

## Contents

	<i>Preface</i>	page ix
1	Introduction	1
1.1	A brief overview of fMRI	1
1.2	The emergence of cognitive neuroscience	3
1.3	A brief history of fMRI analysis	4
1.4	Major components of fMRI analysis	7
1.5	Software packages for fMRI analysis	7
1.6	Choosing a software package	10
1.7	Overview of processing streams	10
1.8	Prerequisites for fMRI analysis	10
2	Image processing basics	13
2.1	What is an image?	13
2.2	Coordinate systems	15
2.3	Spatial transformations	17
2.4	Filtering and Fourier analysis	31
3	Preprocessing fMRI data	34
3.1	Introduction	34
3.2	An overview of fMRI preprocessing	34
3.3	Quality control techniques	34
3.4	Distortion correction	38
3.5	Slice timing correction	41
3.6	Motion correction	43
3.7	Spatial smoothing	50
4	Spatial normalization	53
4.1	Introduction	53
4.2	Anatomical variability	53
4.3	Coordinate spaces for neuroimaging	54

4.4	Atlases and templates	55
4.5	Preprocessing of anatomical images	56
4.6	Processing streams for fMRI normalization	58
4.7	Spatial normalization methods	60
4.8	Surface-based methods	62
4.9	Choosing a spatial normalization method	63
4.10	Quality control for spatial normalization	65
4.11	Troubleshooting normalization problems	66
4.12	Normalizing data from special populations	66
5	Statistical modeling: Single subject analysis	70
5.1	The BOLD signal	70
5.2	The BOLD noise	86
5.3	Study design and modeling strategies	92
6	Statistical modeling: Group analysis	100
6.1	The mixed effects model	100
6.2	Mean centering continuous covariates	105
7	Statistical inference on images	110
7.1	Basics of statistical inference	110
7.2	Features of interest in images	112
7.3	The multiple testing problem and solutions	116
7.4	Combining inferences: masking and conjunctions	123
7.5	Use of region of interest masks	126
7.6	Computing statistical power	126
8	Modeling brain connectivity	130
8.1	Introduction	130
8.2	Functional connectivity	131
8.3	Effective connectivity	144
8.4	Network analysis and graph theory	155
9	Multivoxel pattern analysis and machine learning	160
9.1	Introduction to pattern classification	160
9.2	Applying classifiers to fMRI data	163
9.3	Data extraction	163
9.4	Feature selection	164
9.5	Training and testing the classifier	165
9.6	Characterizing the classifier	171
10	Visualizing, localizing, and reporting fMRI data	173
10.1	Visualizing activation data	173
10.2	Localizing activation	176

## vii

**Contents**

10.3 Localizing and reporting activation	179
10.4 Region of interest analysis	183
Appendix A Review of the General Linear Model	191
A.1 Estimating GLM parameters	191
A.2 Hypothesis testing	194
A.3 Correlation and heterogeneous variances	195
A.4 Why “general” linear model?	197
Appendix B Data organization and management	201
B.1 Computing for fMRI analysis	201
B.2 Data organization	202
B.3 Project management	204
B.4 Scripting for data analysis	205
Appendix C Image formats	208
C.1 Data storage	208
C.2 File formats	209
<i>Bibliography</i>	211
<i>Index</i>	225