Data Processing of Resting-State fMRI: DPARSF

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DPARSF

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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

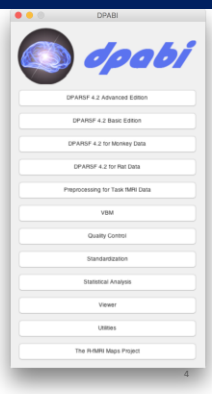
DPABI: a toolbox for Data Processing & Analysis of Brain Imaging

License: GNU GPL

Chao-Gan Yan
Programmer
Initiator

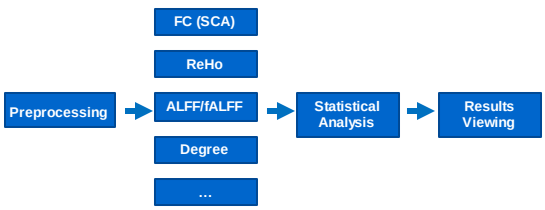
Xin-Di Wang
Programmer

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



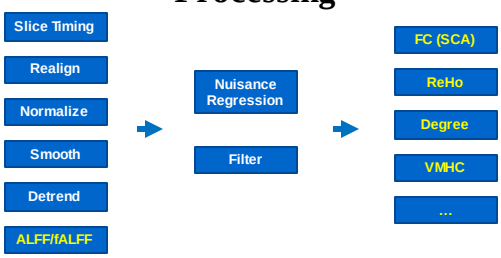
DPABI

Resting State fMRI Data Processing



DPABI

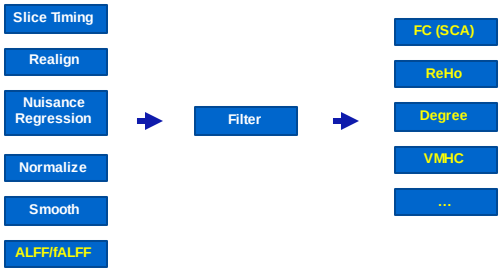
Resting State fMRI Data Processing



Calculate in MNI Space: TRADITIONAL order

DPABI

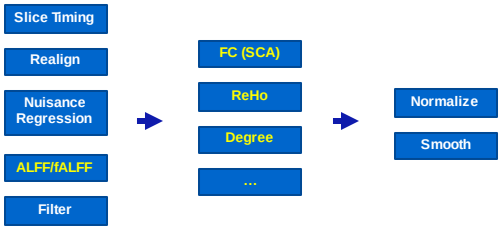
Resting State fMRI Data Processing



Calculate in MNI Space: alternative order

DPABI

Resting State fMRI Data Processing



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

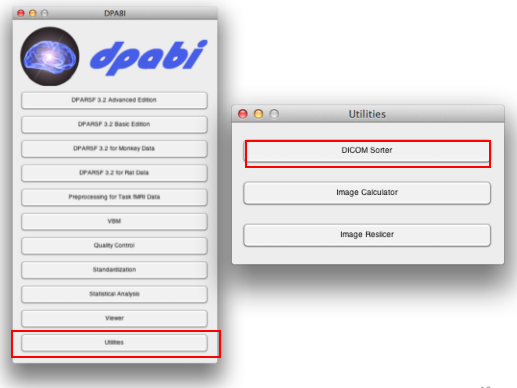
Sub_001
Sub_002
Sub_003

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

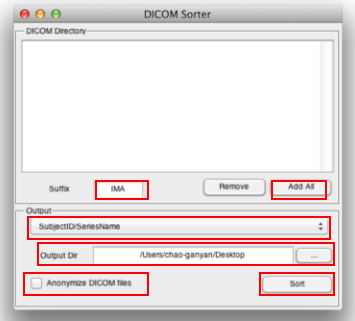
T1Img

Sub_001
Sub_002
Sub_003

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



IMA
dcm
none



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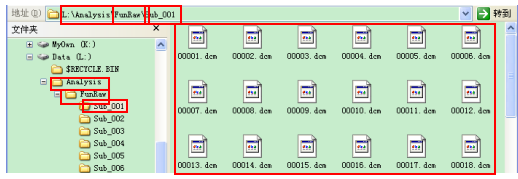
Data preparation

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



SubjectID directory, please name as this
Working directory

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Data preparation

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

SubjectID directory, please name as this
Working directory

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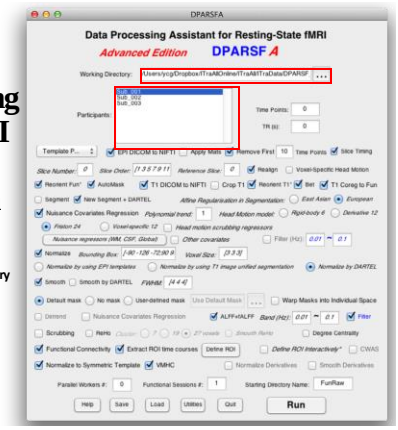
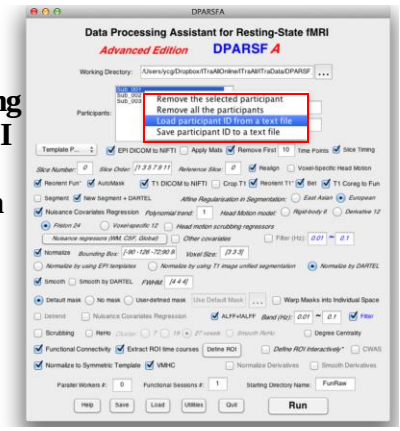
Preprocessing and R-fMRI measures Calculation

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



Preprocessing and R-fMRI measures Calculation

Detected participants



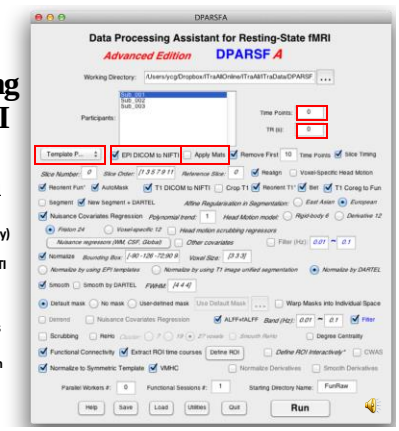
Preprocessing and R-fMRI measures Calculation

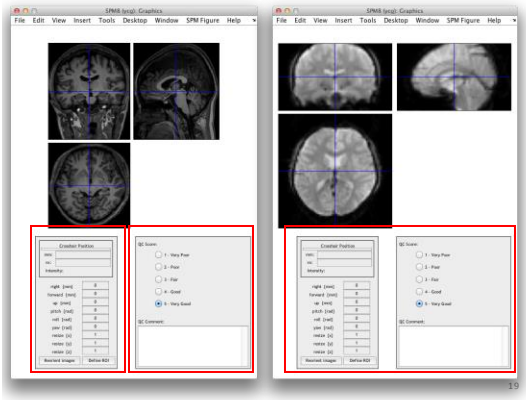
Number of time points (if 0, detect automatically)
TR (if 0, detect from NIfTI header)

Template Parameters

DICOM to NIfTI, based on MRIcroN's dcm2nii

Apply reorientation matrices





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Preprocessing and R-fMRI measures Calculation

Apply reorientation matrices:

ReorientMats

Rename to:

DownloadedReorientMats

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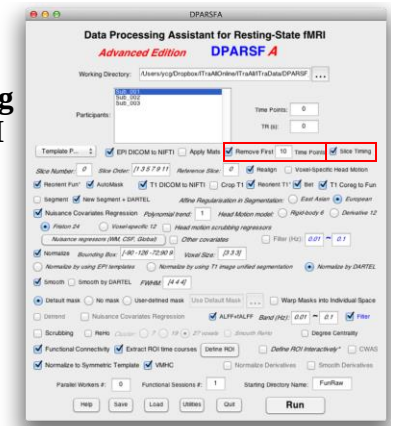
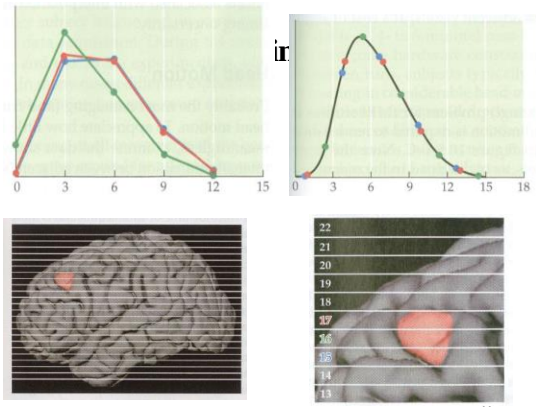
Preprocessing and R-fMRI measures Calculation

Remove several first time points

Slice Timing





Huettel et al., 2004

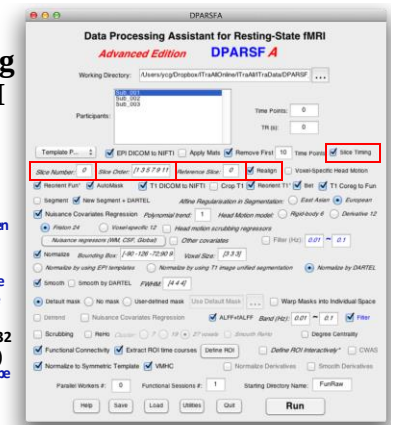
Preprocessing and R-fMRI measures Calculation

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 acquired in the middle time of each TR

Slice order: [1:2:33,2:2:32] (Interleaved scanning)

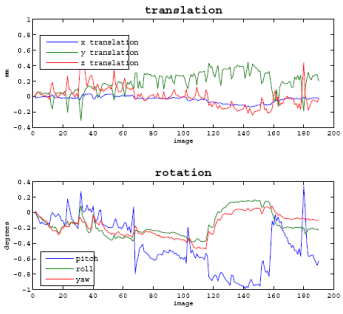
Reference slice: 17

CAUTIOUS!!!)



Realign

Why?



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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)

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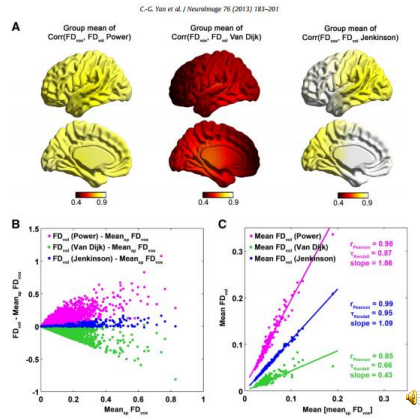
(Yan et al., Neuroimage 2013)



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

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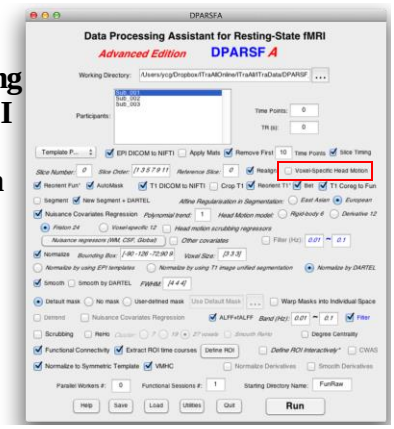
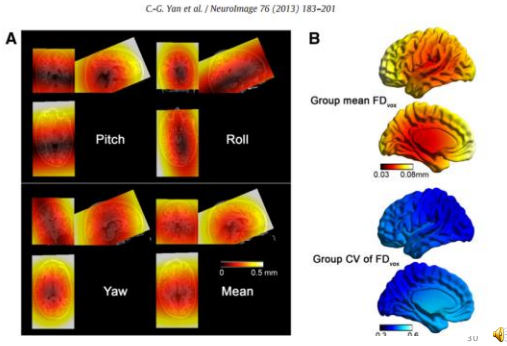
Preprocessing and R-fMRI measures Calculation

Voxel-Specific Head Motion Calculation

(Yan et al., Neuroimage 2013)



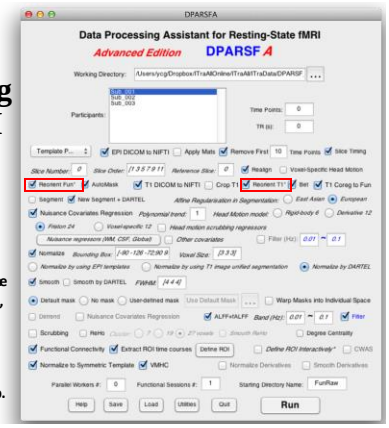
Voxel-Specific Head Motion Calculation

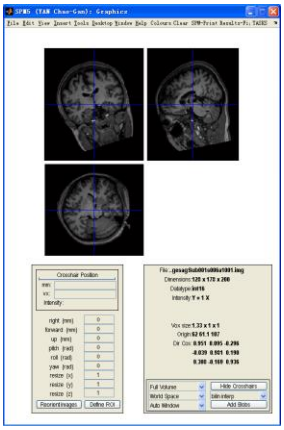


Preprocessing and R-fMRI measures Calculation

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.





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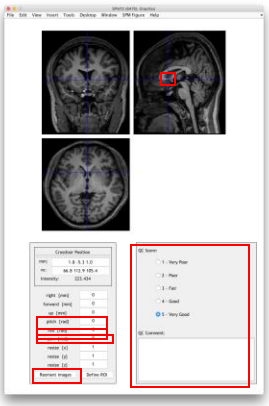

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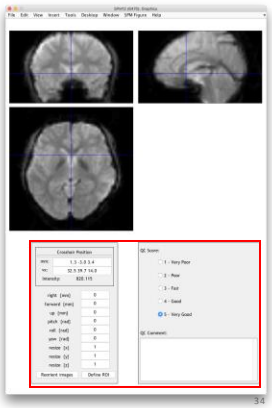
Display the mean image after realignment. (Could take this step as a QC procedure.)

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

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



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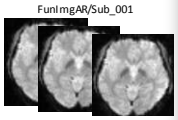
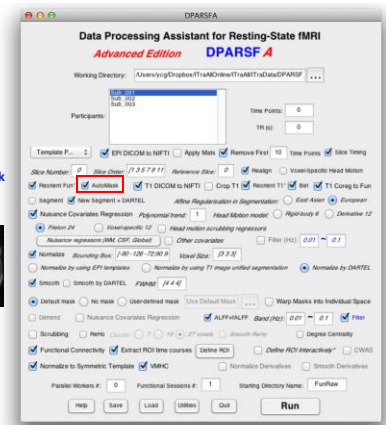
Automask generation

For checking EPI coverage and generating group mask

FunImgAR/Sub_001



Masks/AutoMasks/

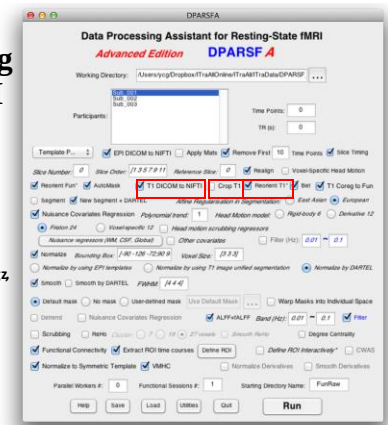


Preprocessing and R-fMRI measures Calculation

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

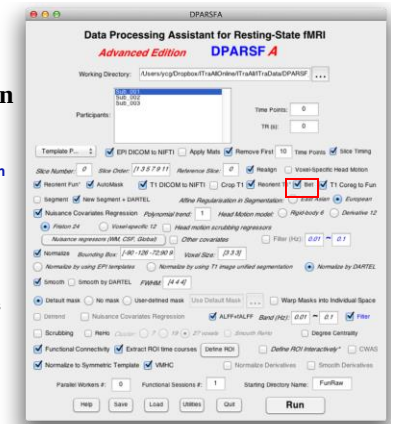


Brain extraction (Skullstrip)

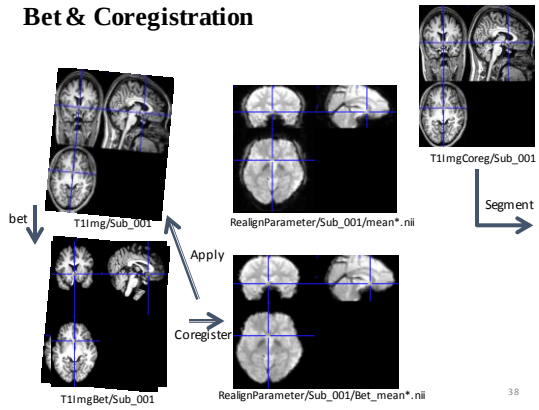
For better coregistration

For Linux and Mac:
Need to install FSL or dpabi docker

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



Bet & Coregistration



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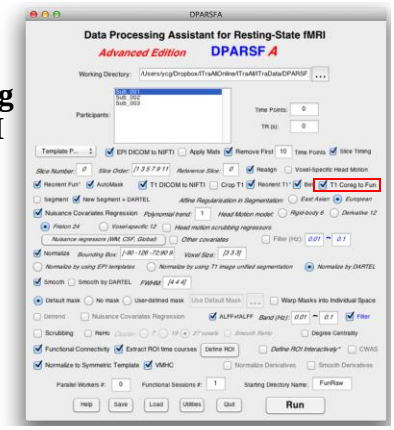
Preprocessing and R-fMRI measures Calculation

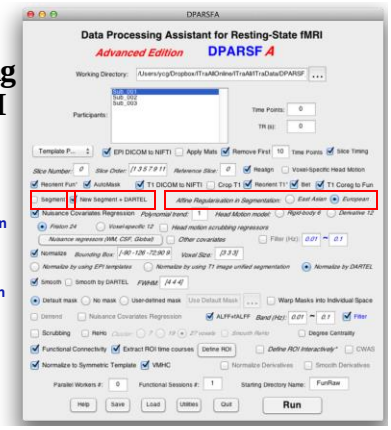
Coregister T1 image to functional space



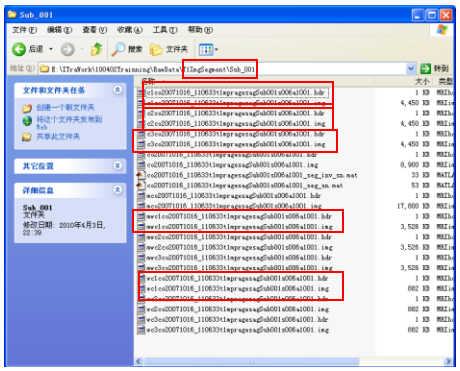
Preprocessing and R-fMRI measures Calculation

Unified Segmentation.
Information will be used in spatial normalization.
(In SPM12 old 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

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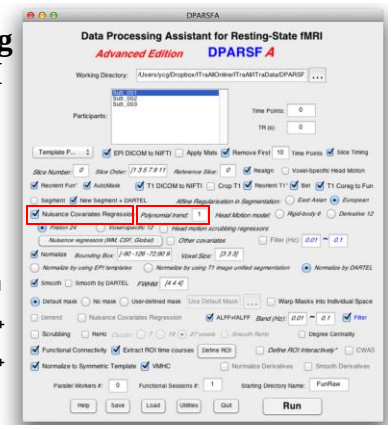
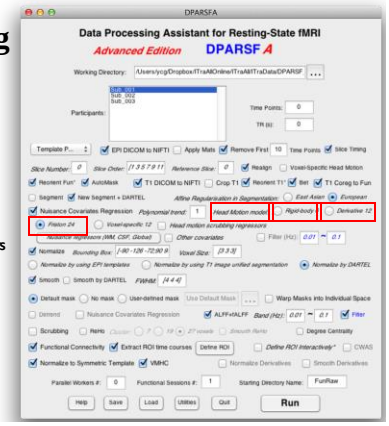
Preprocessing and R-fMRI measures Calculation

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

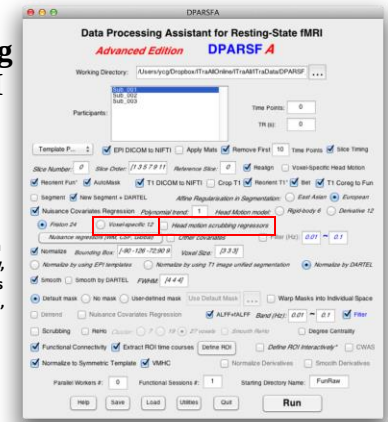
Head Motion regression model
6 head motion parameters
Derivative 12: 6 head motion parameters, 6 first derivatives
Friston 24-parameter model: 6 head motion parameters one time point before, and the 12 corresponding squared items (Friston et al., 1996).



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.

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Yan et al., 2013, Neuroimage

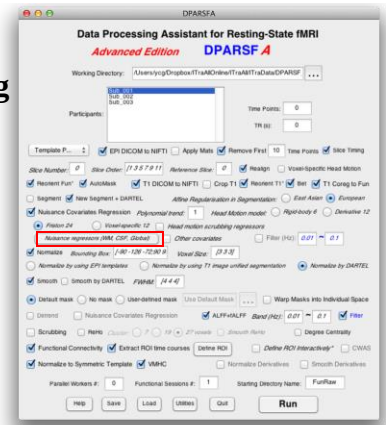
Table 3
Summary recommendations.

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.

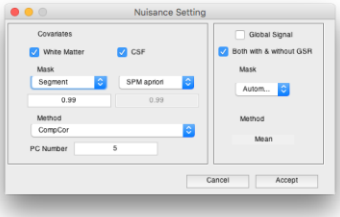
[a] Recommendations against scrubbing for ALFF and fALFF apply to commonly employed FFT-based implementations (see Limitations and future directions section for alternatives).
[b] Recommendations against scrubbing for DC were based on concerns regarding its ability to compromise graph construction (see 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

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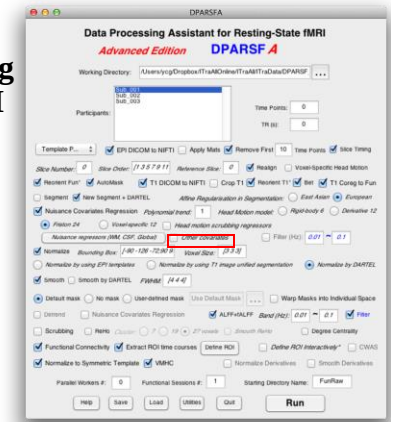
Preprocessing and R-fMRI measures Calculation

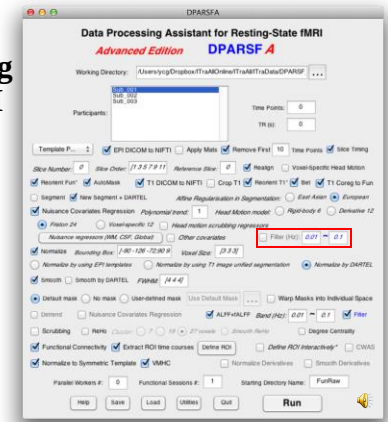
Define other covariates



Preprocessing and R-fMRI measures Calculation

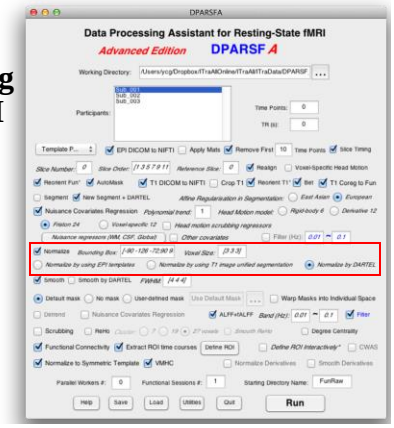
Filtering

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



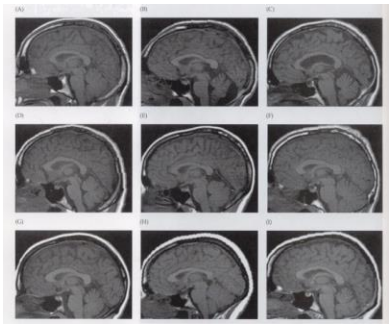
Preprocessing and R-fMRI measures Calculation

Spatial Normalization



Normalize

Huettel et al., 2004



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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)

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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.

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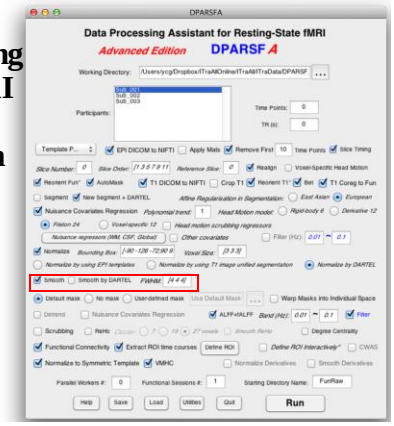
Preprocessing and R-fMRI measures Calculation

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**
- **...**

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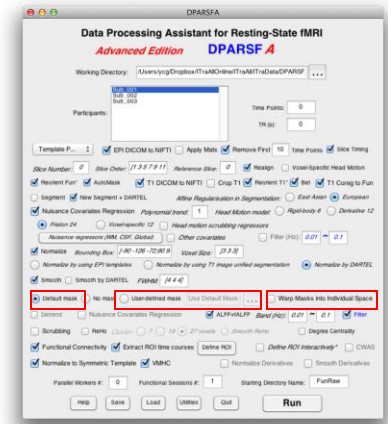
Mask

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

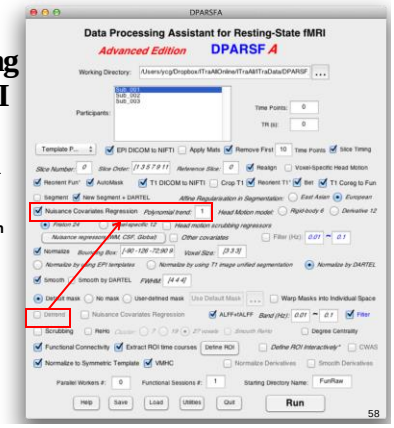
User-defined mask

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



Preprocessing and R-fMRI measures Calculation

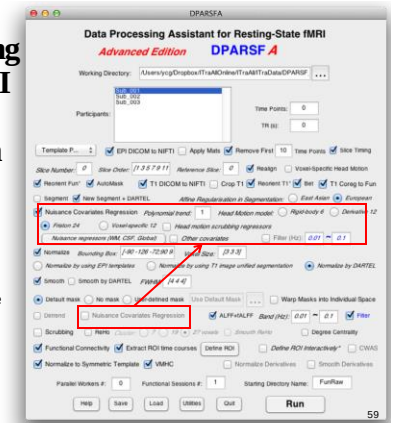
Linear detrend (NO need since included in nuisance covariate regression)



Preprocessing and R-fMRI measures Calculation

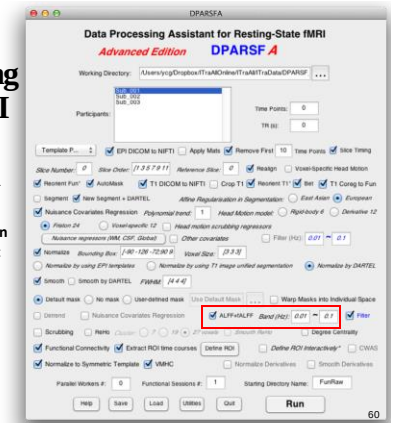
Nuisance Covariates Regression

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



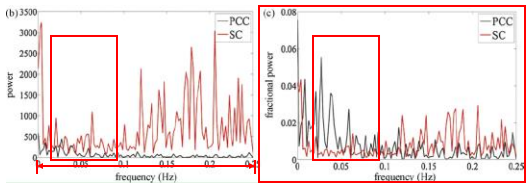
Preprocessing and R-fMRI measures Calculation

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



ALFF/fALFF

Amplitude of low frequency fluctuation / Fractional ALFF



PCC: posterior cingulate cortex

SC: suprasellar cistern

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

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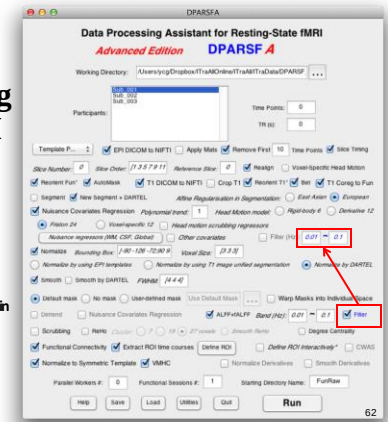
Preprocessing and R-fMRI measures Calculation

Filtering

Use the parameters set in the blue edit boxes.



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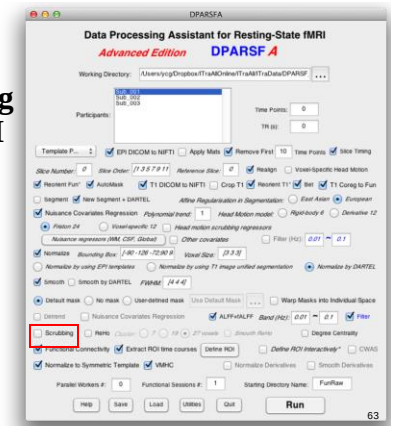
Preprocessing and R-fMRI measures Calculation

Scrubbing



63

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

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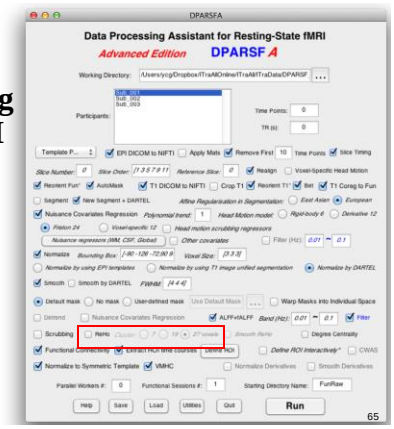
Preprocessing and R-fMRI measures Calculation

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



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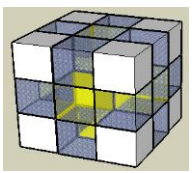
ReHo (Regional Homogeneity)



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

Zang et al., 2004

Zang YF, Jiang TZ, Lu YL, He Y, Tian LX (2004) Regional homogeneity approach to fMRI data analysis. Neuroimage 22: 394–400.

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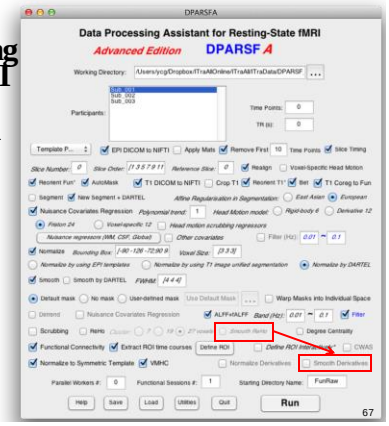
Preprocessing and R-fMRI measures Calculation

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



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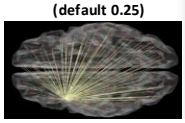
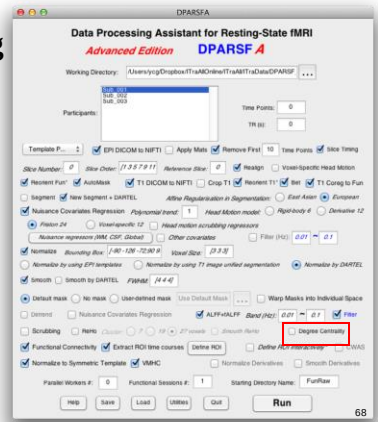
Preprocessing and R-fMRI measures Calculation

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

> r Threshold (default 0.25)





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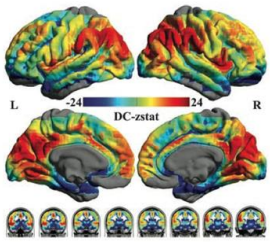

Zuo et al., 2012

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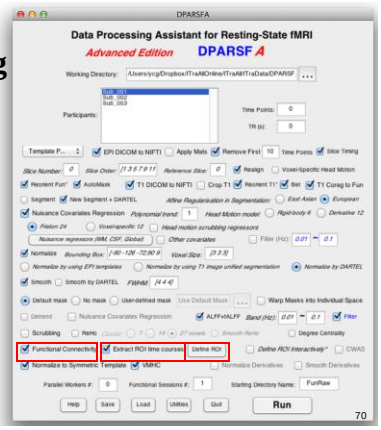
Preprocessing and R-fMRI measures Calculation

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

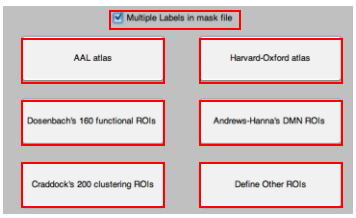
Multiple labels in mask file: each label is considered as one ROI

Dosenbach et al., 2010

Andrews-Hanna et al., 2010

Craddock et al., 2011

Define other ROIs



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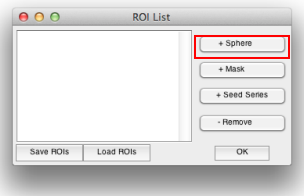
Define ROI



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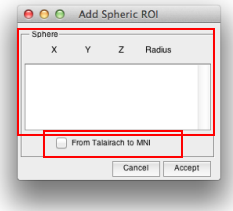
Define ROI



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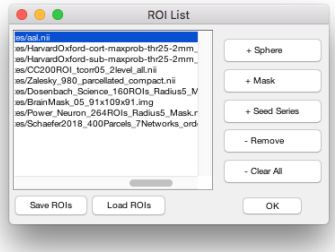
Define ROI



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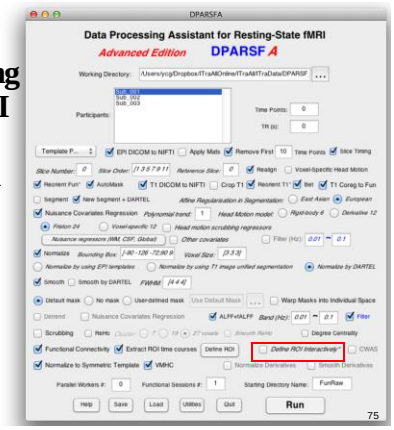
Preprocessing and R-fMRI measures Calculation

Define ROI Interactively



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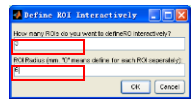
Define ROI



0 means define ROI Radius for each ROI seperately

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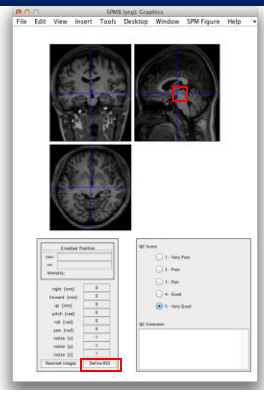
Define ROI



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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.

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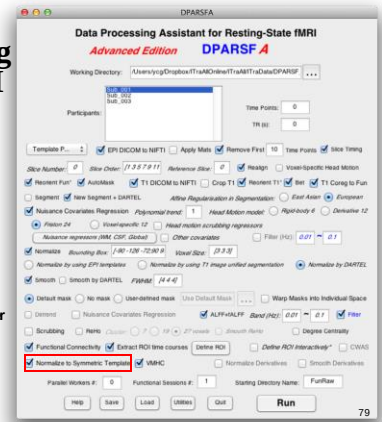
Preprocessing and R-fMRI measures Calculation

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.

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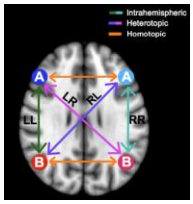
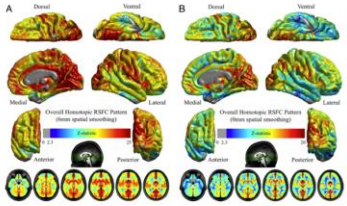


Gee et al., 2011



Zuo et al., 2010

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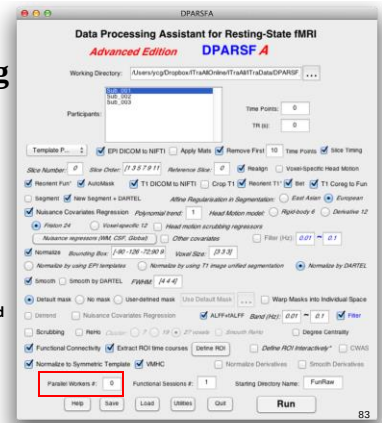
Preprocessing and R-fMRI measures Calculation

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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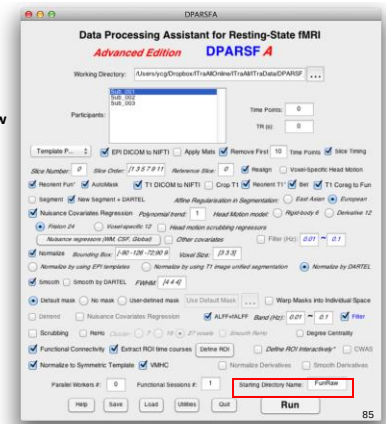
Starting Directory Name

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



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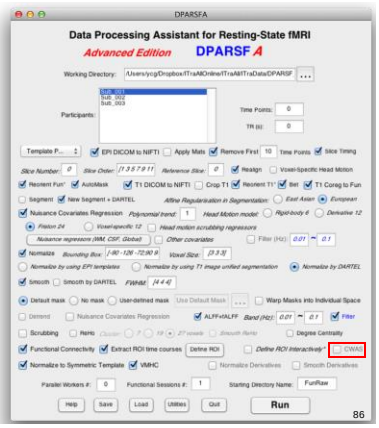
Preprocessing and R-fMRI measures Calculation

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

Resource consuming as compared to other measures



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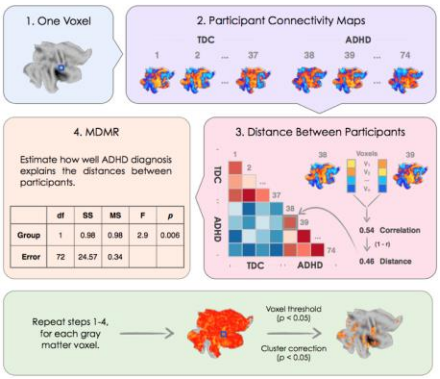

Shehzad et al., 2014. Neuroimage

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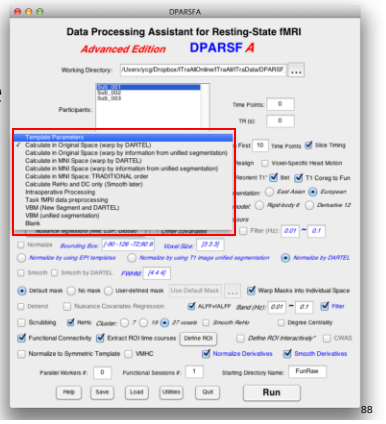
Resting State fMRI Data Processing

Template Parameters



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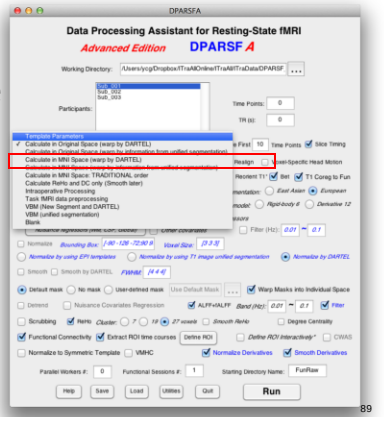
Resting State fMRI Data Processing

Calculate in MNI space

Calculate in Original space



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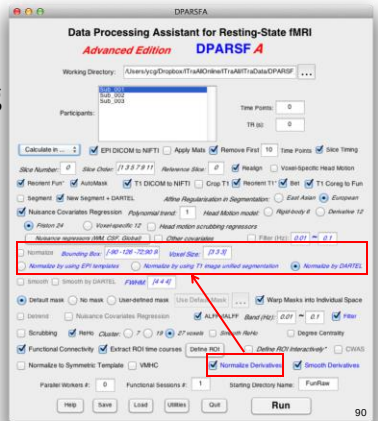
Preprocessing and R-fMRI measures Calculation

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

Use the parameters set in the upper section.



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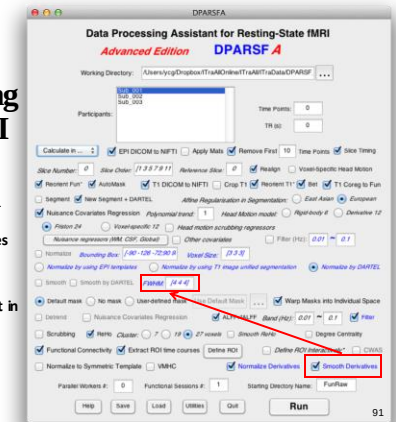
Preprocessing and R-fMRI measures Calculation

Smooth R-fMRI measures (derivatives)

Use the parameters set in the upper section.

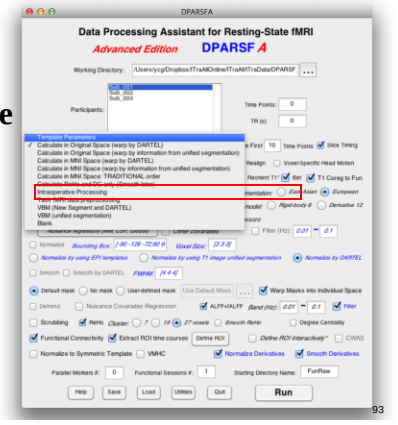


Preprocessing and R-fMRI measures Calculation

Warp masks into original space

Resting State fMRI Data Processing

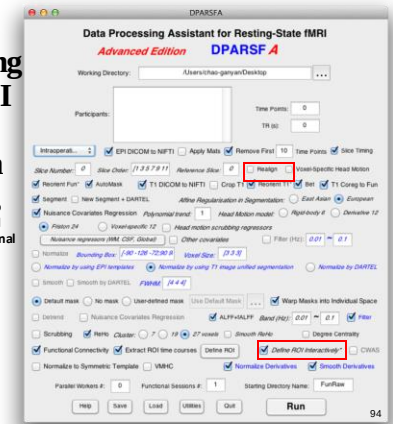
Intraoperative Processing



Preprocessing and R-fMRI measures Calculation

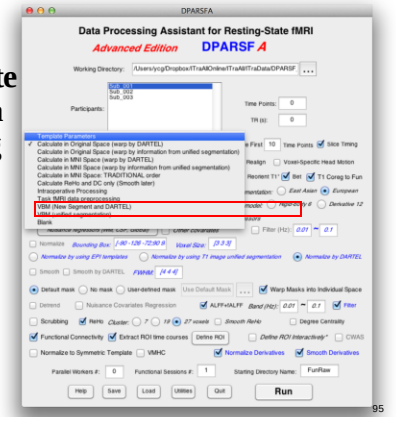
No realign since there is no head motion. DPARSFA will generate the mean functional images automatically.

Define ROI Interactively



Resting State fMRI Data Processing

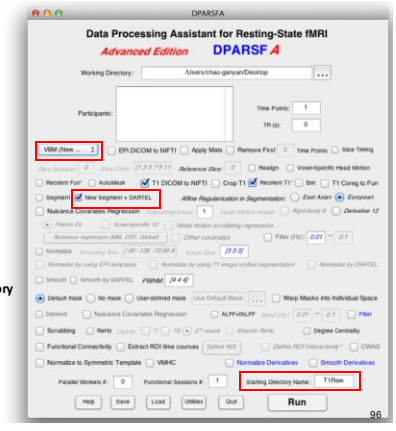
VBM



VBM

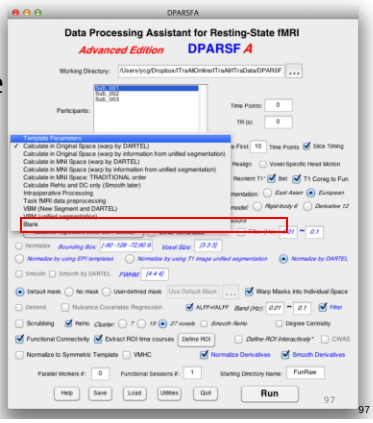
Only New Segment + DARTEL is checked

Define the Starting Directory Name as T1Raw



Resting State fMRI Data Processing

Blank



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Blank

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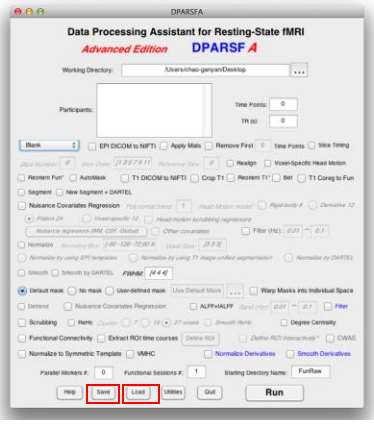
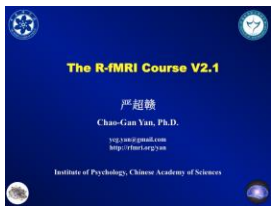
Save and Load Parameters

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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DPABI特训营与DPABISurf加强营

第六届DPABI/DPARSF特训营
暨DPABISurf加强营通知
中国·北京 2019.10.26～10.28

定期举办，请关注http://rfmri.org

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深度特训与数据分析

DEEP BRAIN

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，您便将有机会与 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

http://deepbrain.com

DEEP BRAIN

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 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。

DPABISurf工作站

DPABI工作站

序号	名称	参数	市场指导价
1.	DPABI教育工作站 (Windows) DPABI Educational Core Windows	14英寸轻薄笔记本商务办公笔记本电脑 八代四核i5处理器(i5-8250U, 16G内存, 256G固态硬盘+1T机械硬盘, PCIe, 独立显卡, 指纹识别	￥8999
2.	DPABI计算工作站 (Linux/Windows) DPABI Computational Core	塔式服务器 20核40线程英特尔至强4114 2.2G *2,9.6GT/s 25M,14M ,Turbo, HT(85W), 4*16GB RDIMM, 64G内存, 2666MT/s, 4*4TB 7.2K RPM NLSAS, 16T硬盘, 万兆电口, RAID卡: H330, DVD-RW 双电 三年服务	￥59999
3.	DPABI移动工作站 (Windows) DPABI Mobile Core Windows	15.6英寸移动图形工作站 八代六核十二线程i7-8750H, 16G内存, 256G固态硬盘+1T机械硬盘, P1000 4G独立显卡	￥24999
4.	DPABI计算工作站 (Mac) DPABI Computational Core Mac	iMac Pro 14核2颗Intel Xeon W 处理器, 2.5GHz Turbo Boost 最高可达 4.3GHz, 64G内存 2666MHz DDR4 ECC, 1TB 固态硬盘, Radeon Pro Vega 56 图形处理器 8G HBM2 显存	￥64999
5.	DPABI移动工作站 (Mac) DPABI Mobile Core Mac	15 英寸 MacBook Pro 八代六核十二线程Intel Core i7 处理器, Turbo Boost 最高可达 4.3GHz, 16G内存 2400MHz DDR4, 512G固态硬盘, Radeon Pro 560X 图形处理器, 配备 4G GDDR5 显存, 采用新款显示技术的视网膜显示屏, 触控栏和触控 ID, 四个雷雳 3 端口	￥32999
6.	DPABI定制工作站	如果您有更为足的预算, 需要更为强大的性能, 请联系我们按需定制服务器	定制

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DPABI计算工作站

2.	DPABI计算工作站 (Linux/Windows) DPABI Computational Core	塔式服务器 20核40线程英特尔至强4114 2.2G *2,9.6GT/s 25M,14M ,Turbo, HT(85W), 4*16GB RDIMM, 64G内存, 2666MT/s, 4*4TB 7.2K RPM NLSAS, 16T硬盘, 万兆电口, RAID卡: H330, DVD-RW 双电 三年服务	￥59999

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DPABISurf 并行计算:

每天完成 **20** 个被试的皮层计算!!!

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Thanks for your attention!