measures Calculation

Apply reorientation matrices:

ReorientMats

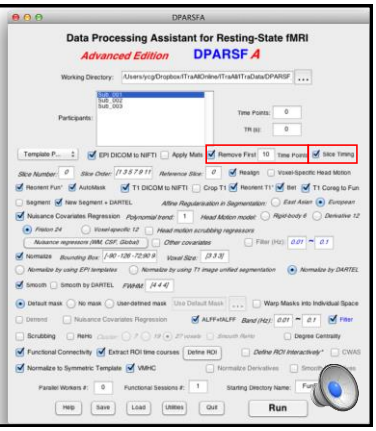
Rename to:

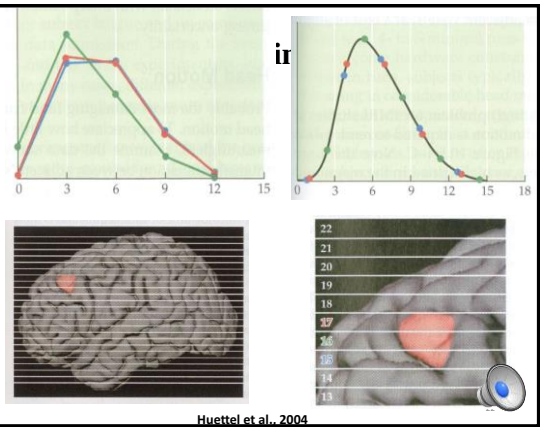
DownloadedReorientMats

Preprocessing and R-fMRI measures Calculation

Remove several first time points

Slice Timing





Preprocessing and R-fMRI measures Calculation

Total slice number

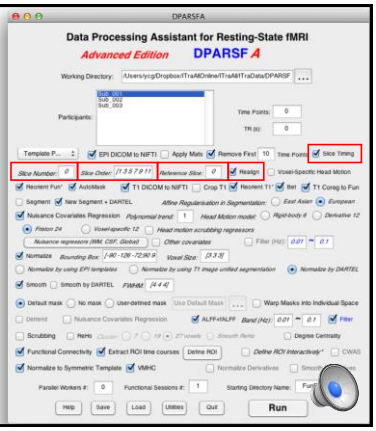
(if 0, The slice order is then assumed as interleaved scanning: [1:2:SliceNumber,2:2:SliceNumber]. The reference slice is set to the slice

slice order: 1:2:33,2:2:32

(ascending interleaved scanning)

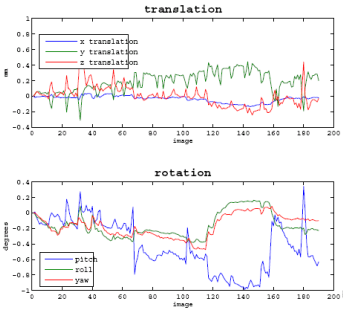
slice acquired in the middle time of each TR

(e.g., SHOULD BE CAUTIOUS!!!)



Realign

Why?



Realign

Check head motion:

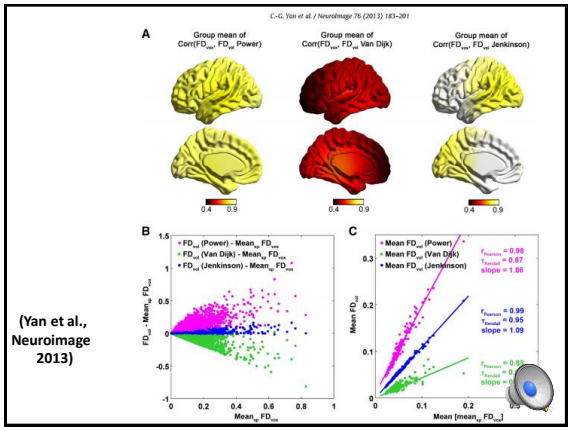
{WorkingDir}\RealignParameter\Sub_xxx:

rp_*.txt: realign parameters

FD_Power_*.txt: Frame-wise Displacement (Power et al., 2012)

FD_VanDijk_*.txt: Relative Displacement (Van Dijk et al., 2012)

FD_Jenkinson_*.txt: Relative RMS (Jenkinson et al., 2002)



(Yan et al., Neuroimage 2013)

Realign

Check hea

{WorkingD

ExcludeSu

Excluding Criteria: 2.5mm and 2.5 degree in max head motion
None

Excluding Criteria: 2.0mm and 2.0 degree in max head motion
Sub_013

Excluding Criteria: 1.5mm and 1.5 degree in max head motion
Sub_013

Excluding Criteria: 1.0mm and 1.0 degree in max head motion
Sub_007
Sub_012
Sub_013
Sub_017
Sub_018

Realign

Check head motion:

HeadMotion.csv: head motion characteristics for each subject (e.g., max or mean motion, mean FD, # or % of FD>0.2)

Threshold:

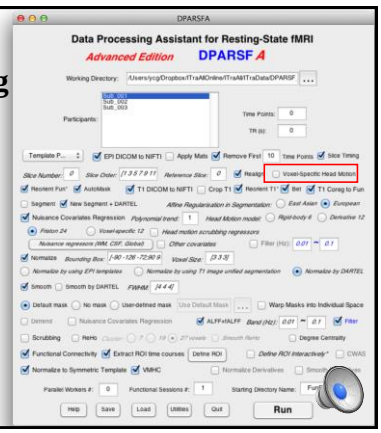
Group mean (mean FD) + 2 * Group SD (mean FD)

Yan et al., in press Neuroimage; Di Martino, in press, Mol Psychiatry

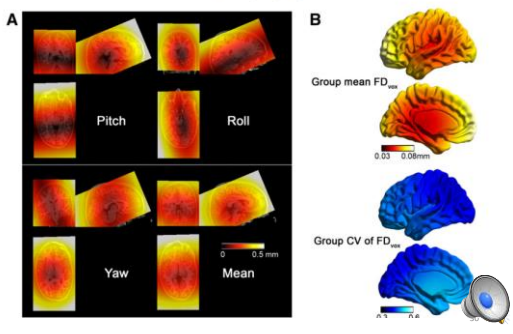
Preprocessing and R-fMRI measures Calculation

Voxel-Specific Head Motion Calculation

(Yan et al., Neuroimage 2013)



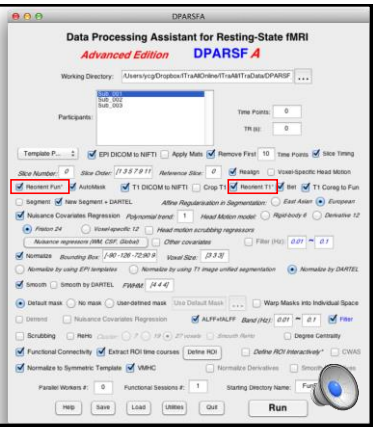
Voxel-Specific Head Motion Calculation

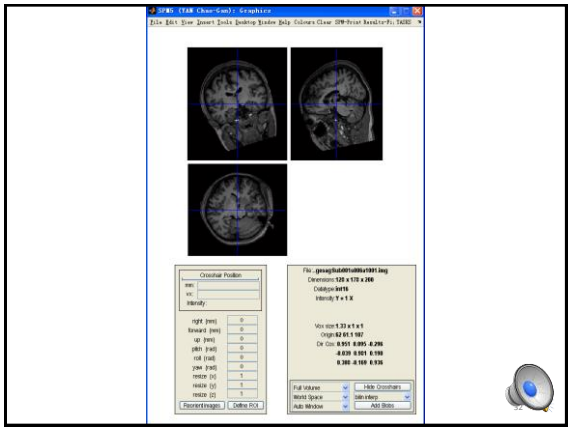


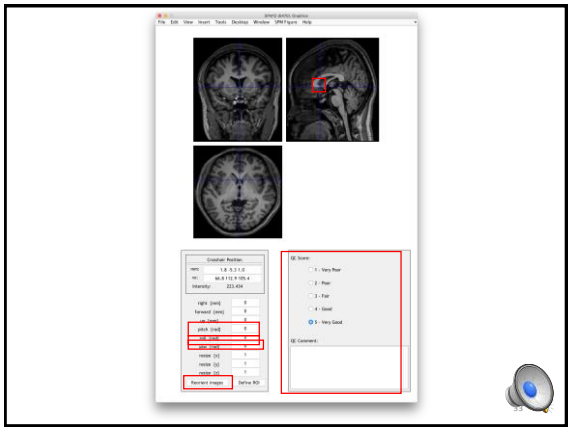
Preprocessing and R-fMRI measures Calculation

Reorient Interactively

This step could improve the accuracy in coregistration, segmentation and normalization, especially when images had a bad initial orientation. Also can take as a QC step.



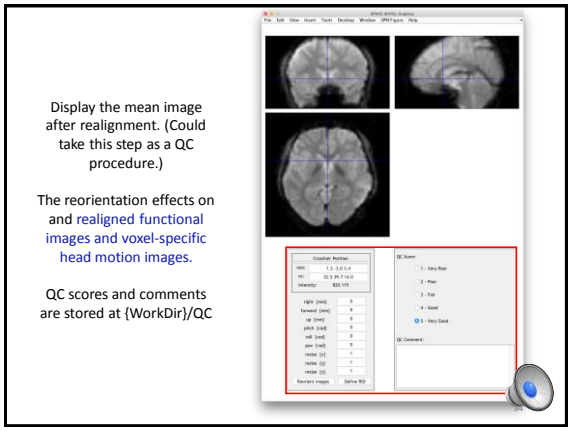




Display the mean image after realignment. (Could take this step as a QC procedure.)

The reorientation effects on and realigned functional images and voxel-specific head motion images.

QC scores and comments are stored at {WorkDir}/QC

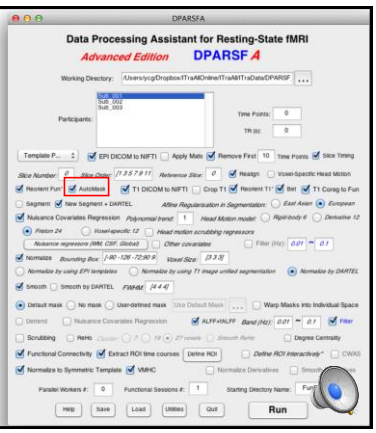


Automask generation

For checking EPI coverage and generating group mask

FunImgAR/Sub_001

Masks/AutoMasks/

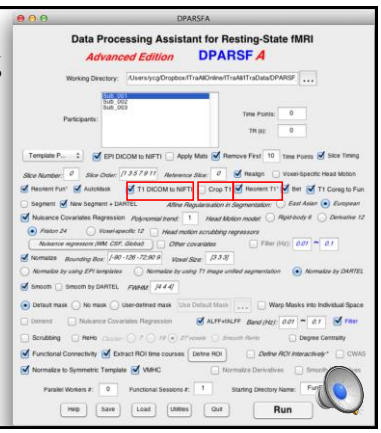


Preprocessing and R-fMRI measures Calculation

T1 DICOM files to NIfTI (based on MRIcroN's dcm2nii)

Crop T1 image (.nii, .nii.gz, .img) (based on MRIcroN's Dcm2nii)

Reorient T1 image Interactively

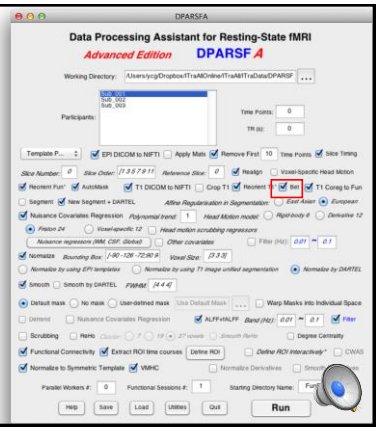


Brain extraction (Skullstrip)

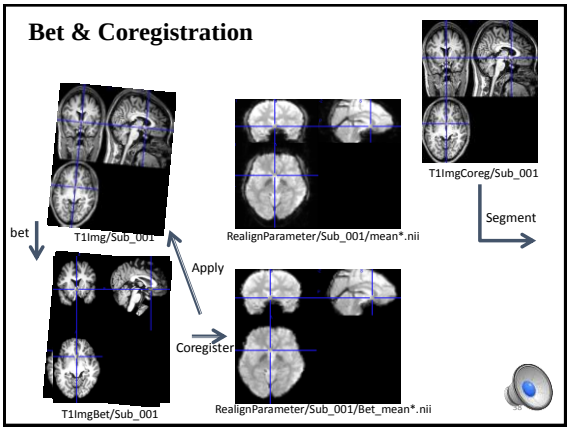
For better coregistration

For Linux and Mac:
Need to install FSL.

For Windows:
Thanks to Chris Rorden's compiled version of bet in MRIcroN, our modified version can work on NIfTI images directly.



Bet & Coregistration



Preprocessing and R-fMRI measures Calculation

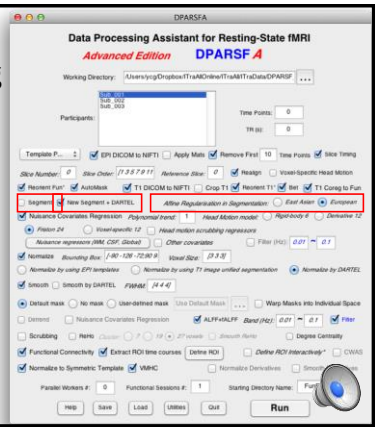
Coregister T1 image to functional space

Preprocessing and R-fMRI measures Calculation

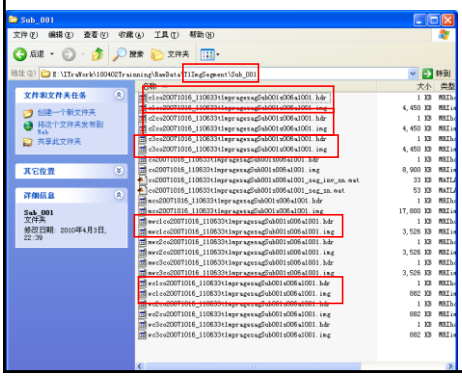
Unified Segmentation.
Information will be used in spatial normalization.

(In SPM12 only Segment)
New Segment and DARTEL.
Information will be used in spatial normalization.

Affine regularisation in segmentation



By-Product: VBM



GM in original space

WM in original space

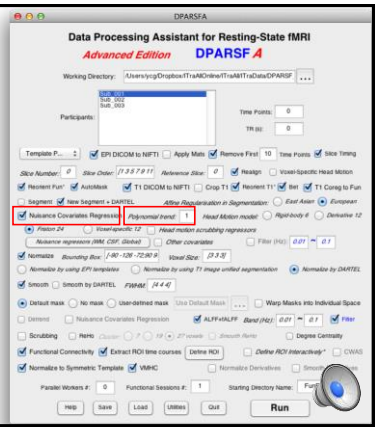
CSF in original space

Modulated GM in normalized space

GM in normalized space

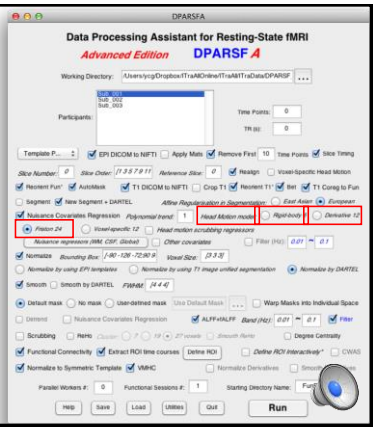
Preprocessing and R-fMRI measures Calculation

Nuisance Covariates Regression
Polynomial trends as regressors:
0: constant (no trends)
1: constant + linear trend (same as linear detrend)
2: constant + linear trend + quadratic trend
3: constant + linear trend + quadratic trend + cubic trend
...



Preprocessing and R-fMRI measures Calculation

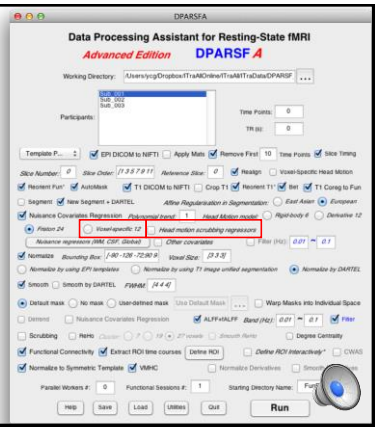
Head Motion regression model
6 head motion parameters
Friston 24-parameter model: 6 head motion parameters, 6 first derivatives, 6 head motion parameters one time point before, and the 12 corresponding squared items (Friston et al., 1996).
Derivative 12: 6 head



Preprocessing and R-fMRI measures Calculation

Voxel-specific 12-parameter model: the 3 voxel-specific translation motion parameters in x, y, z, the same 3 parameters for one time point before, and the 6 corresponding squared items

Head Motion Scrubbing Regressors



Each "bad" time point defined by FD will be used as a separate regressor.

Yan et al., 2013, Neuroimage

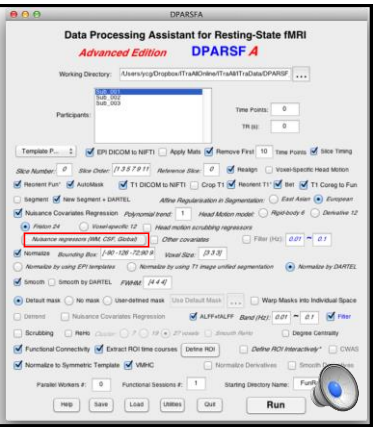
Table 3
Summary recommendations.

Summary recommendation
• Individual-level correction with the Friston-24 model is recommended. • Additionally, group-level correction for mean FD is recommended, and removes the need for scrubbing. • If group-level correction for mean FD is contraindicated or not practical, then individual-level correction with scrubbing is recommended for PCC-FC, VMHC and ReHo (not ALFF[a], fALFF, DC[b]).
Additional considerations
• Inclusion of global signal regression at the individual-level produces robust reductions in the relationships between motion and R-fMRI measures across participants – particularly for measures without Z-standardization. The benefits of GSR need to be balanced against potential risks for introduction of artifact in the specific analyses employed. • For studies limited to low motion datasets, the utility of higher-order Friston 24 model decreases. In this case, we recommend consideration of lower-order (i.e., 6 or 12-parameter) models to minimize the potential for over-fitting, as noted in Satterthwaite et al. (2013). • fALFF appeared to be relatively insensitive to motion correction strategies in the present work. Prior work (Satterthwaite et al., 2012) has suggested greater sensitivity in higher motion populations; as such we recommend continued application of correction procedures at the present time.

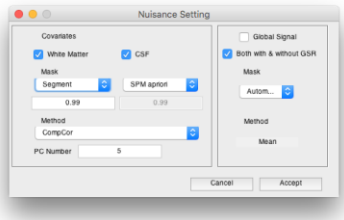
[a] Recommendations against scrubbing for ALFF and fALFF apply to commonly employed FFT-based implementations (see Limitations and future directions section for alternatives).
[b] Recommendations against scrubbing for DC were based on concerns regarding ability to compromise graph construction (see The ability of motion correction strategies to decrease residual relationships between motion and R-fMRI metrics at group-level section for demonstration).

Preprocessing and R-fMRI measures Calculation

Nuisance Regressors (WM, CSF, Global)



Nuisance Regression



- Mask based on segmentation or SPM apriori
- CompCor or mean [note: for CompCor, detrend (demean) and variance normalization will be applied before PCA, according to Behzadi et al., 2007]
- Global Signal based on Automask

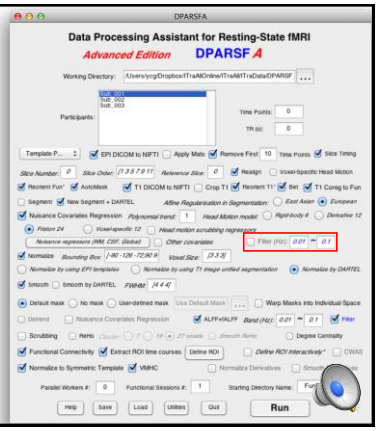
Preprocessing and R-fMRI measures Calculation

Define other covariates

Preprocessing and R-fMRI measures Calculation

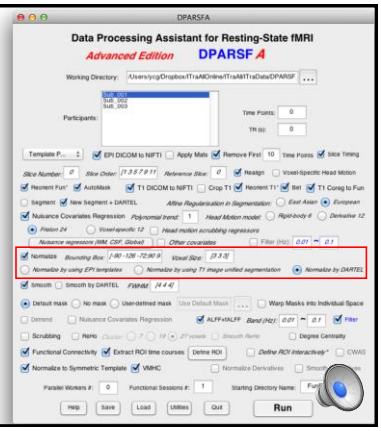
Filtering

The filtering parameters will be used later (Blue checkbox).

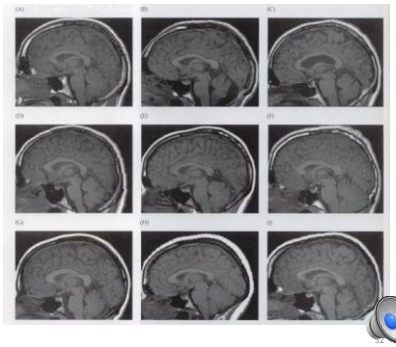


Preprocessing and R-fMRI measures Calculation

Spatial Normalization



Normalize



Huettel et al., 2004

Normalize

Methods:

I. Normalize by using EPI templates

II. Normalize by using T1 image unified segmentation

➡ III. Normalize by using DARTEL

IV. Normalize by using T1 templates (hidden)

Normalize

III. Normalize by using DARTEL

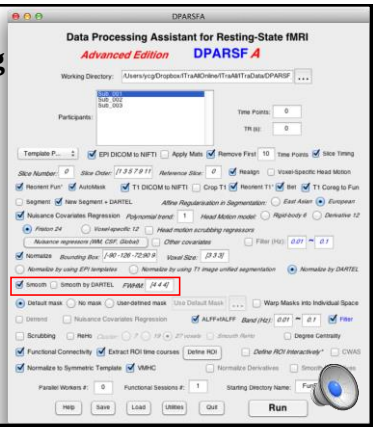
- Structural image was coregistered to the mean functional image after motion correction
- The transformed structural image was then segmented into gray matter, white matter, cerebrospinal fluid by using a unified segmentation algorithm (New Segment)
- DARTEL: create template
- DARTEL: Normalize to MNI space. The motion corrected functional volumes were spatially normalized to the MNI space using the normalization parameters estimated in DARTEL.

Preprocessing and R-fMRI measures Calculation

Smooth

For ReHo, Degree Centrality: don't smooth before calculation

FWHM kernel settings can be applied to later steps



Smooth

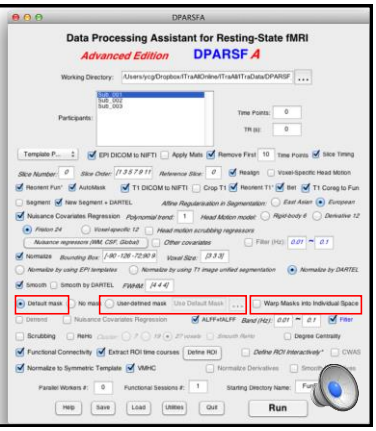
Why?

- Reduce the effects of bad normalization
- Increase SNR
- …

Mask

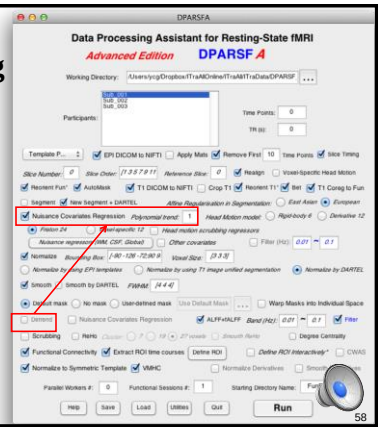
Default mask: SPM5 apriori mask (brainmask.nii) thresholded at 50%.
User-defined mask

Warp the masks into individual space by the information of DARTEL or unified segmentation.



Preprocessing and R-fMRI measures Calculation

Linear detrend (NO need since included in nuisance covariate regression)



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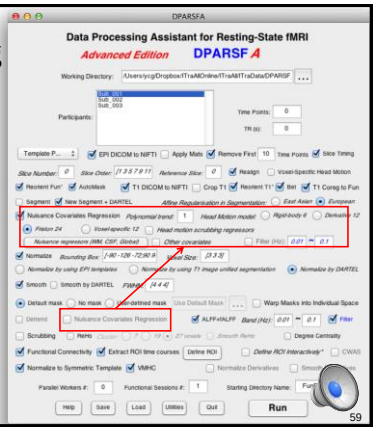
Preprocessing and R-fMRI measures Calculation

Nuisance Covariates Regression

If needed, then use the parameters set in the upper section.



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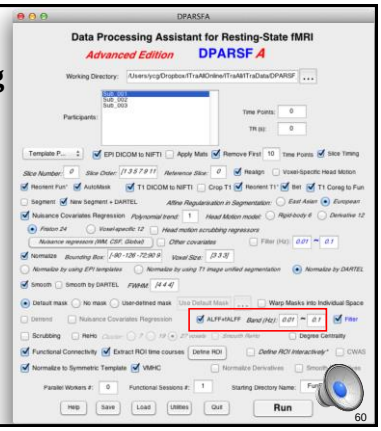
Preprocessing and R-fMRI measures Calculation

ALFF and fALFF calculation (Zang et al., 2007; Zou et al., 2008)



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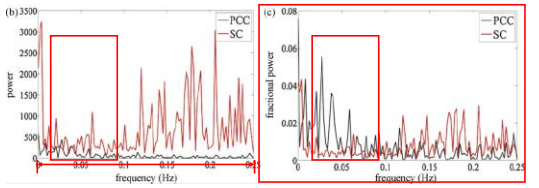
ALFF/fALFF

Amplitude of low frequency fluctuation / Fractional ALFF



PCC: posterior cingulate cortex

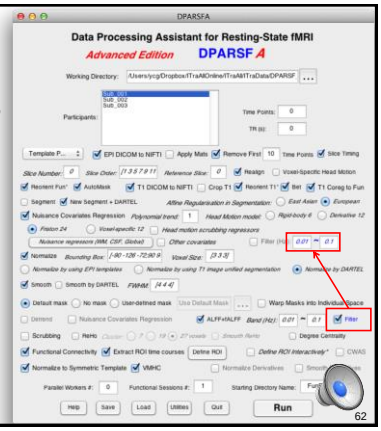
SC: suprasellar cistern

Zang et al., 2007; Zou et al., 2008

Preprocessing and R-fMRI measures Calculation

Filtering

Use the parameters set in the blue edit boxes.



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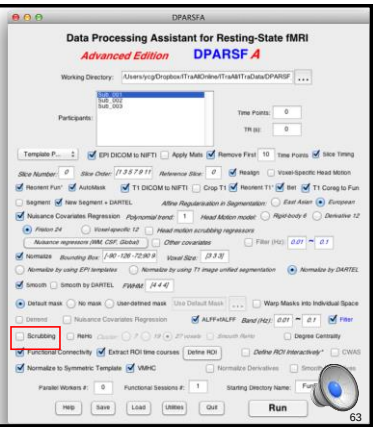
Preprocessing and R-fMRI measures Calculation

Scrubbing



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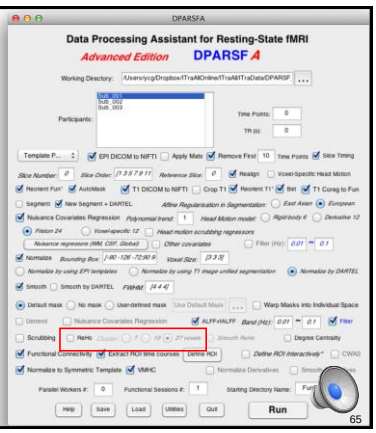
The "bad" time points defined by FD_Power (Power et al., 2012) will be interpolated or deleted as the specified method.

Preprocessing and R-fMRI measures Calculation

Regional Homogeneity (ReHo) Calculation (Zang et al., 2004)



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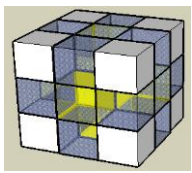
ReHo (Regional Homogeneity)



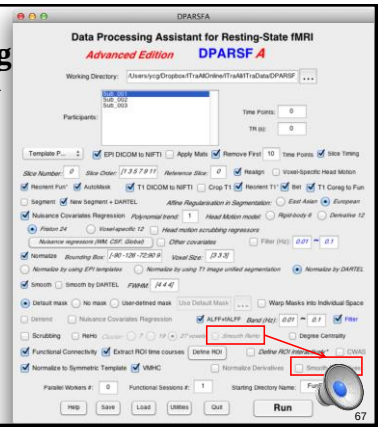
$$W = \frac{\Sigma(R_i)^2 - n(\overline{R})^2}{\frac{1}{12}K^2(n^3 - n)}$$

Zang et al., 2004

Zang YF, Jiang TZ, Lu YL, He Y, Tian LX (2004) Regional homogeneity approach to fMRI data analysis. Neuroimage 22: 39-

Preprocessing and R-fMRI measures Calculation

Regional Homogeneity (ReHo) Calculation (Zang et al., 2004)



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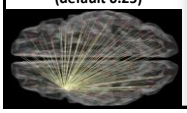
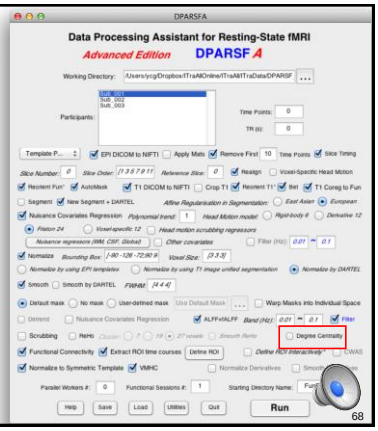
Preprocessing and R-fMRI measures Calculation

Degree Centrality Calculation (Buckner et al., 2009; Zuo et al, 2012)

> r Threshold (default 0.25)





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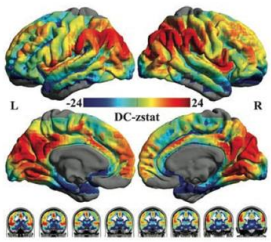


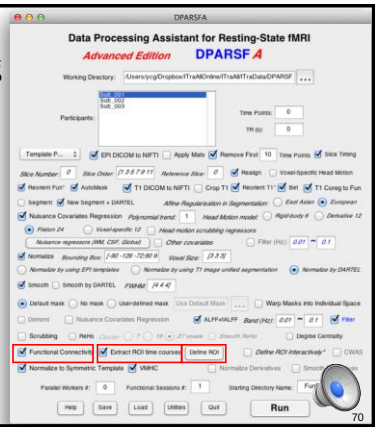
Zuo et al., 2012

Preprocessing and R-fMRI measures Calculation

Functional Connectivity (voxel-wise seed based correlation analysis)

Extract ROI time courses (also for ROI-wise Functional Connectivity)

Define ROI



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Define ROI

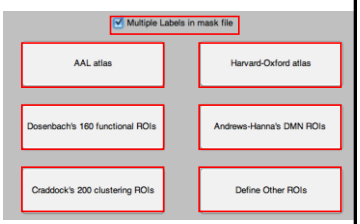
Multiple labels in mask file: each label is considered as one ROI

Dosenbach et al., 2010

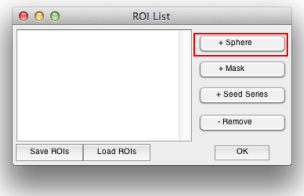
Andrews-Hanna et al., 2010

Craddock et al., 2011

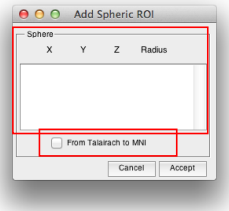
Define other ROIs



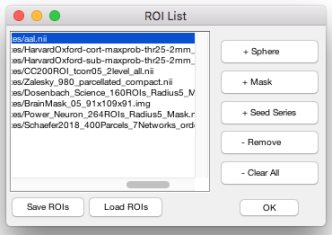
Define ROI



Define ROI

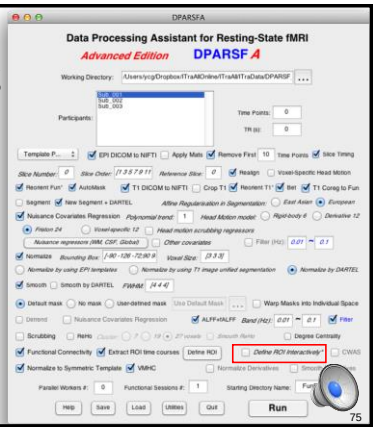


Define ROI



Preprocessing and R-fMRI measures Calculation

Define ROI Interactively



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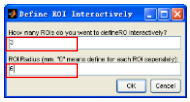
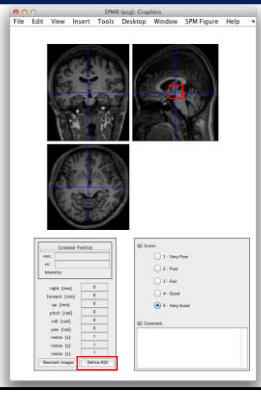
Define ROI



0 means define ROI Radius for each ROI seperately

Define ROI



Functional Connectivity

You will get the Voxel-wise functional connectivity results of each ROI in {working directory}\Results\FC:

zROI1FCMap_Sub_001.img

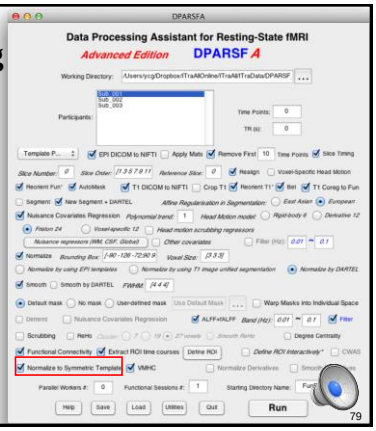
zROI2FCMap_Sub_001.img

For ROI-wise results, please see {working directory}\Results\FunImgARCW*_ROISignals.

Preprocessing and R-fMRI measures Calculation

Voxel-mirrored homotopic connectivity (VMHC) (Zuo et al., 2010)

Prepare for VMHC: Further register to a symmetric template



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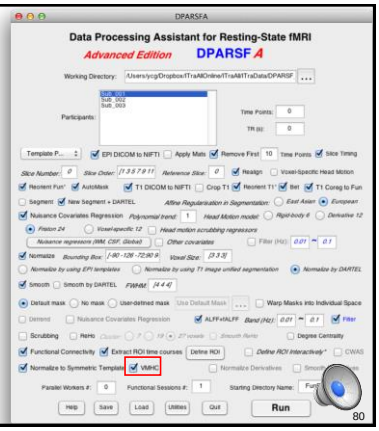
Preprocessing and R-fMRI measures Calculation

Voxel-mirrored homotopic connectivity (VMHC) (Zuo et al., 2010)



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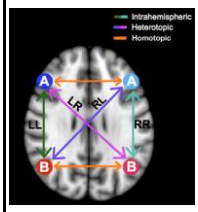
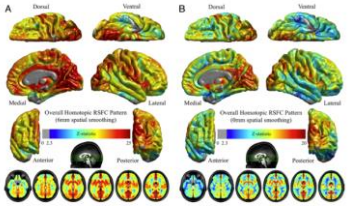
VMHC

1) Get the T1 images in MNI space (e.g., wco*.img or wco*.nii under T1ImgNewSegment or T1ImgSegment) for each subject, and then create a mean T1 image template (averaged across all the subjects).
2) Create a symmetric T1 template by averaging the mean T1 template (created in Step 1) with it's flipped version (flipped over x axis).
3) Normalize the T1 image in MNI space (e.g., wco*.img or wco*.nii under T1ImgNewSegment or T1ImgSegment) for each subject to the symmetric T1 template (created in Step 2), and apply the transformations to the functional data (which have been normalized to MNI space beforehand). Please see a reference from Zuo et al., 2010.



Gee et al., 2011



Zuo et al., 2010

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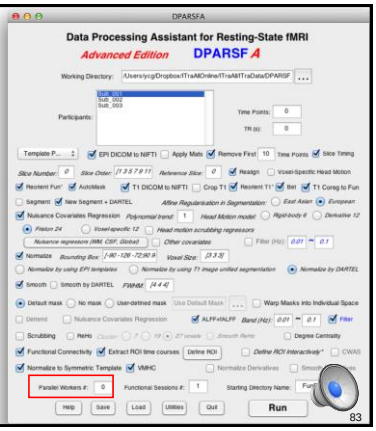
Preprocessing and R-fMRI measures Calculation

Parallel Workers (if parallel computing toolbox is installed)

Each subject is distributed into a different worker. (Except DARTEL-Create Template)



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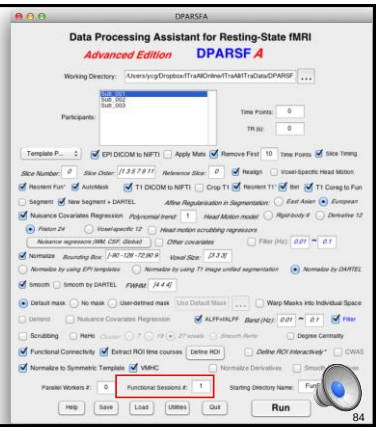
Preprocessing and R-fMRI measures Calculation

Multiple functional sessions

1st session: FunRaw
2nd session: S2_FunRaw
3rd session: S3_FunRaw
…



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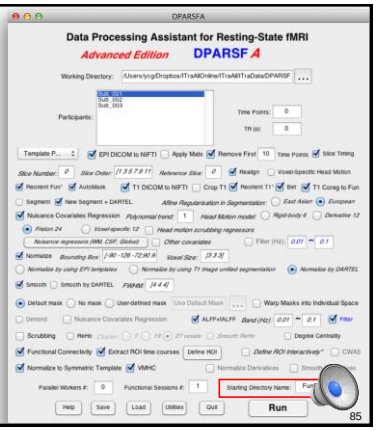
Starting Directory Name

If you do not start with raw DICOM images, you need to specify the Starting Directory Name.

E.g. "FunImgARW" means you start with images which have been slice timed, realigned and normalized.

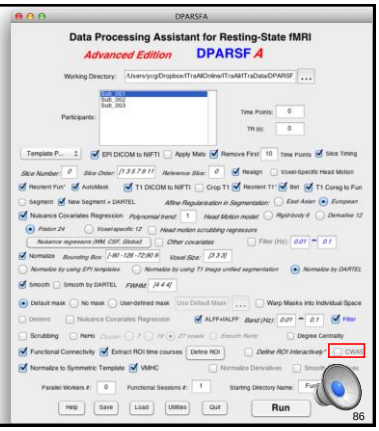
Abbreviations:
A - Slice Timing
R - Realign
W - Normalize
S - Smooth
D - Detrend
F - Filter
C - Covariates Removed
B - ScruBBing

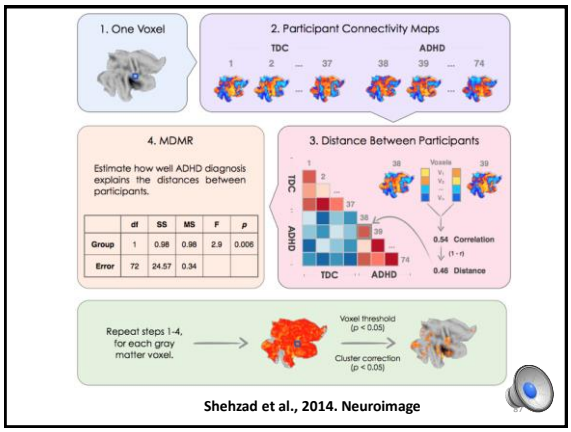


Preprocessing and R-fMRI measures Calculation

Connectome-wide association studies based on multivariate distance matrix regression (Shehzad et al., 2014)

Resource consuming as compared to other measures

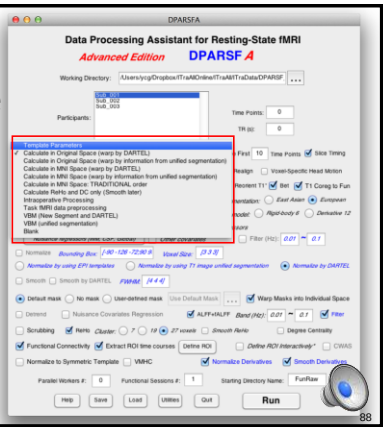




Shehzad et al., 2014. Neuroimage

Resting State fMRI Data Processing

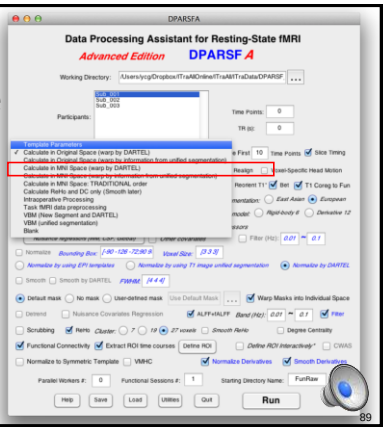
Template Parameters



Resting State fMRI Data Processing

Calculate in MNI space

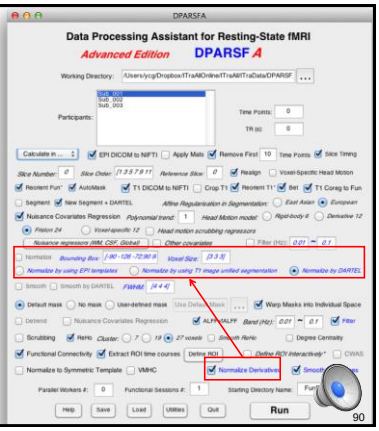
Calculate in Original space



Preprocessing and R-fMRI measures Calculation

Normalize measures (derivatives) calculated in original space into MNI space

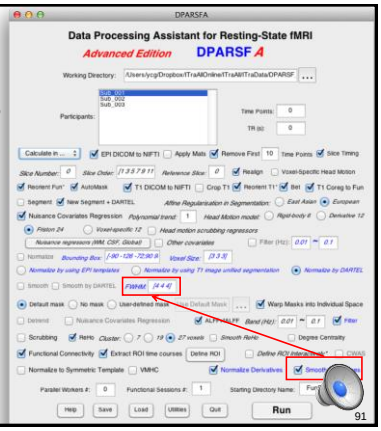
Use the parameters set in the upper section.



Preprocessing and R-fMRI measures Calculation

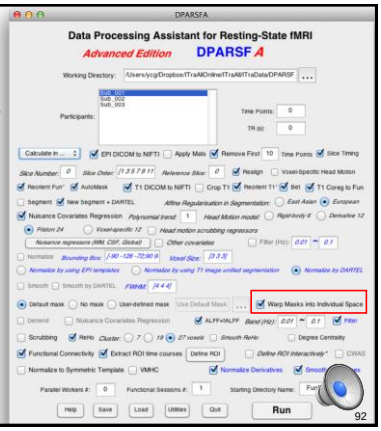
Smooth R-fMRI measures (derivatives)

Use the parameters set in the upper section.



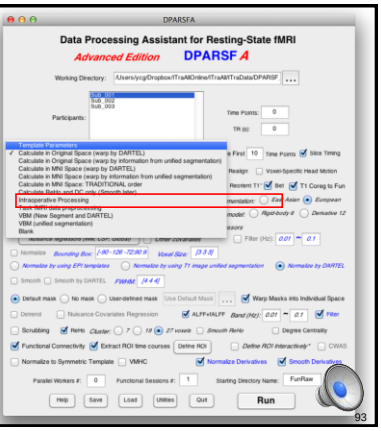
Preprocessing and R-fMRI measures Calculation

Warp masks into original space



Resting State fMRI Data Processing

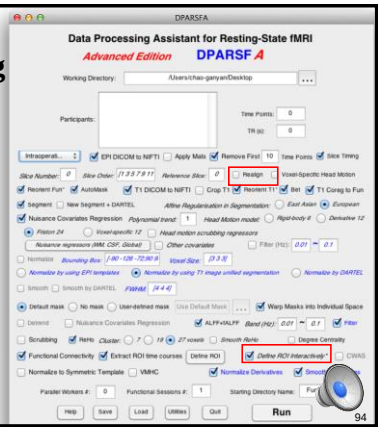
Intraoperative Processing



Preprocessing and R-fMRI measures Calculation

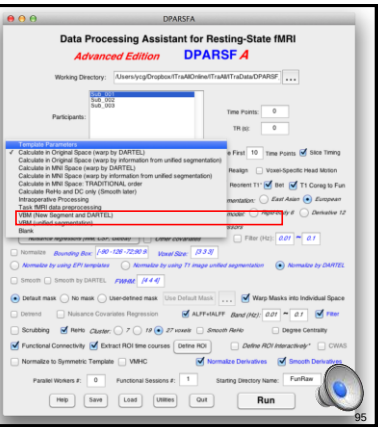
No realign since there is no head motion. DPARSFA will generate the mean functional images automatically.

Define ROI Interactively



Resting State fMRI Data Processing

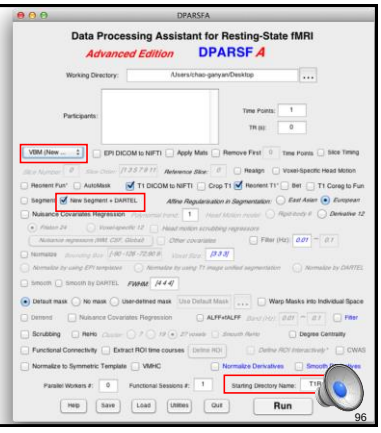
VBM



VBM

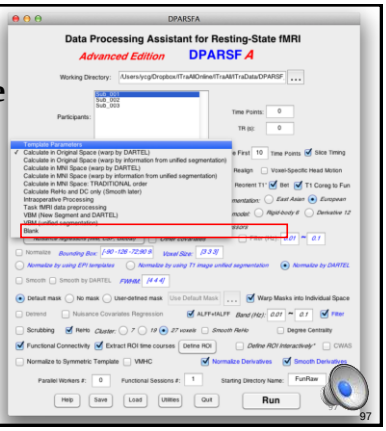
Only New Segment + DARTEL is checked

Define the Starting Directory Name as T1Raw



Resting State fMRI Data Processing

Blank



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Blank

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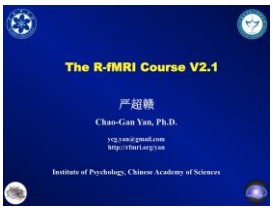
Save and Load Parameters

Save parameters to *.mat

Load parameters from *.mat

Further Help



http://rfmri.org/Course

http://rfmri.org/wiki

The R-fMRI Journal Club

Official Account: RFMRILab

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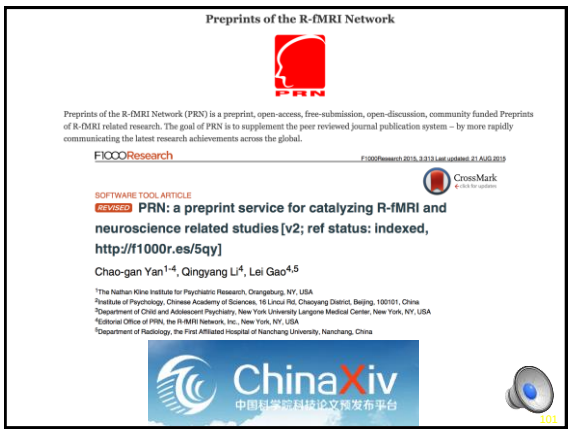

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数据分析与深度培训

静息态功能磁共振成像深度数据分析

功能磁共振成像越来越成为一种主流的科研手段，然而功能磁共振的数据分析却是一项具有高度挑战性的工作。海量的原始数据，繁多的分析步骤，复杂的分析方法都让研究者们无所适从。恰当的分析方法可以从普通的数据中挖掘出富有创新性的结果，而不适当的分析则可能让精心收集的数据黯然失色。深度大脑公司联合中国科学院 The R-fMRI Lab 的专业脑功能成像研究团队推出一站式功能磁共振数据分析解决方案，助您从容应对功能磁共振数据带来的挑战。

http://deepbrain.com

静息态功能磁共振成像数据处理深度特训

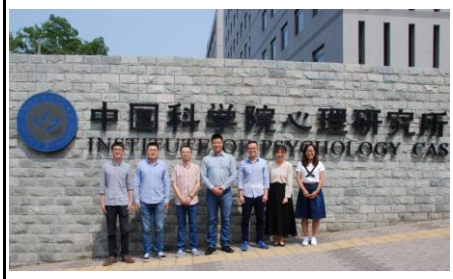
从您见到这条消息开始，您便拥有机会与中国科学院 The R-fMRI Lab 的静息态功能磁共振专家团队共同探索大脑的奥秘！深度跟组特训期间，您将会亲身体验：

- 数据处理　专家指导下高效学习静息态功能磁共振成像数据处理
- 思路设计　与国际知名专家讨论形成研究思路
- 论文撰写　系统的 SCI 论文写作训练

The R-fMRI Lab

WeChat Official Account: RFMRILab

Acknowledgments



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NYU Child Study Center
F. Xavier Castellanos

Child Mind Institute
Michael P. Milham

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- National Key R&D Program of China
- Chinese Academy of Sciences

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Thanks for your attention!

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