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SCIENCE DIRECT®
Neurocomputing 67 (2005) 297–305
NEUROCOMPUTING
www.elsevier.com/locate/neucom

Letter

Dimensional complexity analysis of human EEG in visual processing

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Received 27 September 2004; received in revised form 24 January 2005; accepted 24 January 2005
Available online 7 March 2005
Communicated by R.W. Newcomb

Abstract

To assess nonlinear human electroencephalogram (EEG) activities in the visual processing, we estimate the dimensional complexity (*DCx*) of the human EEGs. A similarity index is built to precisely detect dynamic changes in the EEG patterns. Significantly lower *DCx* values are observed at most channels when subjects are performing visual recognition and categorization tasks. This decrease in *DCx* values may be produced by the neural synchronization of cortical field activities caused by the visual processing. Our results may be helpful to understand the nonlinear human EEG activities in the visual processing.

Keywords: Electroencephalogram (EEG); Complexity analysis; Nonlinear dynamics; Visual processing

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doi:10.1016/j.neucom.2005.01.004

1. Introduction

Electroencephalograms (EEGs) record electrical activities that have potential to reflect different states of the human brain. The application of the nonlinear dynamics (ND) in the EEG analysis has recently developed and achieved some successes. According to the ND theory, EEGs are nonlinear time series produced by the brain and exhibit complex behavior. Nonlinear parameters, such as the correlation dimension (D_2), the approximate entropy ($ApEn$), the largest Lyapunov exponent ($L1$), etc., characterize the complexity of ND systems. Most of these ND studies can be divided into two categories: physiological studies and pathological studies. Generally, the former concentrates on the evaluation of conscious and mental states (i.e. classification of different sleep stages [10], effects of anaesthetics [4], etc.) and the latter fixes attention on the research of neural and psychotic illness (i.e. epilepsy [6,9], brain injury [12], Alzheimer's disease [5], etc.).

Image recognition and categorization are daily tasks for the ordinary people. The underlying visual processing mechanism of the brain has attracted substantial attention lately. Several studies have been conducted on the analysis of EEGs to address dynamic activities of the brain during the visual perception and categorization. The results of independent component analysis (ICA) show that individual independent components might index the neural synchrony within and between the intracranial brain sources [2]. Moreover, the outcomes of improved event related potentials (ERP) analysis demonstrates that the event-related changes in the local field activities might modulate the strength of the spike-based communication between the cortical areas during and after the target recognition [7].

In this paper, we choose the ND method to detect the complexity changes of the EEGs in the visual processing. The dimensional complexity (DCx) values are estimated. A similarity index is constructed to precisely detect the changes. Scalp maps are drawn to visualize the dynamic properties.

2. Materials and methods

2.1. Materials

Ten subjects' EEGs were recorded from 32 electrodes mounted on an elastic cap. Electrode CZ was used as the reference and a mastoid electrode was used as the ground. Data acquisition was made at 1000 Hz using a SynAmps recording system coupled with a computer. Subjects were asked to perform a rapid go/nogo visual perception and categorization task. They had to press a touch-sensitive button to start the test. Then they were presented with a series of 100 photographs, half of which contained an animal image. They should release the held button when a presented photograph contained an animal image (go response) or keep pressing the button during at least 1 s when the photograph did not include an animal image (nogo response). And then, the EEG recording was divided into 100 time series, which were extracted from 1 s before to 2 s after the exact time at which the