Independent Component Analysis of EEG Signals and Real Time Data Acquisition Using MyDAQ and Labview

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Abstract - Electroencephalography is the recording of electrical activity along the scalp of a person. This allows us to measure brain activity involved in various types of cognitive functions. Experimental goal of this work is to interpret and characterize the EEG activity during Pranayama breathing with respect to temporal and spatial context, and acquire two channel data using MyDAQ and Labview. This work primarily explores the variation in the EEG wave pattern during different stages of Pranayama as well as the variation of alpha wave level in the left and right frontal, temporal parietal and occipital regions of the brain. Statistical significance test is performed for different cycles of Pranayama to measure the significant change in the alpha power with respect to baseline measures. An effort was made to analyze the difference in the cerebral electrical activity among long term and short term meditation practitioners. Data was recorded for ten subjects during three cycles of Pranayama, each cycle lasting for two minutes. In order to measure the effects towards the end of Pranayama, the last 20 seconds of EEG data were analyzed in each cycle of Pranayama. The analysis revealed that 40% of the subjects were relaxed (means increase in alpha power) as well as alert (means increase in beta power) at the end of Pranayama, whereas 30% of the subjects showed decrease in beta power. Also, 10% showed increase in beta power for only one cycle. Therefore, one may conclude that the practice of Pranayama enhances relaxation and cognition, leading the practitioners to a stress free and healthy life.

Keywords: Electroencephalogram, Independent Component Analysis, Artifacts, Data Acquisition, Labview

1. INTRODUCTION

There is growing interest in the integration of meditation in clinical applications for treatment therapy and in the education field to have the benefits of meditation. This work presents the evidence related to the neuro physiological changes during meditation. Meditation facilitate to achieve educational goals, increases student mental calibre in spite of academic stress, and to enhance the very life style of the person. In short, meditation contributes substantially towards crafting the most effective cognitive training programs.

The Pranayama is derived from two Sanskrit words ‘Prana’ and ‘ayama’, where ‘Prana’ means Energy or life and ‘ayama’ means elongation of life span. The word Pranayana, therefore, means elongation of pranic energy. There are three Stages of Pranayama used in the scriptures [1-3]. They are:

1st Stage: 8-10 times Ujjai breath (meaning deep), Posture: Vajrasana. Thumbs on the hip bone, Palms parallel to the ground, spine erect followed by 30-45 seconds Relaxation. This is shown in Figure 1a.

2nd Stage: 8-10 times Ujjai breath (Posture: Vajrasana, Thumbs under arm pits, Palms parallel to the ground, spine erect) as shown in Figure 1b and followed by 30-45 seconds Relaxation.

3rd Stage: 8-10 times Ujjai breath (Posture: Vajrasana, palms on the back, biceps touching the ear and elbow pointing to the ceiling, spine erect, chin at the normal level), followed by 30-45 seconds Relaxation. This is shown in Figure 1c.

During normal breathing, we use only half the lung capacity, which can be easily understood by taking a deep breath filling the entire lungs. During the practise of Pranayama, we use at least 80% of our lung capacity. Deeper the breath more is the oxygen entering the blood, thus benefitting every blood cell and consequently the whole body. The mind and the breath have a common source, which means our thoughts and breath are directly related. For instance, when we are angry or restless, the number of breaths per minute also increases rapidly. By controlling the breathing, one can control unnecessary thoughts and also the emotions, aided substantially by the practise of Pranayama. In short, if breath is controlled, then the thoughts are also controlled.

Fig. 1 Pranayama in Vajrasana Posture (a) First Stage: Adhama, (b) Second Stage: Madhyama (c) Third Stage: Uttama
An effort was made to analyze the cerebral electrical activity for ten subjects. EEG is recorded during pranayama as a baseline and three cycles of Pranayama. It is a slow and fast breathing exercise. This work is an attempt to score the effect of Pranayama by studying the variation in EEG voltage levels [4]. Most of the referred papers have not presented quantitative analysis [1-8]. Papers on Meditation referred earlier have performed either coherence or qualitative analysis and data has been acquired only for 4 or 5 subjects.

Therefore, aim of our work is to perform a detailed quantitative and qualitative analysis acquiring data for 10 subjects, offering better results. EEG signal comprises five low frequency bands, namely, Alpha (8-13 Hz), Beta (14-30 Hz), theta (4-8 Hz), Delta (0.5-4 Hz) and Gamma (above 30 Hz). Our objective is to do a quantitative analysis of these bands during Pranayama. EEG data for ten subjects was acquired using an RMS Recorder with 10-20 Electrode system. This data was converted into a 32 channel data by setting the important electrodes as shown in Figure 2. The 32 Channel data is used to obtain a Topo plot for further data analysis. 4th order Elliptic filter is applied for the acquired EEG data to extract EEG waves, namely Delta (below 3 Hz), Theta (4-7 Hz), Alpha (8-13 Hz), Beta (14 Hz and above). Through Fast Fourier Transform, power in each wave is calculated [5-8]. Independent Component Analysis (ICA) is a quite powerful higher order statistical technique and is able to separate independent sources linearly mixed in several sensors. For instance, when recording electroencephalograms (EEG) on the scalp, ICA can separate out artefacts embedded in the data (since they are usually independent of each other). A first step in many ICA algorithms is to whiten (or sphere) the data. This means that we remove any correlations in the data, i.e., the different channels are forced to be uncorrelated.

The identification of independent components from EEG signal helps to understand better the sources of EEG signal. This was demonstrated by Hyvarinen A et al. [9]. Resolving of the sources of artefacts and the sources of useful signals are dealt in his work. The use of Independent Component Analysis as a progressive method for removing artefact from EEG signal was presented by Bell A. et al. [10]. The work has helped in recovery of epileptic peak sources, spontaneous activity sources and various grapho elements as K-complexes and sleep spindles. The use of EEG signals to estimate cognitive state was proposed by Boscolo R. et al. [11]. The estimation was done using a mutual information based method. Classification was done in their work by employing a group of three classifiers and using majority voting logic. However, the problem of finding robust features that allows cross-session and cross-subject generalization are not discussed in their work. The combined use of ICA for preprocessing the EEG signal, Discrete Wavelet Transform analysis for feature extraction and fuzzy cluster means algorithm for recognition of some diseases were proposed by Delorme A et al. [12]. Quantitative analysis of EEG signals is a challenge in the cognitive assessment or for diagnostic Applications. In this work, ICA is implemented for artefact removal and for source localisation.

This paper is organized as follows. In section two, the methodology of EEG processing is presented in detail. Section three presents results. Finally, conclusion is drawn.

II. EEG ACQUISITION AND ANALYSIS

EEG signals were acquired for ten normal subjects between the age group of 25 to 40 years. Five of them are practicing Pranayama for more than eight years, considered as long term Practitioners; otherwise taken as short term practitioners. EEG is recorded according to International standard 10-20 Electrode system using Recorders Medicare Systems with 24 channel digital EEG machine having an A/D conversion of 16 bits with sampling frequency of 256 Hz. Software version of Super Spec. 4.2.54. Here, 10-20 denotes the placement of

![Fig. 2 Placement of International Standard 10-20 Electrode](image-url)
the electrodes in a particular manner as shown in Figure 2. EEG is recorded during Pre Meditation stage for first 5 minutes with eyes closed and followed by 3 cycles of Pranayama for six minutes. EEG data for last 20 seconds from each cycle of Pranayama is taken for analysis. EEG data acquired from a 10-20 system has 18 channels as shown in Figure 3; most of the channels having redundant data. Principal Component Analysis (PCA) is applied on the acquired data for dimensionality reduction. By applying Principal component analysis, we get “Scree” plot, from which it is found that 5 channels that have maximum EEG amplitude variations are adequate for analysis as shown in Figure 4. But PCA does not identify which of the 18 channels have maximum EEG amplitude variations. The Independent Component Analysis is applied to find the Maximum EEG variation channels. In this work, Independent Component Analysis is implemented using EEG LAB open source software [13].
The goal of this work is to interpret and characterize the EEG activity during Pranayama with respect to temporal and spatial context. This work primarily analyses the variation in the EEG wave pattern during different cycles of Pranayama as well as variation of alpha wave power in different regions of the brain. Recording Conditions were set for the subjects to be very comfortable. Subjects meditated with their eyes closed in a sitting position in a room free of sound and visual distractions. EEG activity is complex in nature. Therefore every effort has been made to minimize the artefacts that may affect analysis and results. The Methodology implemented is to interpret the frequency waves such as Delta, Theta, Alpha, and Beta that characterize the brain state. The analysis is based on these specific frequency ranges in order to interpret the changes that occurred during meditation.

**Independent Component Analysis**: An electrode sensing a signal at a position may be influenced by the signals picked up by neighbouring electrodes. ICA is a quite powerful technique which is capable of obtaining the desired signals filtering out the unwanted neighbouring signals. ICA can separate out artefacts embedded in the data since they are usually independent of each other. A first step in ICA algorithm is to centre a data by subtracting each channel data from its mean value. This is referred to as “white” or “sphere”. Whitening the data is a Pre-processing step performed by most ICA algorithms before applying ICA. This step removes any correlations in the data, i.e., all channels are forced to be uncorrelated. A geometrical interpretation for two mixed random sinusoidal sources A and B with different amplitudes and frequencies is shown in Figure 6, where the two signals are linearly mixed. This results in Gaussian distribution. If we whiten the two linear mixtures, we get the plot as in Figure 7. The variance on both axes is now equal and the correlation of the projection of the data on both axes is 0, meaning that the covariance matrix is diagonal and that all the diagonal elements are equal. The whitening process is simply a linear change of coordinate of the mixed data. Once the ICA solution is found in this “whitened” coordinate frame, we can easily re project the ICA solution back into the original coordinate frame.

![Fig. 6 Two Mixed Random sources A vs B](image)

![Fig. 7 Whitening of the A and B Mixed Data](image)

ICA components are arranged as a matrix that allows projecting the data in the initial space to one of the axis found by ICA. The weight matrix is the full transformation from the original space. The independent component space may be expressed...
as $S = WX$, where $W$ is the weight matrix going from $S$ space to the $X$ space. $X$ is the acquired data in the original space and $S$ is the source activity. The rows of $W$ are the vector with which we can compute the activity of one independent component. To compute, the component activity in the formula $S = WX$, the weight matrix $W$ is the mixing matrix. The activity of the Brain source $S$ (also called “dipole”) is unit-less unless it is projected to the electrodes. Each dipole creates a voltage signal at each electrode site, which can be measured. To re-project one component to the electrode space, we use $X = W^{-1}S$, where $W^{-1}$ is the inverse matrix to go from the source space $S$ to the data space $X$. Rows of the $S$ matrix are the time information of the component activity and columns of the $W^{-1}$ matrix are the scalp projection of the components. We denote the columns of the $W^{-1}$ matrix as the scalp topography of the components. Each column of this matrix is the topography of one component which is scaled in time by the activity of the component. The scalp topography of each component can be used to estimate the equivalent dipole location for this component. These topo-plots are used to extract the most important five channels which have shown maximum variation in the EEG amplitude.

Topo-plot for one subject at the beginning and at the end of Pranayama for 20 seconds are plotted using EEGLAB Open source software that runs on MATLAB Software and are shown in Figure 8a and Figure 8b respectively.

![Fig. 8a Topo-plot at the beginning of 1st stage of Pranayama](image)

![Fig. 8b: Topo-plot at the End of 3rd stage of Pranayama](image)

Blue to Red color variations in the Topo-plot indicate Electric Field potential variations from minimum to max value of EEG signals represented as a vertical bar with + and – in the figure. By comparison of the plots during pre and post Pranayama stage, it is observed that there is a gradual increase in the field potentials in frontal and occipital regions towards the end of Pranayama.
for some channels. Channels 1, 8, 30, 31, 32 show more Electrical activity in frontal and occipital regions of the brain after Pranayama. These channels are used for extracting different EEG waves. By using elliptic filter, delta wave with a cutoff frequency of 3.5 Hz, theta wave with a cutoff frequency of 7.5 Hz, alpha wave with a cutoff frequency of 11.5 Hz, beta with a cutoff frequency of 30 Hz are extracted as shown in Figure 9. From the extracted EEG waves, by applying Fast Fourier Transform (FFT) the power of all the waves is calculated. Finally, out of these five channels one channel which has got maximum alpha power is considered for Analysis because Alpha wave is dominant when person is relaxed.

![Figure 9 Filtered EEG Data - Amplitude in µ Volts vs Number of Samples](image)

**III. EEG Amplifier Design and Data acquisition using MyDAQ: Biofeedback Application**

Two channel EEG Amplifier has been designed and tested for real time data acquisition of Biofeedback Application. Biofeedback is a technique that measures Physiological functions and gives information about them, which in turn helps in training and controlling the required Physiological functions. Biofeedback is most often based on measurements of Heart rate, Muscle tension, Skin conductivity and Brain waves. By watching these measurements, one can learn how to change these functions by relaxing or by holding pleasant images or experiences in the mind. A sound or visual display may be used to know when a goal or certain state is reached. Biofeedback teaches how to control and change these bodily functions. By doing so, one can feel more relaxed or more able to cause specific muscle relaxation process. This may help treat undesirable conditions such as Anxiety, Insomnia, Constipation, Tension and Migraine headaches. These observations help in the design of Bio feedback system for self controlling alpha and beta level with external audio or video stimulus [14-18]. In this work, Biofeedback is tested for brain waves using the Two-channel EEG Amplifier and MYDAQ System, design of which is presented in the next section.

**IV. EEG Data Acquisition System Design Using MYDAQ and LABVIEW and Results**

In the previous section, it was mentioned that FFT is used to compute the power of delta, theta, alpha and beta waves. The square of the real part of FFT coefficient is the power. Before presenting the design of the EEG Data acquisition system, we need to interpret the effect of Pranayama on subjects. The analysis of power variations would throw more light on the relaxantion trends of the subjects. Accordingly, the Percentage variations of alpha power in different regions of the brain among long term practitioners and the short term practitioners are acquired and presented in Figure 10 and 11 respectively. It may be observed that the Alpha power increases more for long term practitioners than for short term practitioners in Right occipital area of the brain, which is an indication that the corresponding subjects are in relaxed state. It may therefore be concluded that longer the practise effecting the Right occipital area, more relaxed the subject will be. It may also be noted that the left brain activity will be higher than the right during logical thinking, reasoning etc.

Alpha and beta power may also be plotted for subjects in order to find percentage variation in relation to pre-meditation state. Accordingly, power plots are presented in Figure 12 and 13 for various subjects during three Pranayama Stages presented earlier in Figure 1. With respect to the Temporal context, at the end of the third stage of Pranayama, experiment conducted on subjects showed that 40% of the subjects have increase in their alpha power, 50% have increase in alpha power in one stage and 10% no change in alpha power. Further, 20% of the subjects showed no change in beta power, 30% showed decrease in beta power, 10% have increase in beta power in one cycle, and 40% showed increase in their beta power. These are shown in Figure 12 and 13 respectively. Therefore, we can conclude that 40 % of the subjects are relaxed as well as alert during the Pranayama stages.
Fig. 10 Alpha Power Variation Percentage vs Long Term Practitioners

Fig. 11 Alpha Power Variation Percentage vs Short Term Practitioners

Fig. 12 Alpha Power Variation of 10 Subjects During Three Pranayama Stages

Fig. 13 Beta Power Variation for 10 Subjects During Three Pranayama Stages
Fig. 14 Two channel EEG Data Acquisition Setup Using MYDAQ

Fig. 15 Two channel EEG Data acquisition System Design Using MYDAQ and LABVIEW

Biofeedback Application

EEG Data acquisition setup is shown in Figure 14, where a couple of electrodes from the forehead of the Subject are fed to the input of the EEG Amplifier, which in turn is connected to the MyDAQ of National Instruments. EEG data is acquired from Pre-frontal positions FP3 and FP4. The acquired signals are displayed on the Laptop using LabView Design as presented in Figure 15. Acquired EEG Data is passed through second order Butterworth low pass Filter with appropriate cut-off frequencies to extract alpha, beta, theta and delta waves from the Left and Right Pre-frontal positions. Power of Theta, Alpha and Beta for these electrode positions are calculated by using FFT. The Threshold value is set at 50% of the baseline EEG of the subject in order to light the indicators such as “Stabilised”, “2 fold increase” and “4 fold increase” optimally. This threshold need not be 50% and can be set as desired. For a particular cognitive task, if the power level of theta, alpha and beta value is constant, then it means no variations in the power level of EEG waves and therefore the “Stabilised” indicator lights up. If the power increases two times or 4 times then the respective indicator switches on. Subjects were asked to sit with eyes closed and instructed to reduce the thoughts and to meditate for 5 minutes. Results show increase in alpha power in both left and right side of the brain after meditation for 5 minutes as presented in Figure 16. With eyes open, and not performing any task, there was a decrease in alpha and beta power as shown in Figure 17. When the subject performed any Mathematical task in the mind such as counting down a number task, then the beta wave power level increased as can be seen from Figure 18. We can see that the left side beta power increases when compared to that of the right, which is an indication that the Subject is in logical thinking state.
Analysis of EEG data during Pranayama practice shows increase of power in delta, theta, alpha and beta waves in long term practitioners to a larger extent than short term practitioners. Spatial Analysis indicated higher variations in the EEG signals in the right regions of the brain compared to the left regions of the brain. The Experimental results clearly show a higher level of consciousness experienced during Pranayama, which proves to be one of the best relaxation methods for cognitive enhancement, which helps the people to lead a stress free life. This paper presented the design of EEG Data Acquisition System using MYDAQ and LABVIEW. This pilot study suggests a biofeedback protocol that might be useful in cultivating meditative states of consciousness and providing real time feedback of enhanced alpha activity. There are now several mainstream health care programs which aid those, both sick and healthy, in promoting their inner well-being, especially mindfulness-based programs. More Research is required in this domain to prove to be of use for treatment of patients in Hospitals and rehabilitation centres.
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REFERENCES