

# EEG Neurofeedback therapy: Can it attenuate brain changes in TBI?

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## Abstract

**BACKGROUND:** Electroencephalogram Neurofeedback therapy (EEG-NFT) has several potential beneficial effects in terms of improving cognition and electrophysiological regulation among patients with brain injury. However, *in vivo* structural and functional changes remain less explored.

**OBJECTIVE:** The aim of the present study is to explore EEG-NFT induced *in vivo* changes in traumatic brain injury (TBI) patients.

**METHOD:** Two patients with mean age of 15 years with moderate head injury who had more than seven post concussion symptoms and poor cognitive performances (<5 percentile) were subjected to 20 sessions of EEG-NFT. The neuropsychological test scores, post concussion symptoms and MRI scan of the brain were recorded pre-post to EEG-NFT.

**RESULTS:** During EEG-NFT the cognitive scores and concussion symptoms improved significantly ( $p < 0.05$ ). The EEG-NFT has shown significant increase in cortical grey matter (GM) volumes ( $p < 0.0001$ ) and fractional anisotropy (FA) of cortical white matter (WM) tracts ( $p < 0.0001$ , voxel max 60 and above). There was a significant decrease in global, local efficiency, cost and clustering coefficient of functional connectivity (Wilcoxon Sign Rank Test  $p < 0.05$ ). Interestingly there was a significant increase in thalamo-cortical connection (increase FA value) after EEG-NFT.

**CONCLUSION:** The EEG-NFT therapy has shown significant changes in structural and functional connectivity among young moderately injured TBI patients.

**Keywords:** EEG-NFT, TBI, MRI scan, neuropsychological scores, *in vivo* changes

## 1. Introduction

Traumatic brain injury (TBI) is a dynamic process that is caused by force impact. The resulting characteristic pathological process causes structural and

functional abnormalities in neural networks that are responsible for cognitive and somatic impairments (Podell, Gifford, Bougakov, & Goldberg, 2010). Electroencephalogram Neurofeedback therapy (EEG-NFT) is a potent technique that modifies the structural and functional abnormalities in cortico-cortical and cortico-subcortical neural network. It acts through operant conditioning where altering the intrinsic firing pattern of neural networks in hypocoupling range for better information acquisition, complex mental activity and

\*Address for correspondence: Dr. Jamuna Rajeswaran, Additional Professor, Department of Clinical Psychology, National Institute of Mental Health and Neurosciences (NIMHANS), Bangalore, India. Tel.: +91 080 2699 5181; Mobile: +91 9880092042; E-mail: drjamunarajan@gmail.com.

# 2014 Eeg Code Changes

**Felix Putze,Christian Mühl,Fabien  
Lotte,Stephen Fairclough,Christian  
Herff**

## 2014 Eeg Code Changes:

*Anatomical and functional neural networks changes in cognitive impairment and healthy aging* Fermín Segovia, Cosimo Urgesi, 2023-04-14      **Micro-, Meso- and Macro-Dynamics of the Brain** György Buzsáki, Yves Christen, 2016-05-02 This book brings together leading investigators who represent various aspects of brain dynamics with the goal of presenting state of the art current progress and address future developments The individual chapters cover several fascinating facets of contemporary neuroscience from elementary computation of neurons mesoscopic network oscillations internally generated assembly sequences in the service of cognition large scale neuronal interactions within and across systems the impact of sleep on cognition memory motor sensory integration spatial navigation large scale computation and consciousness Each of these topics require appropriate levels of analyses with sufficiently high temporal and spatial resolution of neuronal activity in both local and global networks supplemented by models and theories to explain how different levels of brain dynamics interact with each other and how the failure of such interactions results in neurologic and mental disease While such complex questions cannot be answered exhaustively by a dozen or so chapters this volume offers a nice synthesis of current thinking and work in progress on micro meso and macro dynamics of the brain      **Understanding Hospital Billing and Coding** Debra P. Ferenc, 2013-02-26 A basic guide to hospital billing and reimbursement Understanding Hospital Billing and Coding 3rd Edition helps you understand complete and submit the UB 04 claim form that is used for all Medicare and privately insured patients It describes how hospitals are reimbursed for patient care and services showing how the UB 04 claim form reflects the flow of patient data from the time of admission to the time of discharge Written by coding expert Debra P Ferenc this book also ensures that you understand the essentials of ICD 10 CM and develop skills in both inpatient coding and outpatient ambulatory surgery coding UB 04 Claim Simulation on the companion Evolve website lets you practice entering information from source documents into the claim form Over 300 illustrations and graphics bring important concepts to life Detailed chapter objectives highlight what you are expected to learn Key terms acronyms and abbreviations with definitions are included in each chapter Concept Review boxes reinforce key concepts Test Your Knowledge exercises reinforce lessons as you progress through the material Chapter summaries review key concepts Practice hospital cases let you apply concepts to real life scenarios Updated Claim Forms chapter covers the UB 04 claim form Updated information covers diagnosis and procedural coding with guidelines and applications Updated claim forms and names are used throughout      Augmentation of Brain Function: Facts, Fiction and Controversy Mikhail Lebedev, Ioan Opris, Manuel F. Casanova , 2018-09-14 Volume I entitled Augmentation of Brain Functions Brain Machine Interfaces is a collection of articles on neuroprosthetic technologies that utilize brain machine interfaces BMIs BMIs strive to augment the brain by linking neural activity recorded invasively or noninvasively to external devices such as arm prostheses exoskeletons that enable bipedal walking means of communication and technologies that augment attention In addition to many practical applications

BMIs provide useful research tools for basic science. Several articles cover challenges and controversies in this rapidly developing field such as ways to improve information transfer rate. BMIs can be applied to the awake state of the brain and to the sleep state as well. BMIs can augment action planning and decision making. Importantly, BMI operations evoke brain plasticity which can have long lasting effects. Advanced neural decoding algorithms that utilize optimal feedback controllers are key to the BMI performance. BMI approach can be combined with the other augmentation methods such systems are called hybrid BMIs. Overall it appears that BMI will lead to many powerful and practical brain augmenting technologies in the future.

*Detection and Estimation of Working Memory States and Cognitive Functions Based on Neurophysiological Measures* Felix Putze, Christian Mühl, Fabien Lotte, Stephen Fairclough, Christian Herff, 2019-02-05 Executive cognitive functions like working memory determine the success or failure of a wide variety of different cognitive tasks such as problem solving, navigation or planning. Estimation of constructs like working memory load or memory capacity from neurophysiological or psychophysiological signals would enable adaptive systems to respond to cognitive states experienced by an operator and trigger responses designed to support task performance e.g. by simplifying the exercises of a tutor system when the subject is overloaded or by shutting down distractions from the mobile phone. The determination of cognitive states like working memory load is also useful for automated testing, assessment or for usability evaluation. While there exists a large body of research work on neural and physiological correlates of cognitive functions like working memory activity, fewer publications deal with the application of this research with respect to single trial detection and real time estimation of cognitive functions in complex realistic scenarios. Single trial classifiers based on brain activity measurements such as electroencephalography, functional near infrared spectroscopy, physiological signals or eye tracking have the potential to classify affective or cognitive states based upon short segments of data. For this purpose, signal processing and machine learning techniques need to be developed and transferred to real world user interfaces. The goal of this Frontiers Research Topic was to advance the State of the Art in signal based modeling of cognitive processes. We were especially interested in research towards more complex and realistic study designs for example collecting data in the wild or investigating the interaction between different cognitive processes or signal modalities. Bringing together many contributions in one format allowed us to look at the state of convergence or diversity regarding concepts, methods and paradigms.

*Closed-Loop Systems for Next-Generation Neuroprostheses* Timothée Levi, Paolo Bonifazi, Paolo Massobrio, Michela Chiappalone, 2018-04-26 Millions of people worldwide are affected by neurological disorders which disrupt the connections within the brain and between brain and body causing impairments of primary functions and paralysis. Such a number is likely to increase in the next years and current assistive technology is yet limited. A possible response to such disabilities offered by the neuroscience community is given by Brain Machine Interfaces, BMIs and neuroprostheses. The latter field of research is highly multidisciplinary since it involves very different and disperse scientific communities making it fundamental to create

connections and to join research efforts Indeed the design and development of neuroprosthetic devices span involve different research topics such as interfacing of neural systems at different levels of architectural complexity from in vitro neuronal ensembles to human brain bio artificial interfaces for stimulation e g micro stimulation DBS Deep Brain Stimulation and recording e g EMG Electromyography EEG Electroencephalography LFP Local Field Potential innovative signal processing tools for coding and decoding of neural activity biomimetic artificial Spiking Neural Networks SNN and neural network modeling In order to develop functional communication with the nervous system and to create a new generation of neuroprostheses the study of closed loop systems is mandatory It has been widely recognized that closed loop neuroprosthetic systems achieve more favorable outcomes for users then equivalent open loop devices Improvements in task performance usability and embodiment have all been reported in systems utilizing some form of feedback The bi directional communication between living neurons and artificial devices is the main final goal of those studies However closed loop systems are still uncommon in the literature mostly due to requirement of multidisciplinary effort Therefore through eBook on closed loop systems for next generation neuroprostheses we encourage an active discussion among neurobiologists electrophysiologists bioengineers computational neuroscientists and neuromorphic engineers This eBook aims to facilitate this process by ordering the 25 contributions of this research in which we highlighted in three different parts A Optimization of different blocks composing the closed loop system B Systems for neuromodulation based on DBS EMG and SNN and C Closed loop BMIs for rehabilitation

**Federal Register** ,2013-12      **"Code of Massachusetts regulations, 2014"** ,2014

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regulations and loan and finance risk The contributors show that a carefully planned mix of incentives and supplementary schemes is indispensable The essays are drawn on the presentations and papers offered at the International Conference on a Comprehensive Legal Framework for the Development of Offshore Wind Power Around the World held in Taiwan in August 2016 As a major new contribution to the debate on the importance of a legal framework for offshore wind power and grid interconnections this book will prove indispensable to lawyers policymakers officials and academics concerned with the management of sea space to include the wind power necessary to achieve and sustain renewable energy goals **Language and Language Behavior Abstracts**, 1967 Abstracts of the world's literature in linguistics and language related research book abstracts book review listings and enhanced bibliographic citations of relevant dissertations Related disciplines such as anthropology education ethnology information science medicine and communications are covered Also includes some reference to papers in published conference proceedings *A Bibliography of Electrical Recordings in the CNS and Related Literature*, 1976 References to world literature indexed by the Brain Information Service Alphabetical arrangement by authors under broad topics Titles appear in English as well as in the original of most other languages Author KWIC indexes

**Title 20 Employees' Benefits Parts 400 to 499 (Revised as of April 1, 2014)** Office of The Federal Register, Enhanced by IntraWEB, LLC, 2014-04 The Code of Federal Regulations Title 20 contains the codified Federal laws and regulations that are in effect as of the date of the publication pertaining to Federally mandated employee benefits such as workers compensation Social Security Veterans employment benefits etc *Yearbook of International Organizations 2014-2015, Volumes 1a & 1b (Set)* Union of International Associations, 2014-06-16 Volume 1 A and B covers international organizations throughout the world comprising their aims activities and events **Wildlife Research**, 2014 **Index to IEEE Publications** Institute of Electrical and Electronics Engineers, 1996 Issues for 1973 cover the entire IEEE technical literature *Harrison's Principles of Internal Medicine* Tinsley Randolph Harrison, 1987 **Cognition** Cornelia I. Bargmann, Daphne Bavelier, David Stewart, Terrence Joseph Sejnowski, Bruce Stillman, 2014 The Proceedings of the 79th Symposium capture many of the tremendous discoveries currently being made by neuroscientists and psychologists working on cognitive processes at scales varying from the molecular to circuit to whole brain and theoretical studies Major advances in understanding cognitive function including learning memory language and decision making are being made through the application of powerful new techniques and approaches The scientific results discussed in this volume shed light on many areas of normal brain function but also offer novel insights into the treatment of psychiatric neurological and neurodegenerative diseases This volume includes state of the art neurobiological research at genetic molecular cellular circuit and whole brain resolution Additional chapters address computational neuroscience behavioral and psychophysical studies and evolutionary comparative neuroscience The Conversations included in this volume are based on interviews conducted during the Symposium and offer a broader anecdotal perspective on this fascinating subject by many of the world

s leading cognitive neuroscientists The Symposium Proceedings provides an integrative overview of the current state of the field as well as a glimpse into the emerging connections between molecular cellular circuit mechanisms and higher brain function by leading authorities in the field      **Sleep Research** ,1979      Society for Neuroscience Abstracts Society for Neuroscience. Annual Meeting,1993      *Safety and Health at Work* ,1993

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