

We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

6,900

Open access books available

186,000

International authors and editors

200M

Downloads

Our authors are among the

154

Countries delivered to

TOP 1%

most cited scientists

12.2%

Contributors from top 500 universities



WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com



Introductory Chapter: Cognitive and Computational Neuroscience - Principles, Algorithms, and Applications

Seyyed Abed Hosseini

Additional information is available at the end of the chapter

<http://dx.doi.org/10.5772/intechopen.72824>

1. Cognitive and computational neuroscience: principles, algorithms, and applications

The term “computational neuroscience” was introduced by Schwartz [1] through the organization of a conference in California in 1985. Cognitive and computational neuroscience evaluates the different brain functions (e.g., attention, emotion, perception, learning, consciousness, anesthesia, cognition, and memory) in terms of the information processing procedure of the brain [2]. This topic is an interdisciplinary issue that links the diverse backgrounds of neuroscience, cognitive science, psychology, mathematics, biomedical engineering, computer science, robotics, and physics. Therefore, the main idea of this book is to present a general framework for the researchers from diverse fields.

2. Related works

Cognitive and computational neuroscience has many medical and engineering applications such as rehabilitation [3], psychology and psychiatric disorders (e.g., depression, chronic addiction, post-traumatic stress disorder, dementia, attention deficit hyperactivity disorder, and autism) [4], brain-computer interface [3, 5], human-computer interaction [6], neurofeedback [7, 8], marketing [9], robotic [10], and decision-making [11]. Research in cognitive and computational neuroscience is categorized into four main topics, including experimental neuroscience (e.g., electrophysiology, neuron, synapse, synaptic plasticity, memory, conditioning, learning, consciousness, vision, neuroimaging), theoretical neuroscience (e.g., models of neurons, single-neuron modeling, spiking networks, network dynamics, behaviors of the brain networks, mathematical models of the brain activity, sensory processing, connectivity analysis), dynamical systems (e.g., synchronization, oscillators, pattern formation, chaos),

and computational intelligence (e.g., neural networks, graph theory, reinforcement learning, pattern recognition, evolutionary computation, information theory, statistics, and signal processing).

Suitable brain signals and images are usually used according to invasive or non-invasive acquisition techniques. Therefore, non-invasive techniques, such as electroencephalography (EEG) [12, 13], event-related potentials (ERPs) [14, 15], magnetoencephalography (MEG) [3, 16], functional magnetic resonance imaging (fMRI) [17], positron emission tomography (PET) [18], transcranial direct current stimulation (tDCS) [19], and transcranial magnetic stimulation (TMS) [20], are generally preferred.

This section presents a detailed discussion of previous related works on different methods based on epilepsy and seizure detection along with different machine-learning approaches. In one study, Hosseini et al. [21] proposed a qualitative and quantitative analysis of EEG signals for epileptic seizure recognition. Hosseini et al. [22] proposed an approach for seizure and epilepsy recognition using chaos analysis of EEG signals. Hosseini [23] proposed a hybrid method based on higher order spectra (HOS) for recognition of seizure and epilepsy using EEG and electrocorticography (ECOG) signals.

Several studies have been proposed for the presentation of functional models, conceptual models, bio-inspired frameworks, signal processing approaches, image processing approaches, and electrophysiology studies based on cognitive processes, including emotion, stress, and attention. In one study, Hosseini et al. [24, 25] proposed a labeling approach of EEG signals in emotional stress state using self-assessment and psychophysiological signals. Hosseini [26] and Hosseini et al. [27–29] presented an HOS approach for emotional stress detection using EEG signals. Hosseini et al. [30, 31] designed an emotion recognition system using entropy analysis of EEG signals. Hosseini et al. [32] proposed an improved model of the behavioral calcium channels in the hippocampus CA1 cells during stress.

In another study, Hosseini et al. [33] proposed an emotional stress recognition system using psychophysiological and EEG signals. Hosseini et al. [34] proposed different features including fractal dimension, wavelet coefficients, and Lempel-Ziv complexity of EEG signals for emotional stress recognition. Hosseini et al. [35] presented a cognitive and computational framework of brain activity during emotional stress. Hosseini et al. [36] presented a cognitive and computational framework of the brain activity in emotional stress state. Hosseini [37] proposed attention and emotion recognition systems based on biological images and signals. Hosseini and Naghibi [38] proposed a computationally improved model of brain activity in the visual attentional state. Hosseini proposed [39] a computationally bio-inspired model of brain activity in the selective attentional state and its application for estimating the depth of anesthesia.

This chapter attempts to introduce the different approaches, principles, applications, and theories in cognitive and computational neuroscience, from a historical development, focusing particularly on the recent development of the field and its specialization within psychology, computational neuroscience, and engineering.

Author details

Seyyed Abed Hosseini

Address all correspondence to: hosseyni@mshdiau.ac.ir

Research Center of Biomedical Engineering, Mashhad Branch, Islamic Azad University, Mashhad, Iran

References

- [1] Schwartz EL. Computational Neuroscience. Cambridge: MIT Press; 1993
- [2] Churchland PS, Koch C, Sejnowski TJ. What is computational neuroscience? In: Schwartz EL, editor. Computational Neuroscience. Cambridge: MIT Press; 1993. pp. 46-55
- [3] Hosseini SA, Naghibi-Sistani MB, Akbarzadeh-T MR. A two-dimensional brain-computer interface based on visual selective attention by Magnetoencephalograph (MEG) signals. *Tabriz Journal of Electrical Engineering*. 2015;**45**(2):65-74
- [4] Swanson J, Castellanos FX, Murias M, LaHoste G, Kennedy J. Cognitive neuroscience of attention deficit hyperactivity disorder and hyperkinetic disorder. *Current Opinion in Neurobiology*. 1998;**8**(2):263-271
- [5] Hosseini SA, Akbarzadeh-T MR, Naghibi-Sistani MB. Hybrid approach in recognition of visual covert selective spatial attention based on MEG signals. In: *IEEE International Conference on Fuzzy Systems (FUZZ)*. Istanbul: IEEE; 2015. DOI: 10.1109/FUZZ-IEEE.2015.7337958
- [6] Dix A. Human-Computer Interaction. Berlin: Springer; 2009
- [7] Subramanian L et al. Real-time functional magnetic resonance imaging neurofeedback for treatment of Parkinson's disease. *Journal of Neuroscience*. 2011;**31**(45):16309-16317
- [8] Ros T, Baars BJ, Lanius RA, Vuilleumier P. Tuning pathological brain oscillations with neurofeedback: A systems neuroscience framework. *Frontiers in Human Neuroscience*. 2014;**8**:1008
- [9] Khushaba RN, Wise C, Kodagoda S, Louviere J, Kahn BE, Townsend C. Consumer neuroscience: Assessing the brain response to marketing stimuli using electroencephalogram (EEG) and eye tracking. *Expert System Application*. 2013;**40**(9):3803-3812
- [10] McFarland DJ, Wolpaw JR. Brain-computer interface operation of robotic and prosthetic devices. *Computer*. 2008;**41**(10):52-56
- [11] Sanfey AG. Social decision-making: Insights from game theory and neuroscience. *Science*. 2007;**318**(5850):598-602

- [12] Hosseini SA, Quantification of EEG signals for evaluation of emotional stress level [MSc thesis]. Biomedical Department, Faculty of Engineering, Islamic Azad University Mashhad Branch; 2009
- [13] Schomer DL, Da Silva FL. Niedermeyer's Electroencephalography: Basic Principles, Clinical Applications, and Related Fields. Philadelphia: Lippincott Williams & Wilkins; 2012
- [14] Hosseini SA, Akbarzadeh-T MR, Naghibi-Sistani MB. Evaluation of visual selective attention by event related potential analysis in brain activity. *Tabriz Journal of Electrical Engineering*. 2015;**46**(1):13-24
- [15] Rugg MD, Coles MG. *Electrophysiology of Mind: Event-Related Brain Potentials and Cognition*. Oxford: Oxford University Press; 1995
- [16] Hansen P, Kringelbach M, Salmelin R. *MEG: An Introduction to Methods*. Oxford: Oxford University Press; 2010
- [17] Huettel SA, Song AW, McCarthy G. *Functional Magnetic Resonance Imaging*. Vol. 1. Sunderland: Sinauer Associates Sunderland; 2004
- [18] Bailey DL, Townsend DW, Valk PE, Maisey MN. *Positron Emission Tomography*. Berlin: Springer; 2005
- [19] Fregni F, Boggio PS, Nitsche M, Pascual-Leone A. Transcranial direct current stimulation. *The British Journal of Psychiatry*. 2005;**186**(5):446-447
- [20] George MS, Nahas Z, Lisanby SH, Schlaepfer T, Kozel FA, Greenberg BD. Transcranial magnetic stimulation. *Neurosurgery Clinics of North America*. 2003;**14**(2):283-301
- [21] Hosseini SA, Akbarzadeh-T MR, Naghibi-Sistani MB. Qualitative and quantitative evaluation of EEG signals in epileptic seizure recognition. *International Journal of Intelligent System Application*. 2013;**6**:41-46
- [22] Hosseini SA, Akbarzadeh-T M-R, Naghibi-Sistani M-B. Methodology for epilepsy and epileptic seizure recognition using chaos analysis of brain signals. *Intelligent Technologies and Techniques for Pervasive Computing*. In: Kolomvatsos K, Anagnostopoulos C, Hadjiefthymiades S, Editors. Book Chapter 2, IGI Global. pp. 20-36, May 2013. DOI: 10.4018/978-1-4666-4038-2.ch002
- [23] Hosseini SA. A hybrid approach based on higher order spectra for clinical recognition of seizure and epilepsy using brain activity. *Journal of Basic and Clinical Neuroscience*. 2017;**8**(6)
- [24] Hosseini SA, Naghibi-Sistani M-B. Classification of emotional stress using brain activity. *Applied Biomedical Engineering*. In: Gargiulo GD, McEwan A, editors. Book Chapter 14, InTech. pp. 313-336, August 2011. DOI: 10.5772/18294
- [25] Hosseini SA, Khalilzadeh MA. Emotional stress recognition system using EEG and psychophysiological signals: Using new labelling process of EEG signals in emotional

- stress state. In: 2010 International Conference on Biomedical Engineering and Computer Science (ICBECS). Wuhan, China: IEEE; 2010. pp. 1-6. DOI: 10.1109/ICBECS.2010.5462520
- [26] Hosseini SA. Classification of brain activity in emotional states using HOS analysis. *International Journal of Image Graphics Signal Process.* 2012;**4**(1):21
 - [27] Hosseini SA, Khalilzadeh MA, Naghibi-Sistani MB, Niazmand V. Higher order spectra analysis of EEG signals in emotional stress states. In: 2010 Second International Conference on Information Technology and Computer Science (ITCS). Kiev, Ukraine: IEEE; 2010. pp. 60-63. DOI: 10.1109/ITCS.2010.21
 - [28] Hosseini SA, Khalilzadeh MA, Homam M. Emotional stress detection using nonlinear and higher order spectra features in EEG signal. *Journal of Electrical Engineering.* 2009;**39**(2):13-24
 - [29] Hosseini SA, Khalilzadeh MA. Qualitative and quantitative evaluation of EEG signals in emotional state with through higher order spectra, In: 3rd Iranian Congress on Fuzzy and Intelligent Systems. Yazd: Intelligent Systems Scientific Society of Iran; 2009
 - [30] Khalilzadeh MA, Homam SM, Hosseini SA, Niazmand V. Qualitative and quantitative evaluation of brain activity in emotional stress. *Iranian Journal of Neurology.* 2010;**8**(28):605-618
 - [31] Hosseini SA, Naghibi-Sistani MB. Emotion recognition method using entropy analysis of EEG signals. *International Journal of Image Graphics Signal Process.* 2011;**3**(5):30
 - [32] Hosseini SA, Khalilzadeh MA, Homam SM. Modeling of the behavioral calcium channels in the hippocampus cells, during stress. *Iranian Journal of Biomedical Engineering.* 2010;**4**:23-32
 - [33] Hosseini SA, Khalilzadeh MA, Changiz S. Emotional stress recognition system for affective computing based on bio-signals. *Journal of Biological Systems.* 2010;**18**(Spec. 01):101-114
 - [34] Hosseini SA, Khalilzadeh MA, Naghibi-Sistani MB, Homam SM. Emotional stress recognition using a new fusion link between electroencephalogram and peripheral signals. *Iranian Journal of Neurology.* 2015;**14**(3):142
 - [35] Hosseini SA, Khalilzadeh MA, Homam M. A cognitive and computational model of brain activity during emotional stress. *Advances Cognitive Science.* 2010;**12**(2):1-14
 - [36] Hosseini SA, Khalilzadeh MA, Homam SM, Azarnoosh M. Presenting a cognitive map and computational model of the brain activity in emotional stress state. *Journal of Advances Cognitive Science.* 2010;**12**(1):1-16
 - [37] Hosseini SA. Introductory chapter: Emotion and attention recognition based on biological signals and images. *Emotion and Attention Recognition Based on Biological Signals and Images.* In: Hosseini SA editor. Book Chapter, pp. 1-3, InTech. 2017. DOI: 10.5772/66483

- [38] Hosseini SA, Naghibi-Sistani M-B. A computationally improved model of brain activity in visual attentional state. *Advances Cognitive Science*. 2017;**19**(1):1-13
- [39] Hosseini SA. A computationally inspired model of brain activity in selective attentional state and its application for estimating the depth of anesthesia [PhD thesis]. Electrical Department, Faculty of Engineering, Ferdowsi University of Mashhad; 2016

IntechOpen

IntechOpen