Analysis of Speech Imagery using Functional and Effective EEG based Brain Connectivity Parameters

Sandhya Chengaiyan, Centre for Healthcare Technologies, Department of Biomedical Engineering, SSN College of Engineering, Tamilnadu, India

Kavitha Anandhan, Centre for Healthcare Technologies, Department of Biomedical Engineering, SSN College of Engineering, Tamilnadu, India

ABSTRACT

Speech imagery is a form of mental imagery which refers to the activity of talking to oneself in silence. In this paper, EEG coherence, a functional connectivity parameter is calculated to analyze the concurrence of the different regions of the brain and Effective connectivity parameters such as Partial Directed Coherence (PDC), Directed Transfer Function (DTF) and Information theory based parameter Transfer Entropy (TE) are estimated to find the direction and strength of the connectivity patterns of the given speech imagery task. It has been observed from the results that by using functional and effective connectivity parameters the left frontal lobe electrodes was found to be high during speech production and left temporal lobe electrodes was found to be high while imagining the word silently in the brain due to the proximity of the electrodes to the Broca’s and Wernicke’s area respectively. The results suggest that the proposed methodology is a promising non-invasive approach to study directional connectivity in the brain between mutually interconnected neural populations.

Keywords: Brain Connectivity Estimators, Directed Transfer Function (DTF), EEG Phase Coherence, Electroencephalography, Partial Directed Coherence (PDC), Speech Imagery, Transfer Entropy

INTRODUCTION

Mental imagery is an experience that exists in our everyday life from recollecting the past to deciding the future. Research on the nature and analysis of mental imagery has a wide range of applications and is still far from being exhausted (Kuzmicov, 2013). Mental imagery is a multi-perceptual experience that resembles perceivable experience, but which occurs in the absence of the relevant perceptual stimuli. Imagery is represented in various sensory modes such as visual, auditory, speech, olfactory and kinaesthetic. Mental imagery has been studied to observe the performance characteristics of various modes of it while being used during various tasks (Koss-
lynn, 2005). Speech imagery is one form of mental imagery which is specific to the processing of verbal or sequential materials. The neural interaction behind speech imagery and processing has been a subject of intense investigation for over a century (Anderson, 1982).

Communicating with others is a natural part of people’s daily lives. However, several people suffer from speech and language disorders. Although speech and language are two separate entities, they go hand-in-hand. Speech disorders refer to problems in producing the sounds of speech or with the quality of voice while language disorders are usually an impairment of understanding. People with speech impairments such as spasmodic dysphonia and dysarthria use electronic devices that translate typed messages to ease their communication. Speech therapists prescribe treatment to help strengthen the vocal cords, improve articulation and increase the controlling capability of the vocal muscles. These treatments are usually exasperating and do not directly convert thoughts to words and do not take over the role of the malfunctioning vocal articulators (Pennington, 2010).

The main regions of interest in the brain for speech production and language comprehension are Broca’s area and the Wernicke’s area. Running around the lateral sulcus or the fissure of Sylvius in the left hemisphere of the brain, there is a neural loop that is involved both in understanding and in producing spoken language (Price et al. 2011). At the front end of this loop lies Broca’s area, which is connected to the production of language and speech, or language outputs, as well as control of facial neurons. At the other end the superior posterior temporal lobe, lies the Wernicke’s area, which is associated with the comprehension, processing and interpretation of words that we hear being spoken, or language inputs. The two areas are connected by a large bundle of nerve fibres called the arcuate fasciculus (Poeppel & Hickok, 2007).

This work focuses on subjects whose frontal and temporal regions function optimally. Waveforms are acquired when the person imagines saying a word as well as when the person actually says the word. Hence, the word or phoneme being imagined can be numerically processed and can be manifested in the form of brain connectivity parameters. In general, cognitive process or mental process differs from one individual to the other. There are many cognitive measures to analyse an individual’s performance. One such measure is lexile measure which estimates the difficulty levels of learning of a foreign language (Subbaraj et al., 2014). The existence of brain connectivity parameters is useful in quantitatively measuring the frequency synchronization between the different regions of the brain. Coherence and synchronization analysis are widely used approaches to detect cooperative neuronal activity in electrophysiological signals for any of the given cognitive task such as learning and memory (Sandhya & Kavitha, 2015). Coherence can be considered as the correlation in the frequency domain between two channels (Thatcher et al., 1986; Thatcher et al., 2004). However, coherence does not provide a directional analysis of the intensity of synchronizations. Various studies have been proposed in order to estimate functional synchronization and effective connectivity on EEG signals (Sakkalis, 2011). Linear methods usually make use of measures such as cross-correlation coefficient or coherence. On the other hand, non-linear methods assess the existence of nonlinear interdependences between signals. There are various measures such as nonlinear correlation coefficient, mutual information and generalized synchronization.

Effective brain connectivity based on Granger causality infers the causal interaction from a process $X$ to a process $Y$ which involves in the prediction of future values of $Y$ when including the past of $X$ (Wiener, 1956; Granger, 1969). This kind of causal relationship between two time series was formulated specifically for linear Gaussian stationary processes in the time and spectral domain using autoregressive models, for bivariate (Geweke, 1982) and multivariate (Geweke, 1984) systems. Multichannel time-series correspond to inherently multivariate processes. Multivariate autoregressive (MVAR) models (Shibata et al., 2004) represent interactions between
Materializing Communication Concepts: Linearity and Surface in Linguistics and Information Theory
www.igi-global.com/chapter/materializing-communication-concepts/18686?camid=4v1a

A Computational Basis for the Emotions
www.igi-global.com/chapter/computational-basis-emotions/49531?camid=4v1a