Resting-State fMRI: Current Research, Methodological Issues and Its Applications

严超赣

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Outline

- Principles & Computational Algorithms
- Methodological Issues & Computational Platform
- Applications to Brain Disorders

2

Resting-State fMRI: Principles

All of the human high mental functions such as thinking, emotion and consciousness rely on brain, an extremely complex system (Singer, 1999)

http://psychcentral.com/news/2010/11/03/new-insights-on-brains-internal-wiring/20500.html

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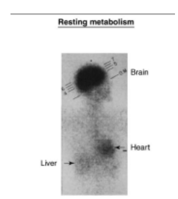
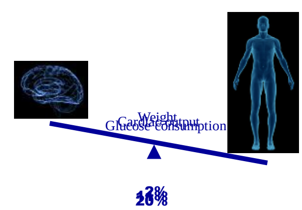
Resting-State fMRI: Principles





Raichle et al., 2010. Trends Cogn Sci

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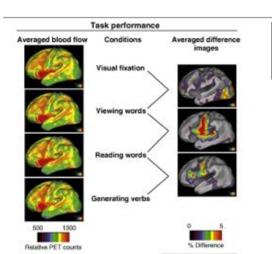
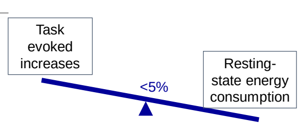
Resting-State fMRI: Principles





There are very important activities in the brain during resting-state (Fox and Raichle, 2007; Zhang and Raichle, 2010)

Raichle et al., 2010. Trends Cogn Sci

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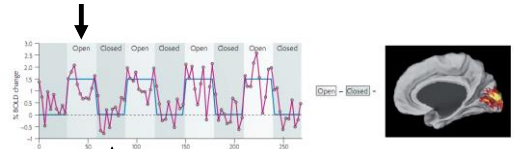
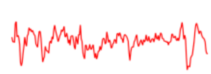
Resting-State fMRI: Principles

Task



Baseline

- Traditional fMRI analysis



→ Noise?

Activities in the baseline state (usually resting-state)

Fox and Raichle, 2007. Nat Rev Neurosci

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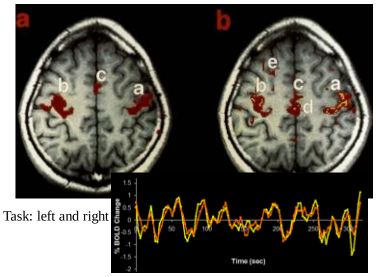
Resting-State fMRI: Principles

- Temporal synchrony of spontaneous fluctuations



Task: left and right

Biswal et al., 1995. Magn Reson Med

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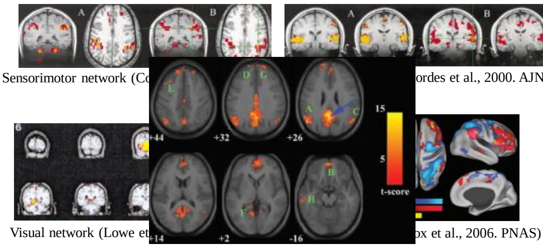
Resting-State fMRI: Principles

- Functional networks identified by functional connectivity with resting-state fMRI (RS-fMRI)



Sensorimotor network (Co… …ordes et al., 2000. AJNR)

Visual network (Lowe et… …ox et al., 2006. PNAS)

DMN (Greicius et al., 2003. PNAS)

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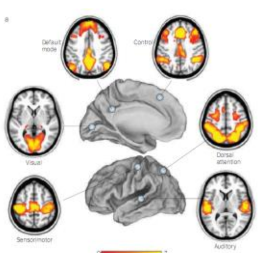
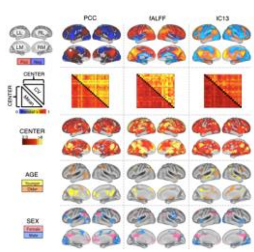
Resting-State fMRI: Principles



Zhang and Raichle, 2010. Nat Rev Neurol



Biswal et al., 2010. PNAS

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Resting-State fMRI: Principles

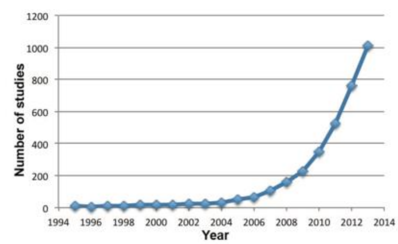

Figure 1. Number of R-fMRI related studies in PubMed (key words: "resting+state+fmri").

Yan et al., 2015. F1000Res

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Outline

- **Resting-State fMRI: Principles**
- **Data Analysis: Computational Algorithms**
- **Data Analysis: Methodological Issues**
- **Data Analysis: Computational Platform**
- **Applications to Brain Disorders**

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Computational Methodology

- Integration approach
- Regional approach
- Graphical approach

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Computational Methodology

Integration approach

- Functional Connectivity
-

a

- Effective Connectivity: (Friston et al., 2002)
- Hierarchical Clustering: (Cordes et al., 2000; Salvador et al., 2005)
- Self Organization Map: (Peltier et al., 2003)
- ....

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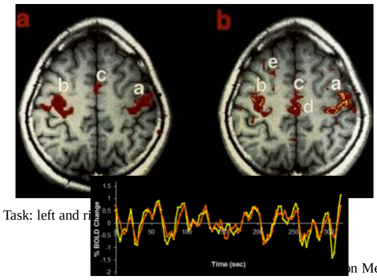
Computational Methodology

- **Correlation: Temporal synchrony of spontaneous fluctuations**



Task: left and ri

n Med

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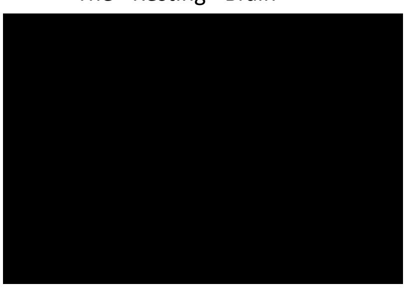
Computational Methodology

The "Resting" Brain



Courtesy of Dr. Daniel Margulies

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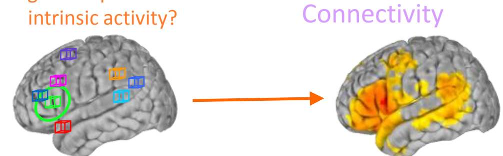
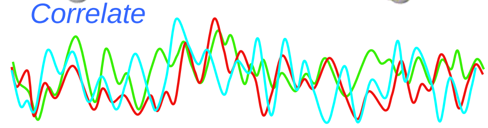
Computational Methodology

How do we detect organized patterns of intrinsic activity?

Resting State Functional Connectivity



Correlate



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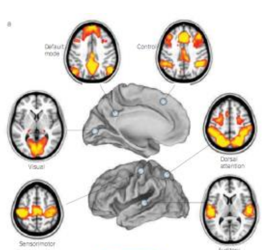
Computational Methodology

- **Correlation**



Zhang and Raichle, 2010. Nat Rev Neurol

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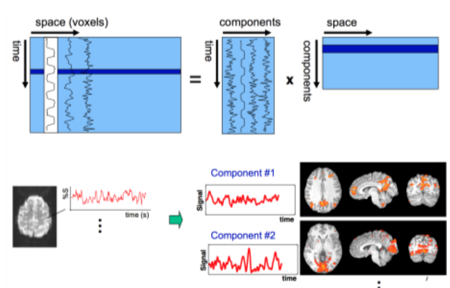
Computational Methodology

- **Independent Component Analysis**



Birn 2015

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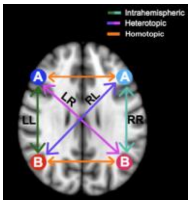
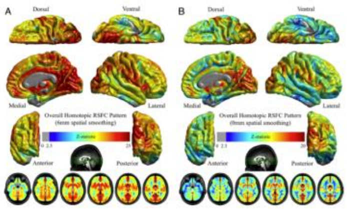
Computational Methodology

- **Voxel-mirrored homotopic connectivity (VMHC)**



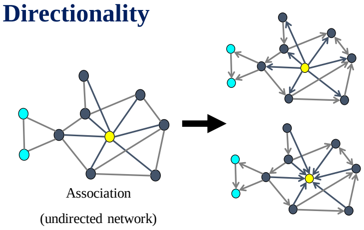
Gee et al., 2011



Zuo et al., 2010

Computational Methodology

Directionality



Association
(undirected network)

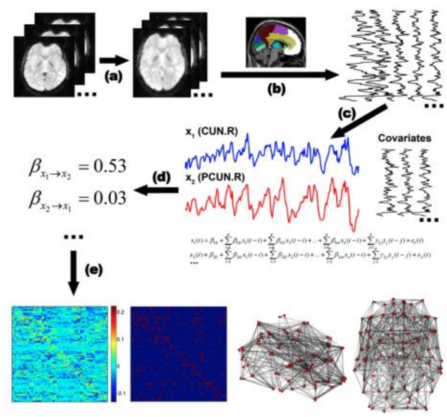
Directionality
Causality
(directed network)

Computational Methodology

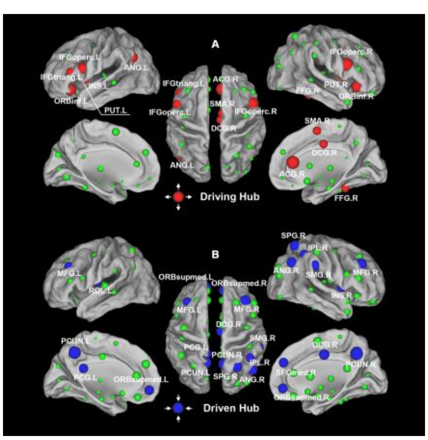
Directionality

- Statistical techniques
  - Structural Equation Modeling (McIntosh and Gonzalez-Lima, 1994)
  - Dynamic Causal Modeling (Friston et al., 2003)
  - Granger Causality Analysis (GCA) (Granger, 1969; Goebel et al., 2003)
  - ....
- Lesion studies
- Brain stimulation

Craddock, , Yan et al., 2013. Nat Methods

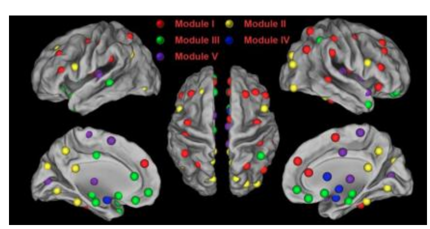


Yan et al., 2011. PLoS ONE



Yan et al., 2011. PLoS ONE

Computational Methodology

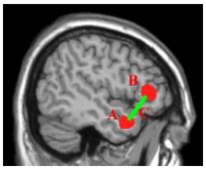


Yan et al., 2011. PLoS ONE

Computational Methodology

Regional approach

“Integrative” is really good, but:



Decreased

functional connectivity

Question: Is A, B, C, or……abnormal?

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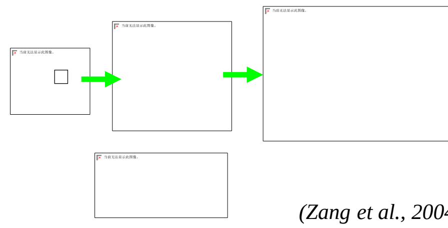
Computational Methodology

Regional Homogeneity (ReHo)

Similarity or coherence of the time courses within a functional cluster



(Zang et al., 2004)

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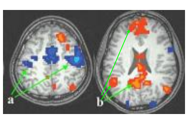
Computational Methodology

ReHo: motor task state vs. pure resting state



Rest > Motor

Motor > Rest

a) Higher ReHo in bilateral primary motor cortices during motor task

b) Higher ReHo in default mode network (PCC, MPFC, IPL) during rest *(Raichle et al., 2001; Greicius et al., 2003)*

(Zang et al., 2004)

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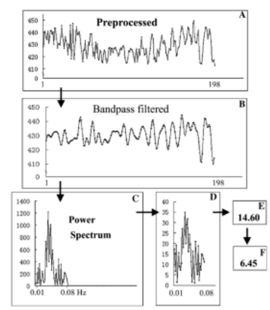
Computational Methodology

Amplitude of low frequency fluctuations



Zang et al., 2007

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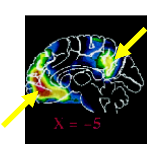
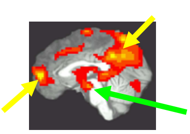
Computational Methodology

ALFF



PET

(Raichle et al., 2001)



ALFF

(Zang et al., 2007)

noise

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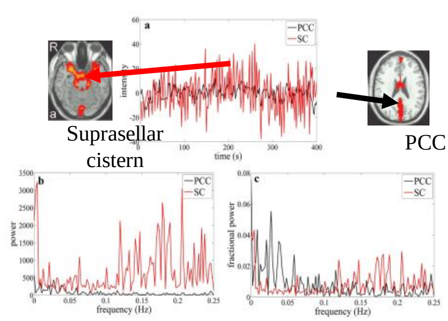
Computational Methodology

Improvement: fractional ALFF



Zou et al., 2008. J Neurosci Methods

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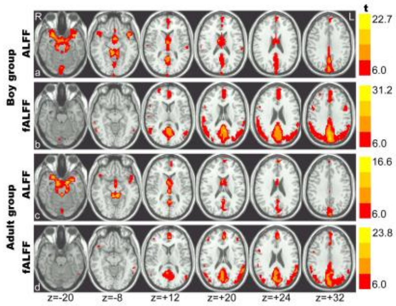
Computational Methodology

Improvement: fractional ALFF



Zou et al., 2008. J Neurosci Methods

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Computational Methodology

Graphical approach

- Graph theoretical analysis: (Salvador et al., 2005, Bullmore and Sporns, 2009)
  - Degree connectivity, functional connectivity density, degree centrality: (Buckner et al., 2009; Tomasi et al., 2010; Cole et al., 2010; Zuo et al., 2012)
- …

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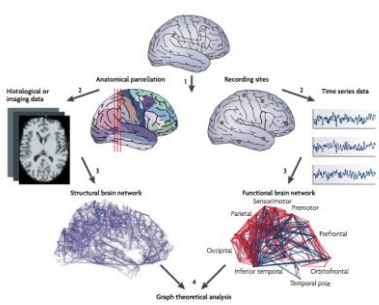
Computational Methodology

Graph theoretical analysis

Bullmore and Sporns, 2009



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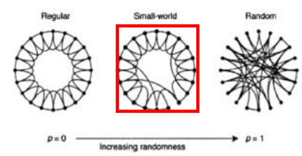
Computational Methodology

Graph theoretical analysis



Watts and Strogatz, 1998. Nature

Node: brain region
Link: connection

Regular: high Cp high Lp

Small-world: high Cp low Lp

Random: low Cp low Lp

Small-world networks contain many local links and a few long-distance links (so-called “shortcuts”).

Cp: average clustering of a network
Lp: average shortest path length of a network

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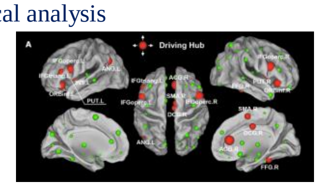
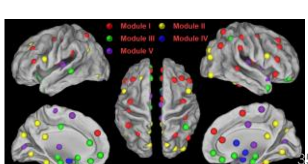
Computational Methodology

Graph theoretical analysis

Hub



Module



Yan et al., 2011. PLoS ONE

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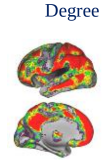
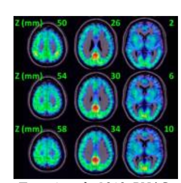
Computational Methodology

Degree centrality

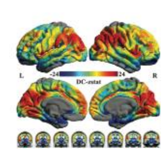


Buckner et al., 2009. J Neurosci



Tomasi et al., 2010. PNAS

Cole et al., 2010. Neuroimage



Zuo et al., 2011. Cereb Cortex

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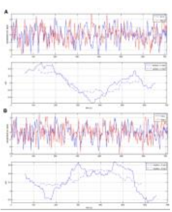
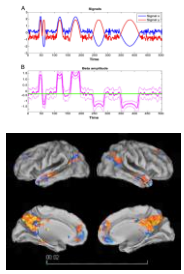
Computational Methodology

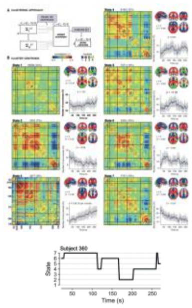
Dynamic perspective



Chang and Glover, 2010. Neuroimage



Kang, , Yan et al., 2011. Neuroimage



Allen et al., 2013. Cereb Cortex

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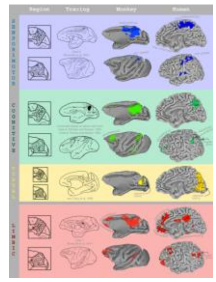
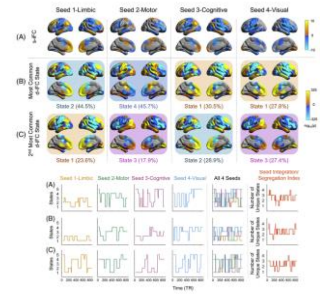
Computational Methodology

Dynamic perspective



Margulies et al., 2009. PNAS



Yang, , Yan, Milham, 2014. Neuroimage

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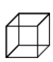
Computational Methodology

A Growing Range of R-fMRI Indices for Intrinsic Brain Function

 Voxel strength: ALFF/fALFF

 Regional synchronization: ReHo

 Homotopic connectivity: VMHC

 Global connectivity: Degree Centrality

 Global Signal Correlation

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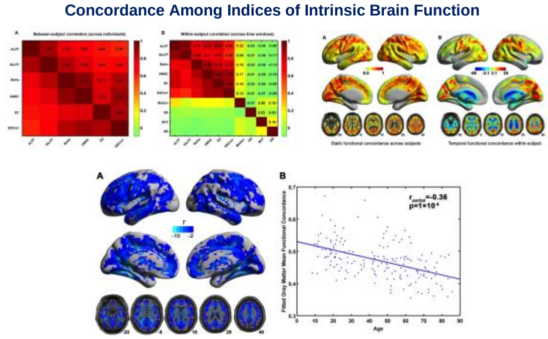
Computational Methodology

Concordance Among Indices of Intrinsic Brain Function



Yan et al., 2017. Science Bulletin

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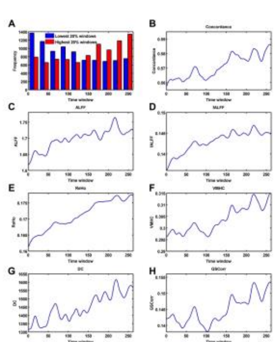
Computational Methodology



Yan et al., 2017. Science Bulletin

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Outline

- Resting-State fMRI: Principles
- Data Analysis: Computational Algorithms
- Data Analysis: Methodological Issues
- Data Analysis: Computational Platform
- Applications to Brain Disorders

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Methodological Issues

- Head motion — *Yan et al., 2013a. Neuroimage; Yan et al., 2013. Front Hum Neurosci*
- Standardization — *Yan et al., 2013b. Neuroimage*
- Multiple-comparison correction — *Chen, Lu, Yan*, 2017. Human Brain Mapping*
- And many many more…

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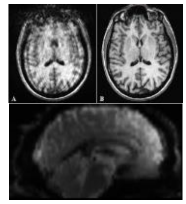
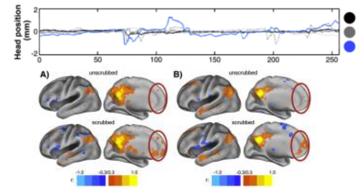
Methodological Issues: Head Motion

Power et al, 2012. Neuroimage
Van Dijk et al, 2012. Neuroimage

Head motion is a critical factor in R-fMRI data processing.

Need an effective motion correction strategy!

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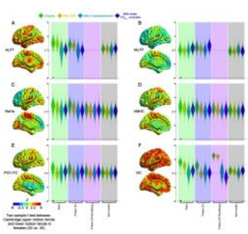
Methodological Issues: Head Motion



Yan et al., 2013a. Neuroimage

Proposed an effective head motion correction strategy
- **Individual-level correction with the Friston-24 model**
- **Group-level correction with head motion covariate**

- Cited: 573 times
- ESI Top 1% highly cited paper

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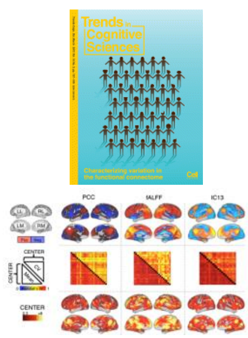
Methodological Issues: Standardization



Biswal et al., 2010, PNAS

Table 1. Factors can introduce unintended variations in fMRI measurement.

Category	Factor
1. Acquisition-related variations	Scanner make and model (Friedman and Glover, 2006b), sequence type (spiral vs. echo planar; single-echo vs. multi-echo) (Klarhofer et al., 2002), parallel vs. conventional acquisition (Feinberg et al., 2010; Lin et al., 2005), coil type (surface vs. volume, number of channels, orientation), repetition time, number of repetitions, flip angle, echo time, and acquisition volume (field of view, voxel size, slice thickness/gaps, slice prescription) (Friedman and Glover, 2006a)
2. Experimental-related variations	Participant instructions (Hartstra et al., 2011), eyes-open/eyes-closed (Yan et al., 2009; Yang et al., 2007), visual displays, experiment duration (Fang et al., 2007; Van Dijk et al., 2010)
3. Environment-related variations	Sound attenuation measures (Cho et al., 1998; Elliott et al., 1999), attempts to improve participant comfort during scans (e.g., music, videos) (Cullen et al., 2009), head-motion restraint techniques (e.g., vacuum pad, foam pad, bite-bar, plaster cast head holder) (Edward et al., 2000; Menon et al., 1997), room temperature and moisture (Vanhoutte et al., 2006).
4. Participant-related variations	Circadian cycle (Shannon et al., 2012), prandial (Haase et al., 2009), caffeine (Rack-Gomer et al., 2009), and nicotine status (Tanabe et al., 2011), sleepiness / arousal (Horovitz et al., 2008), sleep deprivation (Samann et al., 2010), scanner anxiety (de Bie et al., 2010), and menstrual cycle status (for women) (Protopopescu et al., 2005).

Yan et al., 2013b. Neuroimage

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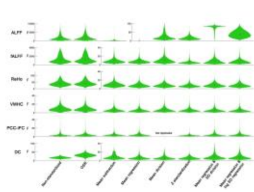
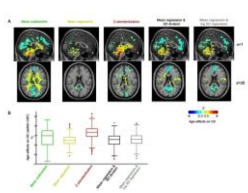
Methodological Issues: Standardization



The Impact of Standardization Procedures on Confound Variables: Site Effects



The Impact of Standardization Procedures on Variables of Interest: Age Effects

Proposed an effective standardization strategy
Mean regression + SD division

- Cited: 176 times
- ESI Top 1% highly cited paper

Yan et al., 2013b. Neuroimage

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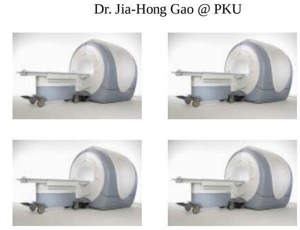
Methodological Issues

Standardization

Collaborate with Dr. Xi-Nian Zuo @ IPCAS
Dr. Jia-Hong Gao @ PKU

National Natural Science Foundation of China (81671774) (PI: Yan)
Beijing Municipal Science & Technology Commission (Z161100000216152) (PI: Gao)
National Basic Research (973) Program (2015CB351702) (Co-I: Zuo)

48

Eklund et al., 2016. PNAS

49

P=0.05 P=0.05 P=0.05 P=0.05 P=0.05

0.95 0.95 0.95 0.95 0.95

0.95^5=0.774

Probability of not getting a false positive result:

1 - 0.05 = 0.95

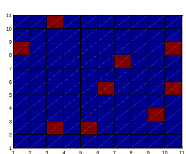
50

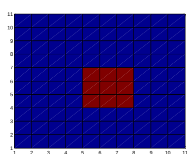
Reproducibility and Multiple Comparison Correction

Multiple Comparisons

Gaussian Random Field Theory Correction

Monte Carlo simulations (AlphaSim)





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Reproducibility and Multiple Comparison Correction

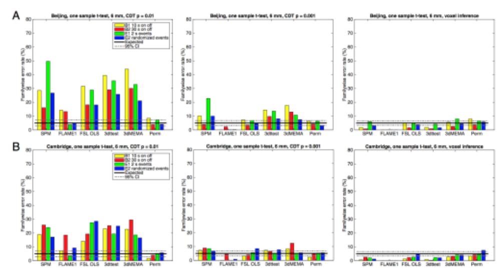

Fig. 1. Results for one-sample *t* test, showing estimated FWE rates for (*A*) Beijing and (*B*) Cambridge data analyzed with 6 mm of smoothing and four different activity paradigms (B1, B2, E1, and E2), for SPM, FSL, AFNI, and a permutation test. These results are for a group size of 20. The estimated FWE rates are simply the number of analyses with any significant group activation divided by the number of analyses (1,000). From *Left* to *Right*: Cluster inference using a cluster-defining threshold (CDT) of $P = 0.01$ and a FWE-corrected threshold of $P = 0.05$, cluster inference using a CDT of $P = 0.001$ and a FWE-corrected threshold of $P = 0.05$, and voxel inference using a FWE-corrected threshold of $P = 0.05$. Note that the default CDT is $P = 0.001$ in SPM and $P = 0.01$ in FSL (AFNI does not have a default setting).

Eklund et al., 2016. PNAS

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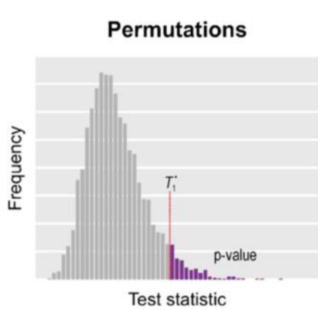
Reproducibility and Multiple Comparison Correction

Permutation Test



Winkler et al., 2016. Neuroimage

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Reproducibility and Multiple Comparison Correction

Threshold-Free Cluster Enhancement (TFCE)

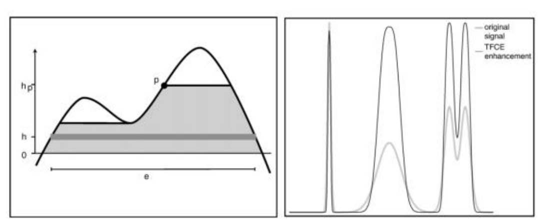

Fig. 1. Illustration of the TFCE approach. Left: the TFCE score at voxel p is given by the sum of the scores of all incremental supporting sections (one such is shown as the dark-grey band) within the area of "support" of p (light grey). The score for each section is a simple function of its height h and extent e. Right: example input image and TFCE-enhanced output. The input contains a focal, high signal, a much more spatially extended, lower, signal and a pair of overlapping signals of intermediate extent and height. The TFCE output has the same maximal values for all three cases, and preserves the distinct local maxima in the third case.

Smith et al., 2009. Neuroimage

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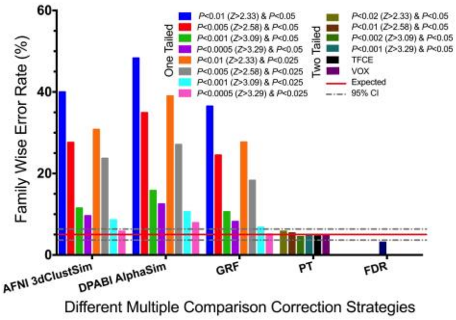
Family wise Error Rate



20 vs. 20 Permutation 1000 times

Chen, Lu, Yan*, 2018. Human Brain Mapping

Family wise Error Rate

20 vs. 20 Permutation 1000 times

Chen, Lu, Yan*, 2018. Human Brain Mapping

Family wise Error Rate

TABLE II. FWER under correction of three kinds of cluster-based correction with the strictest threshold, 6 versions of PT-based correction as well as FDR correction

			FWER										
	Voxel threshold	Cluster threshold	ALFF	fALFF	ReHo	DC	VMHC	ALFF with GSR	fALFF with GSR	ReHo with GSR	DC with GSR	VMHC with GSR	ALFF (8 mm smoothed)
Smoothness (mm, x×y×z)			7.94 × 7.31 × 6.86	7.34 × 7.42 × 7.20	9.36 × 8.72 × 8.39	7.86 × 7.97 × 7.81	6.31 × 6.87 × 6.61	7.99 × 7.31 × 6.84	7.32 × 7.41 × 7.19	9.24 × 8.56 × 8.18	8.06 × 8.16 × 8.09	6.11 × 6.61 × 6.37	11.88 × 11.53 × 11.68
AFNI 3dClustSim (one-tailed)	$P < 0.0005$ ($Z > 3.29$)	$P < 0.025$	5.8%	6.1%	7.3%	8.5%	6.0%	5.3%	6.6%	6.9%	6.8%	6.4%	5.5%
DPABI AlphaSim (one-tailed)			7.9%	8.3%	8.5%	10.2%	9.0%	7.8%	7.7%	7.8%	8.3%	9.6%	6.9%
GRF (one-tailed)			5.1%	5.5%	4.9%	7.4%	5.2%	4.8%	5.9%	5.3%	5.1%	6.4%	4.4%
PT cluster extent correction (two-tailed)	$P < 0.02$ ($Z > 2.33$)	$P < 0.05$	5.8%	3.6%	5.8%	4.6%	5.2%	4.8%	3.9%	5.5%	5.2%	4.3%	5.3%
	$P < 0.01$ ($Z > 2.58$)	$P < 0.05$	5.4%	4.0%	5.7%	4.6%	5.5%	5.3%	3.8%	5.3%	5.0%	4.5%	5.4%
	$P < 0.002$ ($Z > 3.09$)	$P < 0.05$	4.5%	4.1%	5.3%	4.8%	4.2%	4.5%	5.0%	5.1%	4.7%	4.3%	4.4%
	$P < 0.001$ ($Z > 3.29$)	$P < 0.05$	4.8%	4.5%	4.5%	4.9%	3.4%	4.3%	4.8%	5.4%	4.2%	3.9%	4.1%
PT TFCE			4.6%	3.9%	5.7%	5.0%	4.3%	5.3%	4.2%	5.5%	4.7%	4.8%	4.6%
PT VOX			4.9%	4.9%	5.7%	3.9%	4.7%	6.0%	4.5%	5.6%	4.0%	4.6%	3.9%
FDR correction			3.1%	3.4%	4.4%	2.4%	3.9%	4.1%	2.8%	3.6%	2.4%	3.5%	1.6%

The smoothness in the second row is the estimated effective smoothness of the final metric maps feed to statistical analysis, and was different form the applied smoothness (4 mm FWHM) in pre-processing. The effective smoothness was used in 3 versions of cluster-based correction (i.e., GRF theory correction, AFNI 3dClustSim and DPABI AlphaSim)

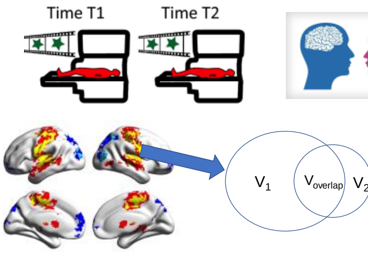
20 vs. 20 Permutation 1000 times

Chen, Lu, Yan*, 2018. Human Brain Mapping

Test-retest Reliability

Test-retest reliability

Sex differences in test and retest



Statistical significant voxels

$$Dice = \frac{2 \times V_{overlap}}{V_1 + V_2}$$

V_1: significant voxels in test

V_2: significant voxels in retest

$V_{overlap}$: voxels significant in both test and retest

Chen, Lu, Yan*, 2018. Human Brain Mapping

Test-retest Reliability

TABLE III. Test–retest reliability of sex differences for all R-fMRI metrics with and without GSR under correction of three kinds of cluster-based correction with the strictest threshold, six kinds of PT-based correction and FDR correction, calculated between the first and second sessions in the CORR dataset

			Test–retest reliability (dice coefficient)									
	Voxel threshold	Cluster threshold	ALFF	fALFF	ReHo	DC	VMHC	ALFF with GSR	fALFF with GSR	ReHo with GSR	DC with GSR	VMHC with GSR
AFNI 3dClustSim (one-tailed)	$P < 0.0005$ ($Z > 3.29$)	$P < 0.025$	0.65	0.51	0.50	0.34	0.39	0.64	0.48	0.44	0.28	0.24
DPABI AlphaSim (one-tailed)			0.65	0.51	0.49	0.34	0.39	0.64	0.48	0.45	0.27	0.27
GRF (one-tailed)			0.64	0.51	0.50	0.35	0.39	0.65	0.48	0.43	0.28	0.24
PT cluster extent correction (two-tailed)	$P < 0.02$ ($Z > 2.33$)	$P < 0.05$	0.65	0.70	0.56	0.45	0.40	0.62	0.68	0.45	0.30	0.40
	$P < 0.01$ ($Z > 2.58$)	$P < 0.05$	0.67	0.66	0.52	0.32	0.33	0.60	0.63	0.46	0.27	0.32
	$P < 0.002$ ($Z > 3.09$)	$P < 0.05$	0.63	0.55	0.51	0.36	0.38	0.63	0.52	0.47	0.23	0.32
	$P < 0.001$ ($Z > 3.29$)	$P < 0.05$	0.64	0.51	0.48	0.37	0.38	0.64	0.48	0.44	0.28	0.26
PT TFCE			0.68	0.75	0.54	0.48	0.44	0.66	0.74	0.44	0.31	0.42
PT VOX			0.66	0.34	0.48	0.37	0.22	0.65	0.31	0.38	0.11	0.14
FDR correction			0.64	0.67	0.54	0.39	0.37	0.63	0.64	0.47	0.23	0.29

For test–retest reliability for all the 31 kinds of multiple comparison correction strategies, please see Supporting Information Table S13

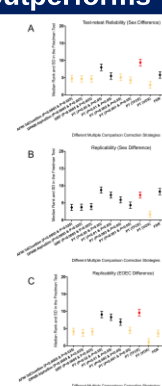
- Moderate test-retest reliability
- ALFF, fALFF, ReHo are better than DC and VMHC

212 M vs. 208 F × 2 times

Chen, Lu, Yan*, 2018. Human Brain Mapping

PT with TFCE outperforms

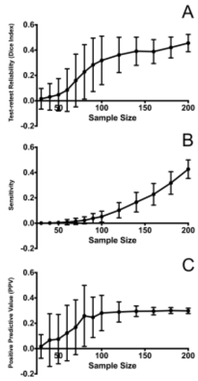
Permutation test TFCE, a strict multiple comparison correction strategy, reached the best balance between family-wise error rate (under 5%) and test-retest reliability / replicability



Chen, Lu, Yan*, 2018. Human Brain Mapping

Sample Size Matters

Randomly draw k subjects from the "SWU 4" site in the CORR dataset, which has two sessions of 116 males and 105 females

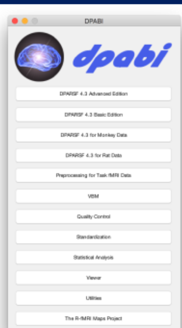


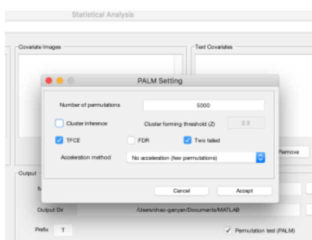
Chen, Lu, Yan*, 2018. Human Brain Mapping

Reproducibility of R-fMRI Metrics on the Impact of Different Strategies for Multiple Comparison Correction and Sample Sizes

- Permutation test with TFCE reached the best balance between FWER and reproducibility
- Although R-fMRI indices attained moderate reliabilities, they replicated poorly in distinct datasets (replicability < 0.3 for between-subject sex differences, < 0.5 for within-subject EOEC differences)
- For studies examining effect sizes similar to or even less than those of sex differences, results from a sample size <80 (40 per group) should be considered preliminary, given their low reliability (< 0.23), sensitivity (< 0.02) and PPV (< 0.26).

Permutation Test with TFCE

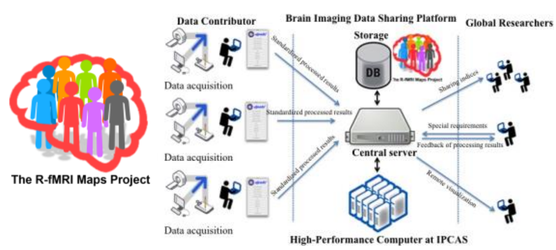




Integrated from PALM
(Winkler et al. 2016. Neuroimage)

Yan* et al., 2016. Neuroinformatics
ESI Top 1% highly cited (>60 times)

The R-fMRI Maps Project



Part of the Human Brain Data Sharing Initiative (HBDSI), IPCAS

The R-fMRI Maps Project

Shared data of 4770 subjects:

1. Amplitude of low frequency fluctuations (ALFF)
2. Fractional ALFF (fALFF)
3. Regional Homogeneity (ReHo)
4. Voxel-mirrored homotopic connectivity (VMHC)
5. Degree Centrality (DC)
6. Functional Connectivity Matrices
   a. Automated Anatomical Labeling (AAL) atlas
   b. Harvard-Oxford atlas
   c. Craddock's clustering 200 ROIs
   d. Zalesky's random parcelations
   e. Dosenbach's 160 functional ROIs

In addition, gray matter, white matter and CSF density and volume files were shared

Downloaded by
593 researchers

Outline

- Resting-State fMRI: Principles
- Data Analysis: Computational Algorithms
- Data Analysis: Methodological Issues
- ➡ Data Analysis: Computational Platform
- Applications to Brain Disorders

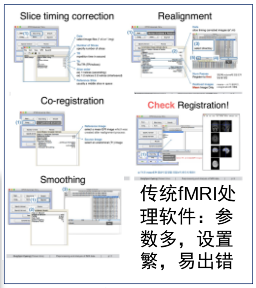
静息态功能磁共振数据处理平台

Yan and Zang, 2010. Front Syst Neurosci.

共同通讯作者；持续更新至今

Cited: 1500 times

DPARSF：流水线式fMRI数据处理软件



传统fMRI处理软件：参数多，设置繁，易出错

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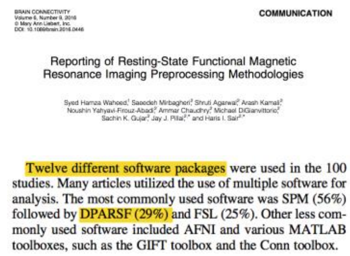
同行评价及影响


BRAIN CONNECTIVITY
Volume 6, Number 9, 2016
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DOI: 10.1089/brain.2016.0446

COMMUNICATION

Reporting of Resting-State Functional Magnetic Resonance Imaging Preprocessing Methodologies

Twelve different software packages were used in the 100 studies. Many articles utilized the use of multiple software for analysis. The most commonly used software was SPM (56%) followed by DPARSF (29%) and FSL (25%). Other less commonly used software included AFNI and various MATLAB toolboxes, such as the GIFT toolbox and the Conn toolbox.

Haris I. Sair
约翰·霍普金斯大学教授

12种不同的软件…使用得最多的软件是SPM（56%），然后是DPARSF（29%）和FSL（25%）…

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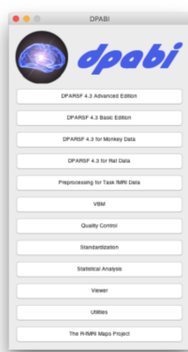
数据处理与共享平台

- 整合方法学改进
- 处理流程规范化
- 统计分析
- 大数据共享平台

Yan et al., 2016. Neuroinformatics

Cited: 181 times. ESI top 1% high cited



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DPARSF

Data Organization

ProcessingDemoData.zip

FunRaw ← **Functional DICOM data**

- Sub_001
- Sub_002
- Sub_003

T1Raw ← **Structural DICOM data**

- Sub_001
- Sub_002
- Sub_003

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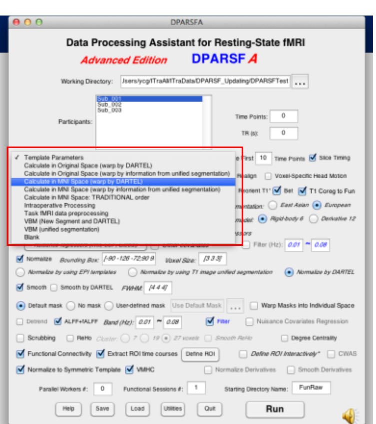
Resting State fMRI Data Processing

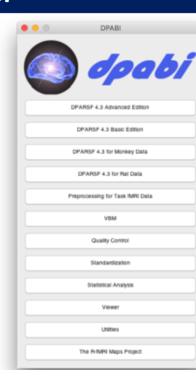
Template Parameters



DPABI

Yan et al., 2016. Neuroinformatics

ESI Top 1% Highly Cited Paper



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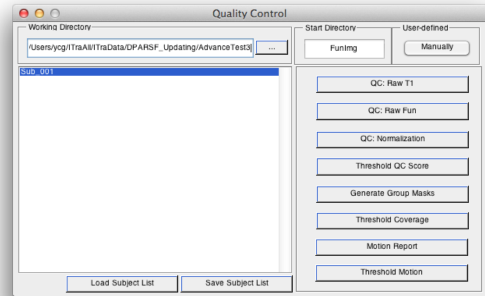
Quality Control



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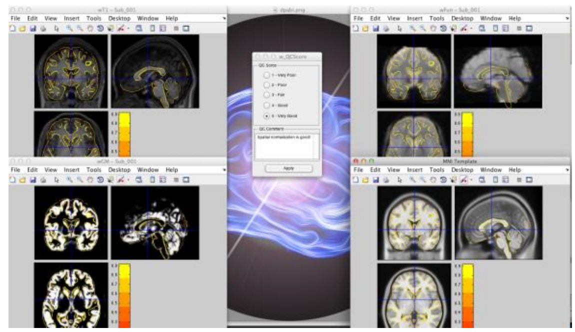
Quality Control



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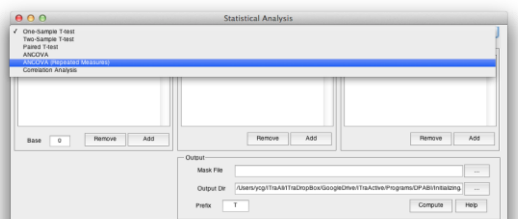
Statistical Analysis



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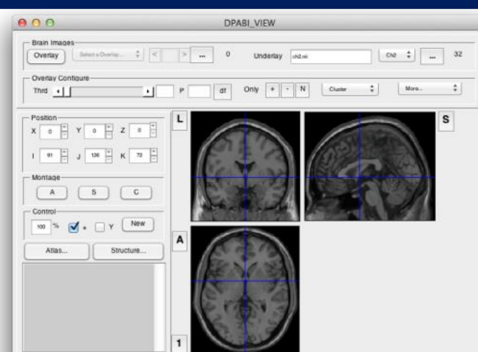
DPABI Viewer



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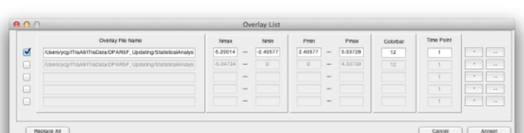
DPABI Viewer



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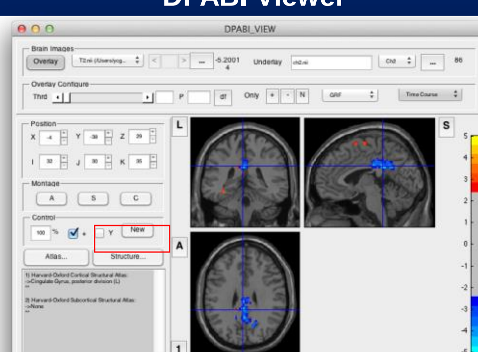
DPABI Viewer



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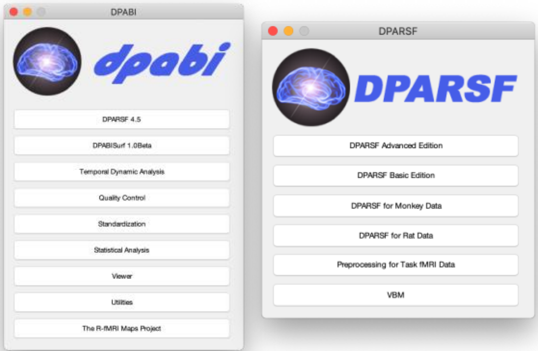
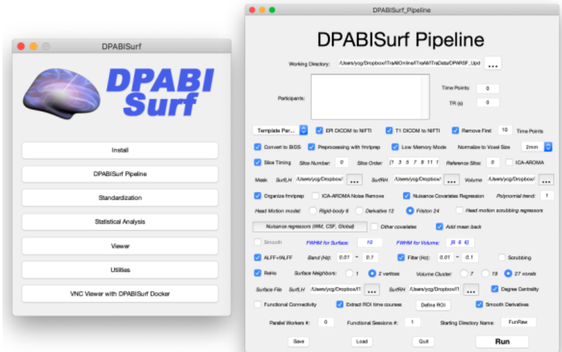
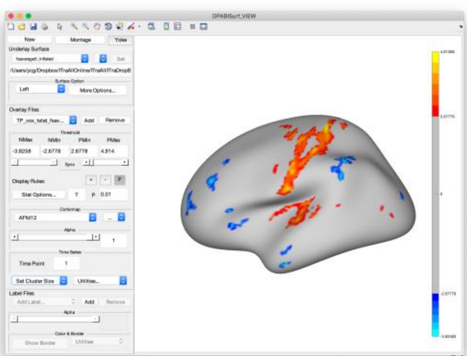
DPABISurf



DPABISurf



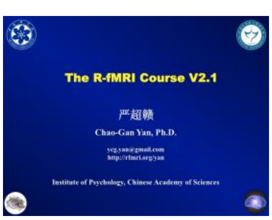
DPABISurf



Future Directions

- **R-fMRI methodology**
- **Mechanism of R-fMRI: electrophysiology/fMRI recording**
- **Modulation and intervention: medication and brain stimulation**
- **Application to brain disorders**

Further Help



http://rfmri.org/Course

http://rfmri.org/wiki

The R-fMRI Journal Club

Official Account: RFMRILab

DPABI特训营与DPABISurf加强营

定期举办，请关注http://rfmri.org

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

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。

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英寸轻薄窄边框商务办公笔记本电脑 八代四核八线程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 2UPI,14M ,Turbo, HT(85W), 4*16GB RDIMM, 64G内存, 2666MT/s, 4*4TB 7.2K RPM NLSAS，16TB硬盘，冗余电源，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28线程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	￥84999
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，采用原彩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	如果您有更充足的预算，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 2UPI,14M ,Turbo, HT(85W), 4*16GB RDIMM, 64G内存, 2666MT/s, 4*4TB 7.2K RPM NLSAS，16TB硬盘，冗余电源，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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The R-fMRI Lab

WeChat Official Account: RFMRILab

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Thanks for your attention!

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