ANIL AGGRAWAL'S

Internet Journal of Book Reviews

A sister journal of AAIJFMT · Anil Aggrawal's Internet Journal of Forensic Medicine and Toxicology

VOL. 2, NO. 2 · JULY – DECEMBER 2003

Downloaded from www.anilaggrawal.com · ISSN 0972-9674 (Online) · https://www.anilaggrawal.com/br/vol_002_no_002/reviews/ts/page002.html

Technical Books Section

THE ITEM

Published	2003
Pages	297
ISBN-10	0-262-19481-3
Price	$45.00

HOW TO CITE

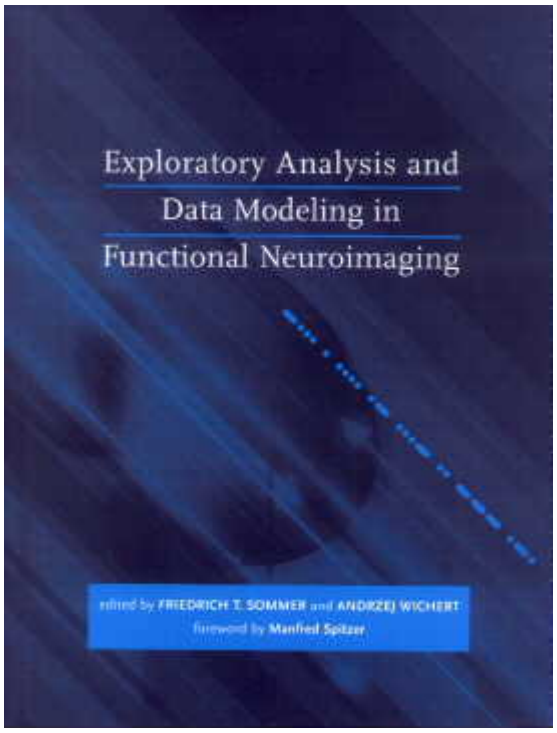
Thomas S. Review of *Exploratory Analysis and Data Modeling in Functional Neuroimaging*. *Anil Aggrawal's Internet Journal of Book Reviews*. 2003;2(2).

Ref: Thomas S.S. Exploratory Analysis and Data Modeling in Functional Neuroimaging (Book Review). *Anil Aggrawal's Internet Journal of Book Reviews, 2003*; Vol. 2, No. 2 (July - December 2003): ; Published November 4, 2003, (Accessed:

Email Dr. Thomas by clicking here

A COMPREHENSIVE SURVEY OF THEORETICAL AND COMPUTATIONAL APPROACHES TO NEUROIMAGING

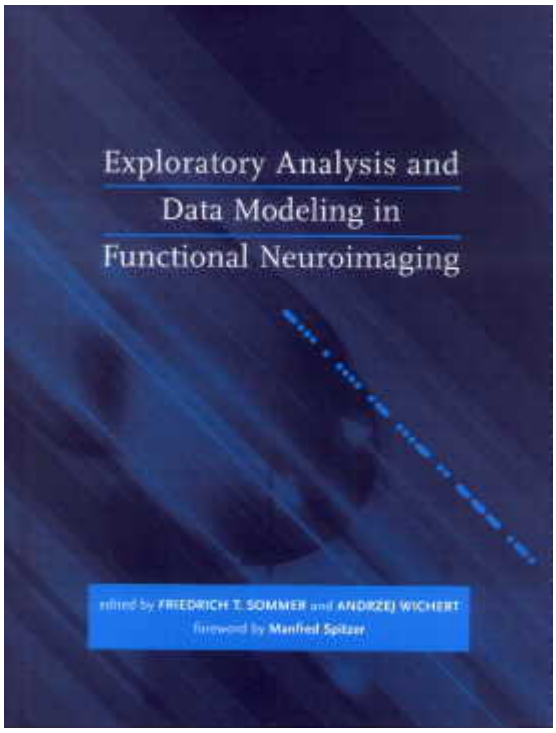
Exploratory Analysis and Data Modeling in Functional Neuroimaging *Edited by* Friedrich T. Sommer and Andrzej Wichert (Foreword by Manfred Spitzer), hard cover, 8" x 10"
The MIT Press, Massachusetts Institute of Technology, Cambridge, Massachusetts 02142: xiv + 297 Pages: Publication Date: 2003: ISBN 0-262-19481-3: Price $45.00



The book under review is a 'Timely, authoritative' account of the latest developments in the exciting field of neural computation.

The topics have been selected on the basis of scientific excellence, intellectual breadth & technical impact in consultation with yearly Neural Information Processing System (NIPS) workshop organizers and members of the NIPS Foundation Board. The purpose of this book is to provide a survey of theoretical and computational approaches in neuroimaging, communicated in the thin air of high altitude, to the broader community of scientists interested in neuroimaging. It is a result of a workshop about theoretical methods in neuroimaging that took place in Dec. 2000 in Breckenridge, Colorado. The workshop was part of the NIPS conference, an annual interdisciplinary event that brings together cognitive scientists, computer scientists, engineers, neuroscientists, physicists, statisticians, and mathematicians interested in all aspects of neural processing and computation.

Neural networks are perfect models for understanding the working principles of the brain. They can describe brain function on an abstract, systems neuroscience level, while at the same time they reflect organizational principles of the neuronal substrate (rather than boxes of logical operators or functions).

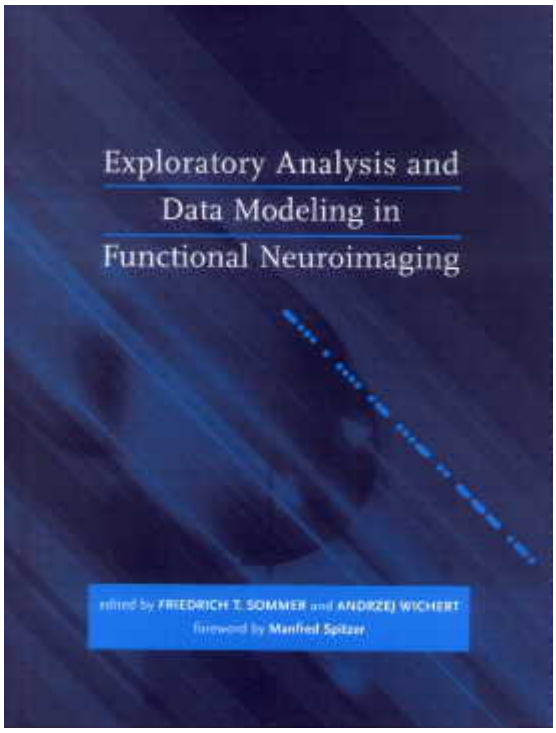


" .. In the United Kingdom, doctors say they consider advice from the computer but decide for themselves, whereas in the United State doctors say they usually let the computer decide. Even psychiatrists use neural networks to group symptoms into syndromes. ... "

Neural network based device had been approved by US FDA in 1998 for the screening of gynecological smears for cancerous cells. It is also used in intensive care units to allocate patients to resources in the most rational way (with cultural differences regarding the interpretation. In the United Kingdom, doctors say they consider advice from the computer but decide for themselves, whereas in the United State doctors say they usually let the computer decide. Even psychiatrists use neural networks to group symptoms into syndromes. In almost every field of medicine, model based top-down strategies and bottom-up strategies of data mining complement each other. For modeling brain function back propagation with biologically less plausible features networks to spiking neuron networks. Various models have been used to account for a wide range of psychological phenomena, from simple perception, via reading and attention, to language acquisition, schizophrenia, and autism. This book is perhaps the first comprehensive volume summarizing the different roles of neural networks in a new important field of physiology, functional neuroimaging. It describes how neural networks --- in a broader sense --- act as tools for sophisticated exploratory data analysis on the one hand, and for brain models on the other.

Finding patterns among noisy signals is a task, which the human brain is particularly good at, up to the point where it is running the risk of generating superstitious beliefs or even outright delusions. Functional magnetic resonance imaging (fMRI), high resolution magneto encephalography (MEG), and event related potentials (ERP) generate signals that are notoriously noisy, and the effect sizes are small. It is therefore equally as important to try to use the brain's strategies for data analysis as it is to reflect upon them and scrutinize what they are unable to achieve. The combination of data from two or more techniques can produce vistas upon the brain that any single method cannot provide and which require ingenious ways of analyzing data such that one method can be used to constrain data generated by the other method and vice versa.

This is like a hermeneutic interpretation of a text as there are thousands of ways to analyze the complex data generated in systems neuroscience research, models have to be used to guide this process from the very beginning on.



" .. The promise of functional neuroimaging is to tackle one of the most fundamental open questions of understanding the brain, namely how microscopic and macroscopic organization in the brain relate and interact in order to produce brain function. ... "

The promise of functional neuroimaging is to tackle one of the most fundamental open questions of understanding the brain, namely how microscopic and macroscopic organization in the brain relate and interact in order to produce brain function.

This book provides an overview of the various contributions theorists can and must deliver in order to apply functional imaging successfully for solving the brain puzzle. Optimal use of functional brain imaging will therefore rely on careful data mining of the raw data. This can be achieved by exploratory and Bayesian methods of data analysis, which are emphasized in this book. Also, there is no generic method of experimental design, and paradigms have to be designed tailor-made for the question to be answered. Furthermore, the temporal structure in brain activity provides indispensable clues about functional organization. At present, these can be assessed only by combining blood - based imaging with EEG/MEG methods.

The book is divided into three parts (13 chapters). The first part deals mainly with theories, data analysis and simulation models in neuroimaging. The second part of this book describes approaches for combining these methods. The third part of this deals with network modeling of the imaging data which is turn depends on the mechanistic interpretations of macroscopic functional correlates depending on additional constraints resulting from microscopic functional studies /from neuroanatomy or from computational assumptions inferred from neural network studies.

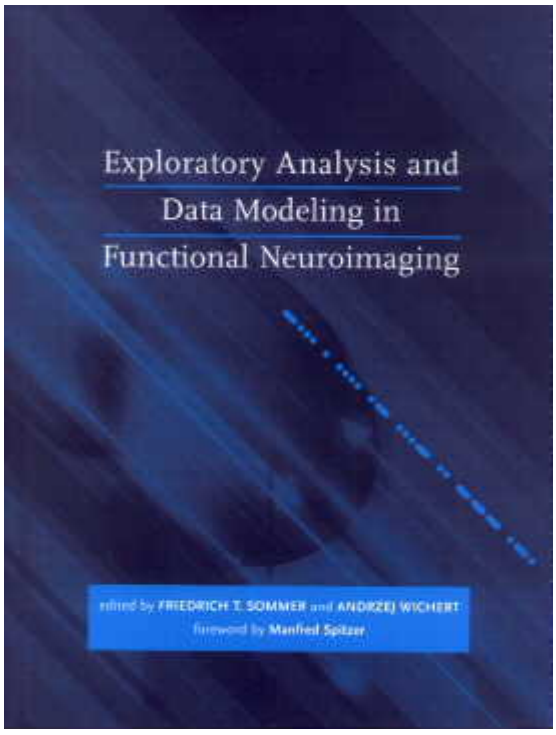
All told, this book is a valuable source of information not only to theorists in the field of neuroimaging, but to all experimenters striving for the best possible use of the brain imaging techniques to creatively address specific questions about the function of the human brain.

PART I : THEORIES, DATA ANALYSIS AND SIMULATION MODELS IN NEUROIMAGING - AN OVERVIEW

Part I of this book comprises of chapters 1 till 6.

Chapter 1

Functional neuroimaging techniques provide novel and exciting means for the investigation of working brains. This chapter gives a brief overview of theoretical methods that are central to the field of experimental neuroimaging. The topics discussed include inferential exploratory and causal methods of data analysis, theories of cerebral function and both biophysical and computational models of neural nets. As well this section helps to guide the reader by referring to later chapters.



" .. The total effort devoted to functional neuroimaging is so great that it has led to the formation of a new scientific field. Human Brain Mapping/Brain Imaging, with large numbers of associated conference and journals. This intense interest is rooted in the distinctive power of techniques such as fMRI and positron emission tomography (PET) ... "

The total effort devoted to functional neuroimaging is so great that it has led to the formation of a new scientific field. Human Brain Mapping/Brain Imaging, with large numbers of associated conference and journals. This intense interest is rooted in the distinctive power of techniques such as fMRI and positron emission tomography (PET), which provide noninvasive means of viewing global patterns of neuronal processing in the human brain with spatial resolution at the millimeter scale. After its recent introduction by Ogawa et al (1990), fMRI in particular, has had an enormous impact. In the fields of cognitive neuroscience and systems neuroscience, fMRI become "the" registration technique of choice for examining macroscopic activation correlates in working brain (Cabeza and Kingstone, 2000).

All current techniques measure local neuronal activity by indirect means. PET and fMRI measure local properties of the cerebral blood flow: the fMRI signal is based on blood oxygen level dependence (BOLD), and the PET signal on regional cerebral blood flow (RCBF). The mechanisms that link metabolic measures to neural activation are not yet well understood. The general impression is that the BOLD signal reflects the magnitude of synaptic events more closely than that of firing rates (Jueptner and Weilles, 1995; Magistretti and Pelerin, 1999).

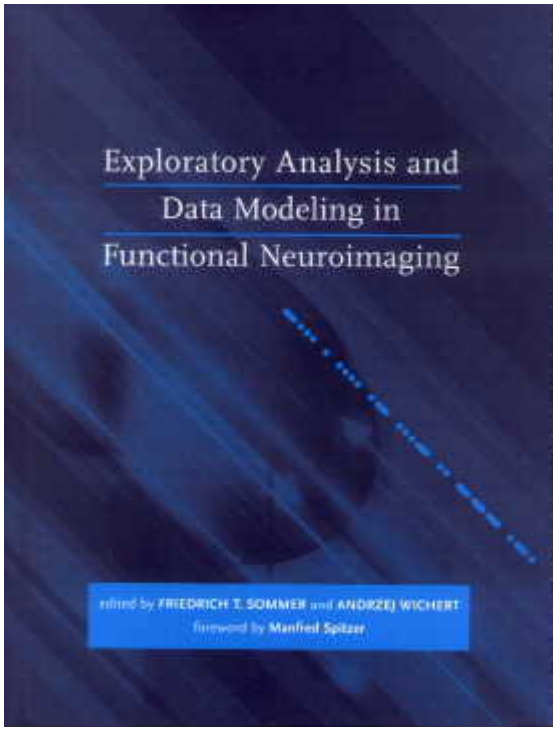
The traditional experimental bases of functional brain theories fall into two broad categories: Lesion studies that assess how cerebral injuries or other manipulations effect function. Recordings with electrodes or microelectrodes that measure neuronal activity in response to peripheral stimulation/during the performance of tasks.

The subtraction paradigm has become the standard in most fMRI and PET studies. This assumes that different brain regions are engaged in different brain functions (Horwitz and Sporns, 1994); i.e. it relies on the existence a of functional specialization. These studies commonly employ an experimental protocol known as block design, which involves switching between two steady states, or blocks, one a rest interval and the other a functional condition.

The second paradigm is called the covariance paradigm (Horwitz and Sporns, 1994). It is motivated by the hypothesis of functional integration. Covariance paradigms assess the temporal covariance between different brain regions during a particular task.

Exploratory data analysis is a main focus of this book; the methods and their application for different imaging techniques are described by a number of chapter:

- fMRI: Samorjai and colleagues, McKeown;
- Event related fMRI: Wichert and colleagues;
- MEG/EEG: Tang and Bark, Vigario and colleagues;
- Auto radiography: Nair and Gonzalez- Lima.



" .. The main goal of EEG/MEG data analysis is source reconstruction. The result of source reconstruction is a configuration of sources in the brain (time-dependent electric or magnetic dipoles or multipoles). ... "

The main goal of EEG/MEG data analysis is source reconstruction. The result of source reconstruction is a configuration of sources in the brain (time-dependent electric or magnetic dipoles or multipoles).

Blood flow based and electrophysiological measurements have complementary strengths and weaknesses in space and time; thus experiments that combine both approaches are potentially powerful.

Chapter 2

A description of a particular realization of Exploratory Data Analysis (EDA), the three - stage strategy Exploring Regions of Interest with Cluster Analysis (EROICA) which is specifically designed to analyze specifically designed to analyze functional MR neuromaging data is given. The first stage consists of an Initial Partition of the data into three groups;

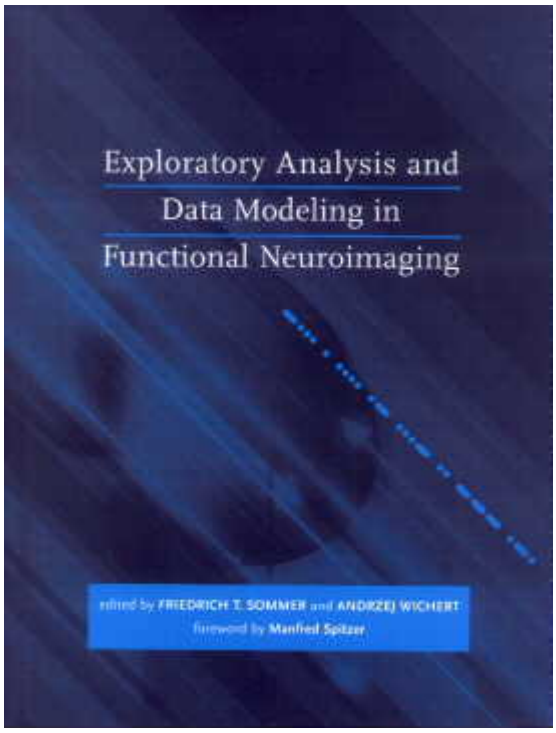
- a group of "trend" time courses (TCs),
- a group of "potentially interesting" TCs and
- a group that contains the remaining putative "noise" tests.

The second stage is the Principal Partition where fuzzy clustering analysis (FCA) is applied to the group of "potentially interesting" TCs.

The third stage, Significance Testing, "validates" the second-stage results by first removing those TCs from the original clusters that fail special.

Chapter 3

The Bayesian framework is described which is used to compute probabilities of competing hypotheses about functional activation based on single trial fMRI measurements. A complete probabilistic picture of competing hypotheses within the framework is obtained with control of both type I & type II errors. An expansion of the Bayesian framework is included along with an explicit treatment of linear hemodynamic response based on so-called conjugate priors.
A main objective of neuroimaging is to ensure questions about the form of activation in regions or locations in the brain. From fMRI studies, a gradient - echo, echo planar imaging (EPI) technique was used.



" .. A Bayesian framework has been outlined for signal detection in noisy linear systems. Weak conjugate priors were used, as a result closed form expressions were obtained for the relative probabilities over competing hypotheses, depending on only one free parameter. ... "

A Bayesian framework has been outlined for signal detection in noisy linear systems. Weak conjugate priors were used, as a result closed form expressions were obtained for the relative probabilities over competing hypotheses, depending on only one free parameter. The value of this parameter can be estimated from simulations and the system appears to be quite insensitive to its precise value. The Bayesian framework was used to estimate the probability of three alternatives in an fMRI experiment involving planning & execution of motion. In a small slap covering both motor & premotor pixels were found to have contiguous regions designated to the null, the execution and to the preparation hypotheses.

Chapter 4

Description of selective averaging of these data sets, using time windows time-locked to repetitive stimuli is given. This method has long been used in Event-Related Potential (ERP) research. The implications of averaging raw fMRI data is given. Before averaging, voxels with similar properties can be segregated using either a restricted region of interest (ROI) or first techniques like Independent Component Analysis (ICA).

Chapter 5

A novel technique for exploratory analysis of event-related fMRI is described, the technique comprises two parts:
1. The first, component is dense latency sampling (DLS), an oversampling scheme for ER fMRI that has advantage of providing volume slice timing without the need for signal interpolation.

2. The second component is dynamical cluster analysis (DCA) of signal time courses; this analysis is done with temporal constraint taken from the event - related design. Signal segments that

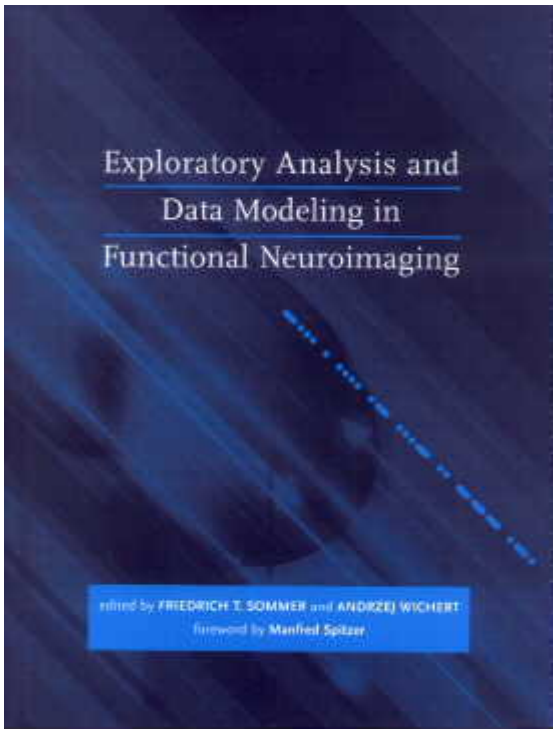
correspond to different types of events are analyzed separately to reveal specific event - related activation.

The technique does not rely on presumptions about the temporal shape of functional activity like common inferential methods.

The utility of the technique is demonstrated and its performance is compared to standard techniques in a study of working memory. The technique reveals spatio-temporal patterns of activity associated with different memory load conditions. Current methods for exploratory analysis of ER fMRI are also described like ER fMRI registration technique, signal averaging to achieve noise reduction (Dale and Buckner, 1997), oversampling to increase resolution of neurofMRI (Josephs et al 1997) and estimating hemodynamic response (HR) functions (Miezin et al, 2000) and volume slice timing that involves phase-shift manipulations in the data.

For multivariate exploratory analysis of fMRI/PET data various methods have been proposed, such as:

1. Principal component analysis (Lai and Fang, 1999; Hansen et al., 1999 Baumgartner et al., 2000),



" .. For multivariate exploratory analysis of fMRI/PET data various methods have been proposed, such as Principal component analysis, independent component analysis and diverse temporal clustering methods ... "

2. Independent component analysis (McKeown et al., 1998 McKeown and Sejnowski 1999) and

3. Diverse temporal clustering methods (Scarth et al., 1995, Baumgartner et al., 1997; Golay et al., 1998; Baune et al., 1999; Goutte et al., 1999; Flizmoser et al., 1999; Fadili et al., 2000). The goal of these approaches is to detect characteristic spatio-temporal properties in the data as much as possible uniformed of a priori assumptions about the results. Exploratory data analysis has been successfully applied for block design experiments.

A description of a technique of exploratory data analysis for ERfMRI experiments is given. The technique includes two components:

1. The first component is a new oversampling and data sorting scheme DLS.

2. The second component is a paradigm informed application of temporal cluster analysis to event-related data combined with a systematic evaluation of clustering results. A dynamical variant of K-means analysis (K-MDI CA) permitted rapid and reproducible cluster analysis of the data.

The technique was used for a study of delayed response working memory. Important features of the results can be extracted by methods that differ in the type of underlying assumptions functional specialization versus functional integration. The exploratory technique yielded results that the standard technique could not provide and it provided a global view of the spatio-temporal structure associated with each different type of event. Thus, it was possible to assess involvement of disparate regions in different process of working memory.

Further advances in fMRI will depend on a better understanding of the relationship between the hemodynamic response and patterns of neural activity.

Chapter 6

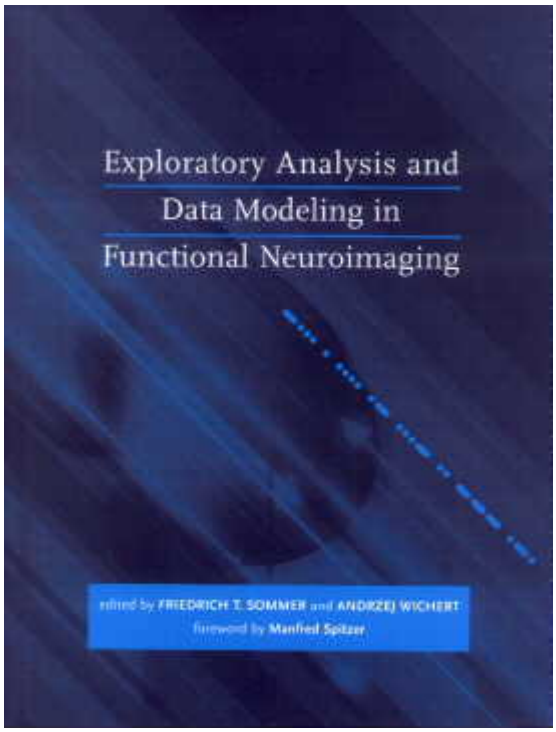
fMRI adaptation is a powerful tool for studying the properties of networks of neurons with imaging techniques. Here evidence is presented that adaptation paradigms can be used in imaging experiments to characterize properties of neuronal populations beyond the spatial resolution of current imaging techniques.
The validity of this technique is illustrated by results from monkey and human fMRI studies.

In addition, adaptation can reveal certain response properties of neurons beyond those known from standard neuronal selectivity experiments.

PART II: EGM/MEG Data Analysis

Part III of this book comprises of chapters 7 and 8.

Chapter 7



" .. SOBI preprocessing can lead to the identification and localization of physiologically and anatomically meaningful neuronal sources and it can also increase the success rate in detecting and localizing neuronal source activation under poor signal-to-noise conditions. ... "

Here the application of second blind identification order (SOBI), an independent component analysis (ICA) method to magneto encephalography (MEG) data is shown especially in preprocessing of sensor data with poor signal to noise ratios resulting in identification of the expected somatosensory sources and localization than the same dipole modeling method applied directly to the raw sensor data.

SOBI preprocessing can lead to the identification and localization of physiologically and anatomically meaningful neuronal sources and it can also increase the success rate in detecting and localizing neuronal source activation under poor signal-to-noise conditions. The usefulness of ICA algorithms in the analysis and interpretation of MEG data are demonstrated.

Chapter 8

This chapter focuses on a signal processing technique, BSS, which allows the blind separation of sources, linearly mixed at the sensors.
BSS very often provides the ideal "weak model" for decomposing brain signals like EEG or MEG of independence is often verified.

PART III: COMBINATION EEG/MEG AND FMRI

Part III of this book comprises of chapters 9 till 13.

Chapter 9

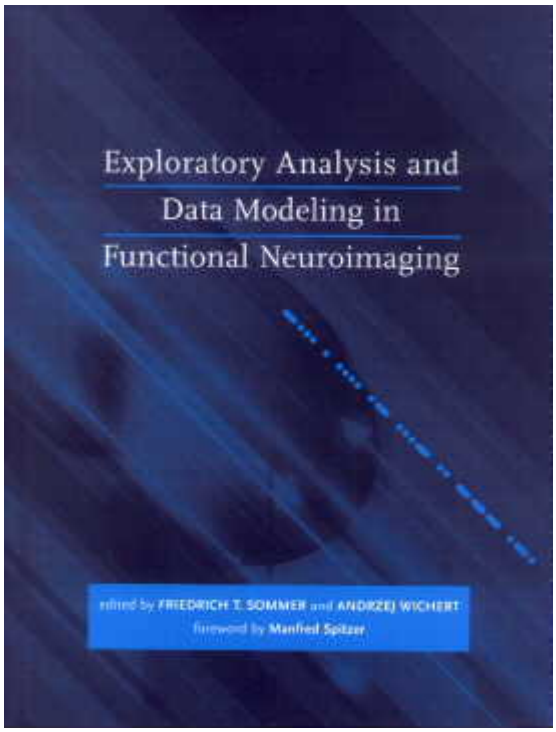
Describes EEG and blood oxygen level difference (BOLD) signals which reflect spatial synchronization and total metabolic consumption, respectively, information transfer in cortex is also controlled in part by the network synchronies that give rise to EEG.

Chapter 10

Two complementary techniques for studying brain functioning are the recording of ERP and observing the hemodynamic response by fMRI scanning.

Chapter 11

Arbib et al. (1995) introduced a new computational technique, called Synthetic PET imaging. Synthetic PET imaging is a technique for using computational models derived from primate neurophysiological data to predict and analyze the results of human PET studies. This chapter gives a description of synthetic PET approach, and demonstrates how it is applied. The synthetic PET measures are computed for a simulated conditional / non-conditional grasping experiment, and then compared to the results of a similar human PET study. A description of how the human PET results may be used to further constrain the computational modal is also shown.



" .. This technique uses neural methods that are based on primate neurophysiology to predict and analyze results from PET brain regional cerebral blood flow (rCBF) or glucose metabolism taken during performance of a variety of human behaviors. ... "

This technique uses neural methods that are based on primate neurophysiology to predict and analyze results from PET brain regional cerebral blood flow (rCBF) or glucose metabolism taken during performance of a variety of human behaviors. PET metabolic imaging is correlated with the integrated synaptic activity in a brain region (Brownell et al., 1982), and thus reflects in part neural activity in regions afferent to the region studied, rather than intrinsic neural activity of the region alone.

Synthetic PET is however only one case of the broader potential for systems neuroscience of Synthetic Brain Imaging (SBI) in general.

Chapter 12

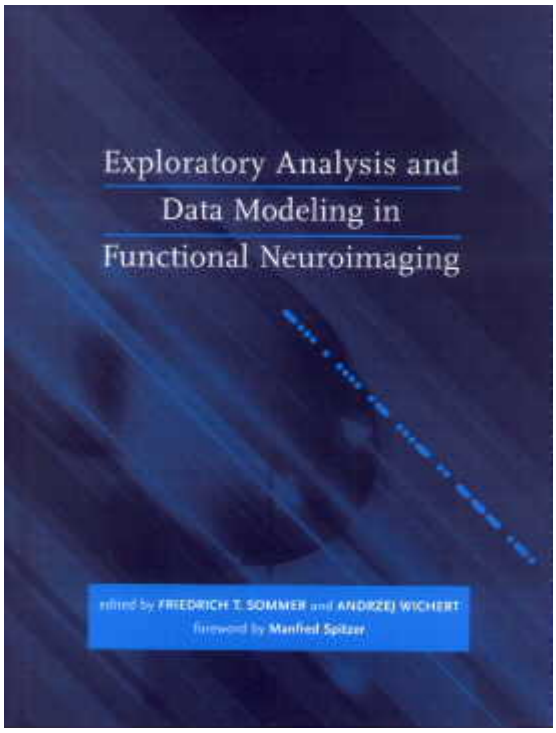
Large-scale modeling helps to bridge the large gap between the imaging results and underlying neuronal processes such as those described in single-cell animal studies. The model performs a task that has been used in both animal single-cell recordings and human brain imaging experiments. The model includes elements that have dynamics similar to the various neuronal populations that have been identified in the ventral visual pathway, while at the same time the total summed synaptic activity in the different regions is similar to human imaging data. In this model, the emphasis is at the circuit level, and the expected effect of balance of excitatory and inhibitory connections on imaging data is discussed.

A model has been developed (Tagamets and Horwitz, 1998) with the specific goal of understanding the neural underpinnings of human imaging data and relating it to animal studies. The model performs a delayed match-to-sample (DMS) task, a paradigm that has been used in both animal single-cell recordings and human brain imaging studies. It includes four separate regions that model the ventral visual pathway, and incorporates a circuit in the model frontal cortex area that maintains delay-period activity, acting as a short term memory.

The most commonly measured entity is the rate of action potentials (spiking) of single neurons (Eskandar et al., 1992; Friston, 1997). While single-cell recording provide a direct measure of this spiking activity, the human imaging methods of PET and fMRI are indirect measures, and apply to large population of neurons. Specifically, rCBF and BOLD are thought to reflect local energy requirements that are a byproduct of synaptic activity. Two factors are especially germane to modeling the relationship between human imaging data and single cell recordings:

1. Glutamatergic synapses are the most abundant in the cortex, and

2. The glutamate cycle as mediated by astrocytes is tightly coupled to changes in local metabolism that are generated from the activity of neurons (Megistretti and Pellerin, 1999).



" .. The development of the ability to express learned behaviour during the postnatal period is presumably related to maturational changes in the recruitment of particular neural systems to guide the behavior. By assessing brain functional activity during transitional period of behavioral development, we may gain valuable insight into when particular neural systems come on-line and impact behavior. ... "

Another factor that affects rCBF and BOLD is the background activity of neurons in the region being examined. In a combined experimental and theoretical study, Scannell and Young (1999) presented results that suggested that changes in the background activity (without a change in spiking level) could modify measured rCBF at least as much as changes in spiking alone. This highlights the importance of modulatory effects in imaging. In particular, there is an interaction of sensory input (feed-forward) and modulatory influences (feedback or transmitter-based) in most regions of the cortex, especially in association areas.

Other studies with the model have also helped clarify the underlying neuronal mechanisms that generate neuroimaging data. The model has recently being applied to simulate transcranial magnetic stimulation (TMS) data, in which a strong, changing magnetic field applied to a region on the scalp induced intracranial electrical currents that can alter regional neuronal function. TMS has been used in conjunction with PET to examine inter-regional connectivity of human cerebral cortex (e.g. Paus et al., 1998). There are many other studies which have helped to clarify the relationship between experimental manipulations and analysis methods, an important factor when interpreting experimental data that is still relatively poorly understood in human imaging.

Chapter 13

The development of the ability to express learned behaviour during the postnatal period is presumably related to maturational changes in the recruitment of particular neural systems to guide the behavior. By assessing brain functional activity during transitional period of behavioral development, we may gain valuable insight into when particular neural systems come on-line and

impact behavior. These issues were investigated by applying Partial Least Squares (PLS) analysis to metabolic mapping data obtained from developing rats.
In the first application of PLS, an analysis analogous to a traditional univariate means analysis was performed to identify large scale networks, within 39 regions of interest, either commonly activated across groups or which differentiated groups. A second application of PLS was used to identify dominant patterns of covariances between regions (i.e. functional connectivity) that distinguished training and age groups.

McIntosh et al. (1996) were the first to adapt the technique to human functional imaging data; in this case PLS identifies spatial patterns of functional activation (singular images) that co-vary with task, behavior, or other regions of interest.

This book provides a comprehensive survey of theoretical and computational approaches to neuroimaging (fMRI, PET, EEG & MEG) including inferential, exploratory, and causal methods of data analysis; theories of cerebral function; and biophysical and computational models of neural networks. It also emphasizes the close relationship between different approaches, for example, between causal data analysis and biophysical modeling, and between functional theories and computational models.



-Sherin S. Thomas
Sherin S. Thomas is currently working as a Senior Resident in the Department of Biochemistry at the Maulana Azad Medical College, New Delhi. She completed her MBBS (graduation in medicine and surgery) in 1994 and completed her specialization (MD in Biochemistry) in 2001.
Dr. Thomas is an avid reader of books, journals etc. on a wide variety of topics, especially on Brain theory and neural networks and Computational Molecular Biology. She is a passionate book lover. Her other interests include listening to music and spending time with her five cats and three dogs.

Order this Book by clicking here

-Editor-in-Chief

of Vol. 2, No. 2 (July - December 2003)