

Cambridge University Press

978-0-521-87979-8 - Electrical Neuroimaging

Edited by Christoph M. Michel, Thomas Koenig, Daniel Brandeis, Lorena R. R. Gianotti and Jiri Wackermann

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Dedicated to  
Dietrich Lehmann, our teacher, mentor  
and friend

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## Preface

In 1929, Hans Berger, the founding father of electroencephalography (EEG), described EEG as a “window into the brain,” because EEG appeared to be a sensitive indicator of mental states. Eighty years later, recording and analysis methods exist that have made EEG a widespread and validated tool to observe the spatial and temporal dynamics of brain network activity during a large variety of mental states and processes in a completely noninvasive fashion. This has been made possible by significant technological advances that now allow the simultaneous recording of an EEG from a large number of electrodes at a high sampling rate, and the application of space-domain oriented approaches to the analysis of these recordings. This book gives an overview of these methods. Illustrated by various examples from experimental and clinical studies, the book is a tutorial on how to use EEG as a modern functional imaging method with the advantage of directly recording neuronal activity with millisecond temporal resolution, an approach called electrical neuroimaging.

Electrical neuroimaging has enormous potential if properly applied, but it can also easily lead to erroneous conclusions if its basic principles are not properly understood. This book intends to give a comprehensive introduction to the basics of multichannel recording of EEG and event-related potential (ERP) data, and to spatio-temporal analysis of the potential fields. All chapters include practical examples from clinical and experimental research. The book enables a researcher to measure valid data, select and apply appropriate analysis strategies and draw the correct conclusions when analyzing and interpreting multichannel EEG/ERP data. It informs the research community about the possibilities opened by these space-domain oriented strategies to the analysis of brain electrical activity, and of their potential for multimodal integration with other (structural, metabolic, etc.) data.

Electrical neuroimaging is decisively different from the traditional analysis of EEG and ERP data, which is based upon waveform morphology and/or frequency characteristics of recordings at certain electrode positions. Electrical neuroimaging exclusively considers the spatial properties of electric fields and the temporal dynamics of these fields. It uses these to conclude on putative generators in the brain that gave rise to these recorded fields on the scalp. The approach therefore fills an important gap that has not been covered by other comprehensive textbooks on the analysis of EEG and ERP.

The book begins with an introduction of what the EEG on the scalp surface actually records. It comprises the basics of what we know about the generation of electric fields in the brain, which can be measured noninvasively at the scalp, and about the generation of oscillatory activity at different frequency ranges. This basic knowledge is needed for understanding the following chapter on how electric potential fields on the scalp are generated and how they are characterized. Knowing the generators in the brain and the expression of these activities on the scalp surface allows the key issue of estimating putative generators in the brain to be addressed. The book therefore contains a thorough discussion of the methods available to solve the electromagnetic inverse problem, focusing mainly on distributed inverse solutions that impose minimal a priori constraints. It is followed by a rather practical chapter on the basic requirements for recording high-density EEG and preparing these data for electrical neuroimaging. The subsequent chapters show with many practical examples how to assess the many different facets of time- and frequency-domain EEG. The knowledge and methods

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presented here are strictly based on well-established facts about the relation between generators in the brain and scalp-surface recordings. The results obtained by these methods thus have simple and unique interpretations in terms of intracerebral brain electric activity. Finally, the emerging field of multimodal integration is discussed, with special emphasis on the combination of EEG-based neuroimaging and functional MRI.

The book will be of great utility to cognitive neuroscientists, but also clinical neurophysiologists, neurologists and psychiatrists, as we emphasize with many practical examples the usefulness of these methods for developmental and clinical applications. The first attempts in the early 1990s to introduce quantitative EEG mapping into clinical applications were hampered by severe technical difficulties. This is not the case any more. High resolution EEG with up to 256 channels is very easy and fast to apply in clinical routine in adults as well as in children, allowing the application of the analysis methods described in this book to pathological alterations of brain function that continue to intrigue clinical neurophysiologists. It should provide them with a new tool to critically increase the sensitivity, specificity and interpretability of the measure they have used for over half of a century, which is the electroencephalogram.