Chapter 82
Effect of Power and Phase Synchronization in Multi-Trial Speech Imagery

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ABSTRACT

Speech imagery is one form of mental imagery which refers to the imagining of speaking a word to oneself silently in the mind without any articulation movement. In this work, electroencephalography (EEG) signals were acquired while speaking and during the imagining of speaking consonant-vowel-consonant (CVC) words in multiple trials of different time frames. Relative powers were computed for each EEG frequency band. It has been observed that relative power of alpha and theta bands was dominant. Phase Locking Value (PLV), a functional brain connectivity parameter has been estimated to understand the phase synchronicity between two brain regions. PLV results show that the left hemispheric frontal and temporal electrodes has maximum phase lock in alpha and theta band during speech and speech imagery process. The combination of brain connectivity estimators and signal processing techniques will thus be a reliable framework for understanding the nature of speech imagery signals captured through EEG.

INTRODUCTION

Mental Imagery is a quasi-perceptual experience which is induced in an absence of external stimuli (Perrone-Bertolotti et al., 2014). Mental Imagery occurs in any of the sense forms- Visual imagery (mind's eye), Auditory imagery (mind's ear), Motor imagery (mind's muscle movement), Tactile imagery (mind's touch). Speech imagery is one form of mental imagery which refers to imagining of speaking a word or sentence to oneself silently in the mind without any articulation movement (Tian & Poeppel, 2012). Speech imagery is also referred to as articulation imagery. The auditory and kinesthetic response induced in speech imagery involves both motor and perceptual systems (Kosslyn, 1994). The speech perception and production of speech must depend upon each other to ensure a proper communication as well as the content of messages being conveyed (Liberman & Mattingly, 1985). Children with Autism disorder have an excellent mind voice like other healthy controls. But Autism children find it difficult to express their thought due to their speech impairment. The concept of speech imagery can be helpful in decoding the thought for such children. Speech imagery can also contribute for speech preparation that has to convey from the decoded thought.

Speech processing theories have predicted that multiple brain regions participate in speech and language comprehension, which includes frontal and temporal lobes of left hemisphere. Broca's area found in the left inferior frontal gyrus and Wernicke's area located in the left posterior superior temporal gyrus are cortical areas specialized for production and comprehension, of human language respectively (Poeppel & Hickok, 2007; Price, 2011). Neuroscientists have followed conventional brain imaging techniques such as fMRI (Dogil et al., 2002) and electrophysiological measures such as EEG (Callan et al., 2000) to study the neuronal activation in these brain regions during speech production from healthy and speech impaired participants.

Electroencephalography (EEG), a non-invasive electrophysiological technique, is used in analyzing the neuronal excitations in different regions of the brain and to understand their functional cooperation while performing a task (Teplan, 2002). EEG signals contain useful information and this information can be analyzed in time domain, frequency domain and time-frequency domain. Transforms like Discrete Fourier Transform (DFT) and Fast Fourier Transform (FFT) can be used for converting a time domain signal into frequency domain in order to analyze the signal information in each frequency band over a wide range of frequencies related to the task. EEG signals have five sub-band frequencies such as Delta band (05.-3Hz), Theta band (4- 8Hz), Alpha band (8-12Hz), Beta band (13-30Hz) and Gamma band. (> 30 Hz) (NeuroSky, 2009). Valipour et al. has used FFT technique for the spectral analysis of alpha band during open and closed eyes (Valipour et al., 2013). Power Spectrum Densities (PSD) describes the power distribution of the signal as a function of frequency of a periodic signal. Saa et al. has analyzed the power spectral density during motor imagery for classifying the imaginary motor movements (Delgado, Saa & Gutierrez, 2010). (Rojas et al., 2016) has analyzed the EEG signal during imagined speech of Spanish vowels using digital signal processing techniques such as Filters, FFT and statistical analysis based on ANOVA test and has reported that by using signal processing it is possible to recognize the Spanish vowels from imagined speech. In general EEG signals are nonlinear and non-stationary. EEG data contains artifacts due to the surrounding noise. The amplitude of artifacts is quite large compared to the task related EEG signal. Artifacts due to eye blinks (electrooculography-EOG) and muscle movements (electromyography-EMG) has to be removed in order to analyze the signal for interpreting correct results. Independent Component Analysis (ICA) techniques have been used to remove the above-mentioned artifacts. There are many source separation algorithms designed for ICA. These techniques attempt to

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