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Source Localization with EEG data for BP shows major activities in the frontal areas of the brain

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Abstract: This paper presents results of dipole source localization in the human cortex for EEG data recorded from subjects performing *Bhramari Pranayama* (BP). It has been suggested that the BP is able to produce neuronal change and thus level of consciousness of the human brain. The EEG signal recorded over the surface of the scalp is the result of the synchronized activities of neurons in the cortex. It is the combination of such neuronal oscillators that results into different spontaneous cognitive activities of the brain. Thus finding the locations of such neuronal sources in the cortex is important and can be performed using source localization techniques. The source identification was performed on band-passed (0-35 Hz and 35Hz to 80 Hz) EEG data for both the pre-BP and BP conditions. The obtained results suggest a symmetric localization of activated sources in the pre-frontal cortex during the BP which indicates a strong, symmetric activation of the higher cognitive functions during an actual BP humming session.
Keywords: Source localization, EEG, pranayama, humming sound, breath control.

1. INTRODUCTION

This paper presents results of dipole source localization in the cortex for EEG data recorded for subjects performing *Bhramari Pranayama* (BP). BP is one of the important types of breathing exercises (Pranayama) related to the yogic methods of breath control. The breath related exercises are also part of yoga. Nowadays yoga is well introduced everywhere and is well accepted health caring practice in everyday's life. It has been reported by many researchers that the regular practice of Yoga is preventive, curative and recuperative. Especially, many breath exercises have been observed by researchers to be effective in bringing good effects on autonomic functions such as parasympathetic activities and sympathetic activities [1][2]. It helps healing process to accelerate process of recovery. The Sanskrit word *Pranayama* contains two meaningful segments namely *Prana* (this means vital force) and *Yama* (this means control). So pranayama literally means a yogic act performed for controlling flow of the vital energy which governs all the physiological process of our body. There are many types of pranayama among which BP is an important item. The term *Bhramari* is also a Sanskrit word which means like a *bumble bee*. Thus in BP subject has to produce sound like bumble bee while exhaling strictly through nasal airways, keeping oral cavity closed at the lips, ears closed by fingers and eyelids are also shut down as shown in Fig. 1. The BP is supposed to produce neuronal changes and thus level of consciousness of the human brain. One of the important parts of the BP is that while practicing subject concentrate on philosophical third eye position which lies in the frontal areas. In previous studies we have also reported about effect of BP on changes in the pattern of EEG signal [3]. It has been found that after BP the powers in different frequency bands increase in the frontal areas of the human brain. The changes in brainwave patterns are related to mental status and are supposed to produce distinctive state of consciousness. For example Delta brain activity is related with sleep and deep sleep. Theta brainwaves also occur in sleep and dominate in the meditation state. It has been identified as the gateway of learning. Its dominance increases creativity, learning, reduces stress, awakens institution and other perception skills. In the ancient texts of yoga BP has been described as the yogic practice for improving intuition, thought process, capacity of visualizations, creativity etc. and in such cognitive process the role of frontal parts of the brain has been reported by many researchers[4][5]. Thus if BP has capacity to influence such cognitive functionalities it should produce changes or activation in the frontal part, however, results presented in this paper has nothing concrete to say in terms of causes and

Fig. 1 BP is performed by sitting in posture like this and imitating humming sound of the bumble bee while exhaling strictly through nostrils keeping ear plugged with fingers or tragus eyelids shut down and attention on third eye point.

such effects for BP. But, the aim is to show if the BP can bring some changes in the frontal areas of the brain using some techniques such as inverse mapping, band spectral power, on the EEG signal recorded on the scalp.

The rest of the paper is organized as follows. Section II presents about source location methods. Section III contains experiments and results. Conclusions are given in section IV which is followed by references.

2. SOURCE LOCALIZATION FROM EEG

Electroencephalography is noninvasive method of measuring scalp potentials. The scalp electric potentials are generated as a result of the firing action of the internal cortical neural network. The brain activities inside the cortex are focalized and hence the related group of neurons. Any active region inside the cortex involves alignment and synchronous synaptic stimulation of large number of neurons [6]. The large group of such neurons behaves like a dipolar current source as if they are orthogonal to cortical surface and it is passage of such currents that are measured at discrete places on scalp by EEG electrodes. Thus knowledge of location of these current sources inside the cortex is of very much clinical importance and its estimation from measured electrode potentials is known as inverse mapping or source localization. There are several approaches in use to solve this problem but very accurate estimation of locations is difficult as one can not determine uniquely the generating sources from scalp potentials. There are two most successful approaches of source localization and are based on different interpretation of scalp potentials [7]. One method assumes sources to be distributed as discrete dipoles and starting from some arbitrary initial distribution of dipoles, sources are moved around and generated eclectic potentials are fitted with real EEG signals. This technique has been implemented in the widely used Brain Electrical Source Analysis (BESA) software [8] which has also been used here. The second technique assumes distribution of dipole on wide range of brain and is like magnetic tomography of the brain. The software Low Resolution brain Electromagnetic Tomography (LORETA) implements this approach [9].

The other two quantitative measurements that is used here as the sign of effect of BP on cognitive ability are temporal variation of Relative Spectral Power (RSP). RSP is defined as the ratio of Band Spectral Power (BSP) and Total Spectral Power (TSP) as follows

$$RSP_i = \frac{BSP_i}{TSP},\ i \in \{\delta, \theta, \alpha, \beta, \gamma\} \qquad (1)$$

where $i = (\delta, \theta, \alpha, \beta, \gamma)$ represents brainwaves in (0. 2Hz-4Hz, 4Hz-8Hz, 8Hz-14Hz, 14Hz-30Hz,30Hz-80Hz and TSP represents power from 0.5Hz to 80Hz.

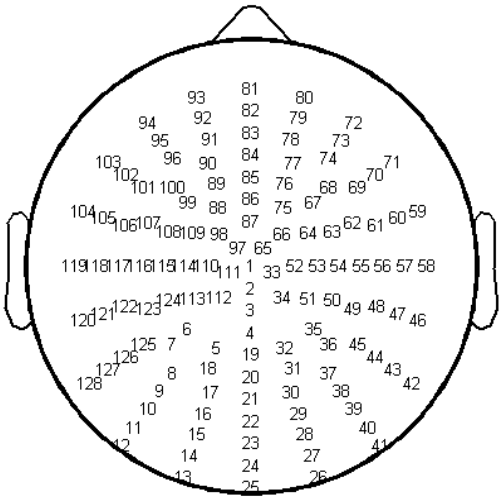

Fig.2 Electrode locations used in EEG data recording.

3. EXPERIMENTS AND RESULTS

In this study two subjects were chosen one with a few months regular experience of BP and other with no prior experience of BP, however, second subject was trained for how to do BP before the EEG recording. Subjects were chosen from different cultural and ethnic groups. Subjects with such contrast were chosen to see if the BP produces quick effect or not and if it can works in similar ways on different people. The experiments were planned for 15-20 rounds of BP by each subject. EEG was recorded with 128 channel BIOSEMI system at RIKEN, Japan. The sensor layout used in the EEG recording is shown in Fig. 2. The sampling frequency was kept at 1024 Hz.

For the source localization, the raw EEG signals were examined and channel with two much artificats or noise were marked as bad. The source localizations were done in two frequency range namely 0-35Hz and 35Hz to 80 Hz for EEG data recorded during BP and before BP. The EEG signals in these frequency bands were obtained by band pass filtering of the raw EEG data. Since humming is very active part of the BP and is assumed that it's humming sound that is main actor in influencing neuronal activity, the effect of BP will be strongest during humming. The EEG data corresponding to humming session were extracted using the microphone data which were recorded in synchronous with EEG data. In the source localization in BESA environment, the criterion for success used was 10% or less of Residual Variance(RV), which is a standard in research community. The dipole models for each condition were calculated 8-10 times with various numbers of dipoles until the exact number of dipoles for each condition was not found under the pursuit of set criterion.

The location of source in pre BP conditions for the trained subject is shown in Fig.3 for the frequency range 0-35 Hz. The source locations results for the same

subject during BP can be seen in Fig.4 which shows a clear 5-dipole distribution of 2 left-side and 3 right-side sources in the pre-frontal cortex, and also another, weaker source in the left parieto-occipital area. This indicates a strong, symmetric activation of the higher cognitive functions during an actual BP humming session. The source localization for pre BP and during BP conditions in high frequency range (35Hz-80Hz) is shown respectively in Fig. 5 and Fig.6 respectively. In the high frequency region there are no patterns of dipoles similar to those in the lower frequency range 0-35Hz. BESA analysis cannot confirm that high frequency is most important, although it may still be sufficiently relevant. This conclusion is drawn because in the BP yoga condition we have 22 dipoles necessary to achieve less than 10% residual variance between the model and the real data. This result indicates either very numerous and weak separate activities, or a very widely distributed activation. The dipoles are concentrated on the posterior, temporal, parietal and occipital sides of the brain. There are a couple of sources also in the pre-frontal cortex. Although, the number of dipoles for the pre-BP condition and during the BP conditions in the frequency range 35Hz -80Hz are slightly different but their distribution seems much similar in Fig. **5** and Fig.6.This could be interpreted in two ways. First the activities in high frequency range can be considered more independent from the actual humming and persists between humming, while during humming weaker sources are getting activated. Secondly, it may be due to some types of artifacts or brain noise. The locations of dipole sources for BP without humming are shown in Fig.7 and Fig.8 but for slightly different conditions. For Fig.7 the used EEG data were of condition in which subject imitated all the actions such as posture and respiration of BP except doing humming while Fig.8 is the source localization for the condition in which subject sat normally without humming and with normal breathing in BP posture. It can be imbued from these figures that humming is critical in BP and BP is just not a sum of breathing, humming and posing. None of them causes strong activation in the prefrontal cortex like humming. The symmetric activation in prefrontal area persists after the BP session is over. The source localizations after end of the BP session are shown in Fig.9.

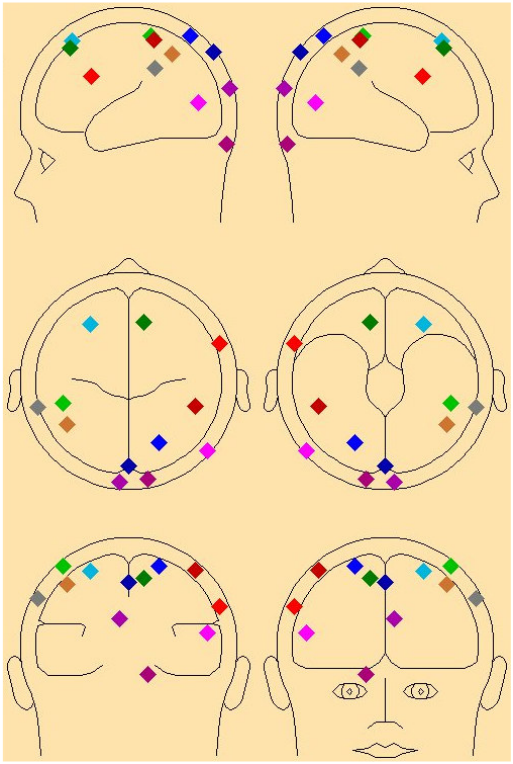

Fig.3 Dipoles location for pre BP conditions for the frequency range 0-35Hz (RV=9.87%).

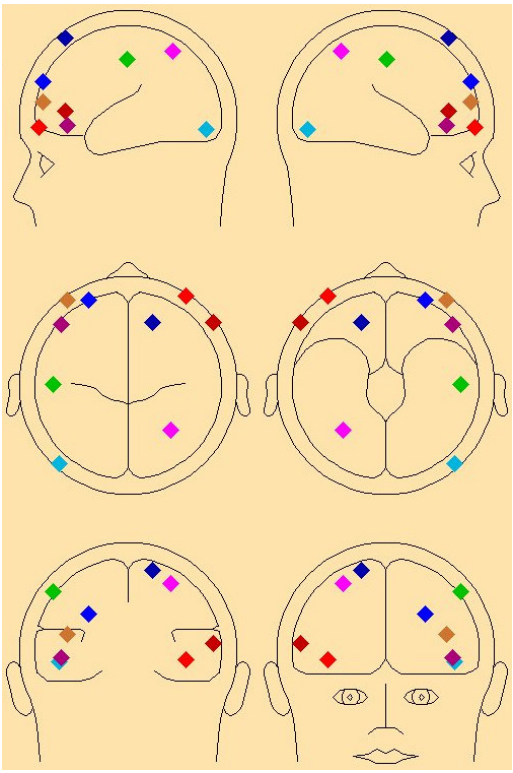

Fig.4 Dipoles location for during BP conditions for the frequency range 0-35Hz (RV=9.9%).

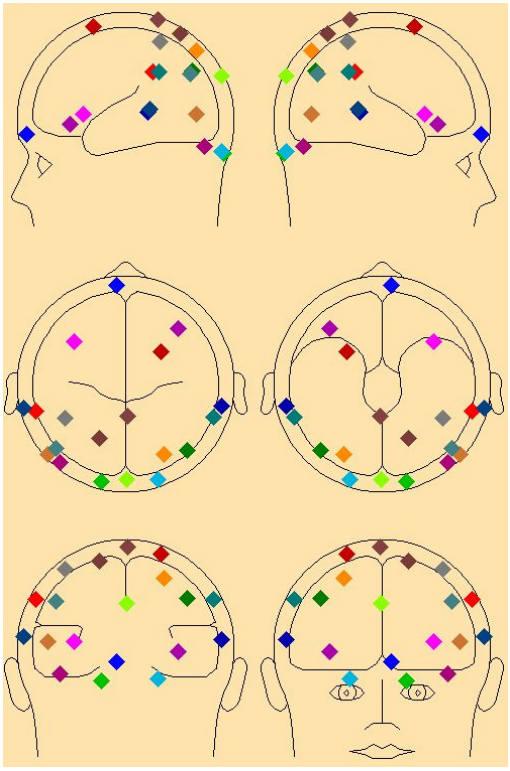

Fig. 5 Dipoles location for pre BP conditions for the frequency range 35Hz-80 Hz (RV=9.6%).

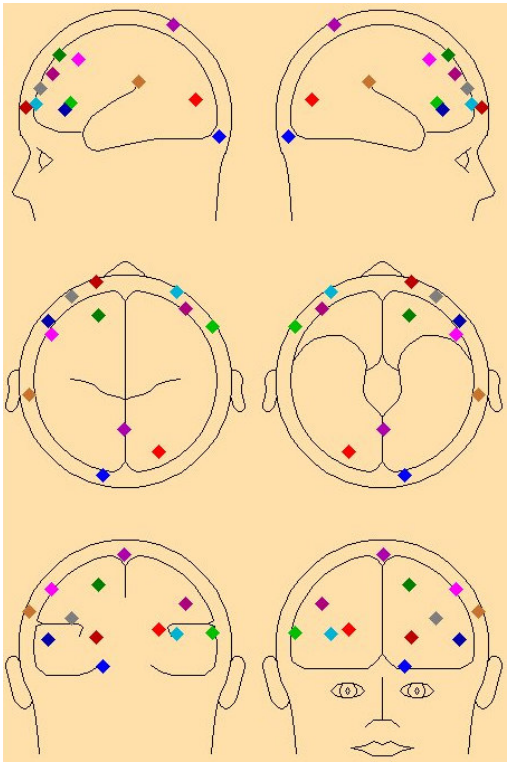

Fig.7 Source localization during BP without humming in frequency range (0-35Hz)(effect of hyper ventilation) (RV=10.077%).

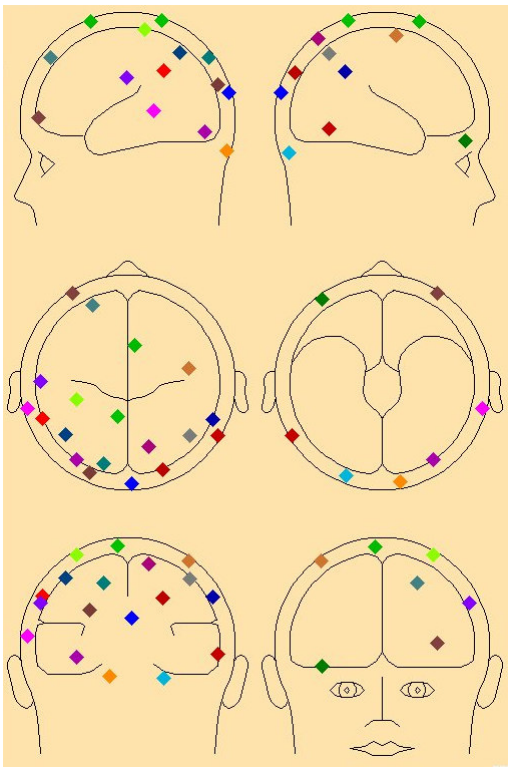

Fig.6 Source localization during BP in high frequency range (35Hz-80Hz) (RV=9.6%).

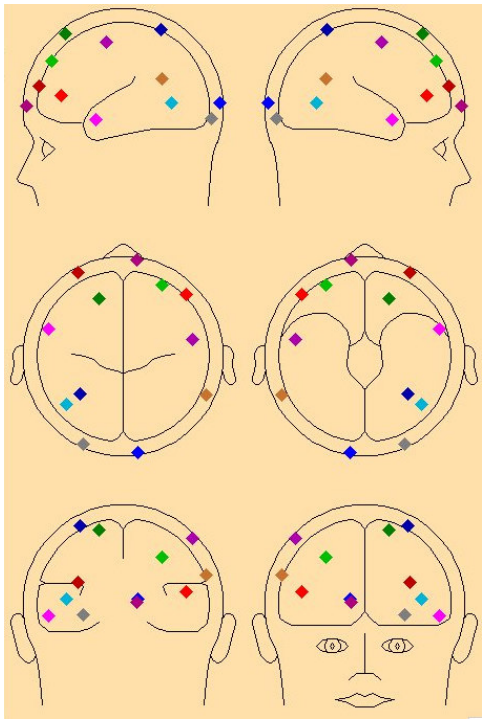

Fig.8 Source localization during BP posture only in frequency range (0-35Hz) (RV=8.6%).

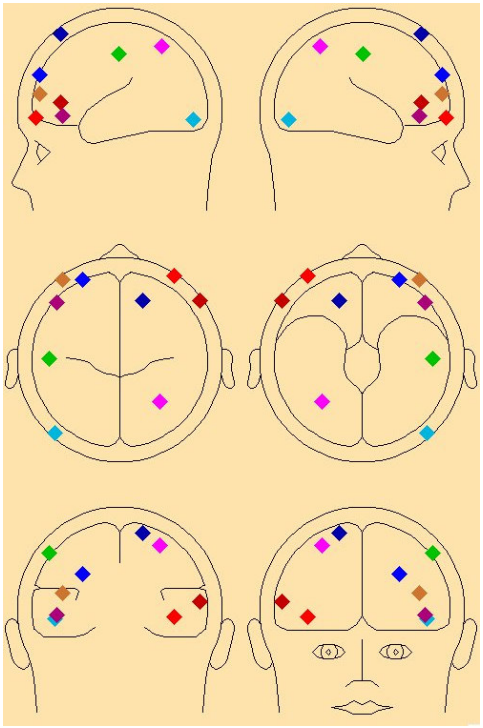

Fig.9 Source localization after BP eye closed (sses sion 16) RV=9.47 %

Based on the presented results it is not possible to draw conclusions regarding the role of attention on the third eye point. But the stimulation of prefrontal area in BP can cause changes in different band power and coherencies among different electrode signal. In order to calculate RSP and MSCH as per Eq.1 and Eq.2, we selected the sensor positions located in the part of temporal lobe, parietal lobe and frontal lobe from both the left and right sides of the head. The reason for this is many folds. First reason is localization of dipoles sources in these areas after BP as shown before. Secondly, in BP concentration is kept at the third eye point which lies in frontal areas. However, biological third eye is inside the cortex. The humming sound is produced in BP and its interaction will be related with the temporal lobe of the brain. In this way total 21 sensor signals were chosen covering all these regions. The selected EEG signals were filtered using AMUSE algorithm, a blind signal processing technique [12]. The results of Relative Spectral Power (RSP) computations on the EEG signals are shown in Fig. 10 for a subject which is in confirmation with the results of source localizations.

4. CONCLUSIONS AND FUTURE WORK

In this paper we have presented source identification using BESA software for the EEG data for BP yoga. It has been shown that the BP can produce symmetric activation in the prefrontal areas which is largely due to self humming sound. The activated prefrontal area has its role in thought process and higher cognitive

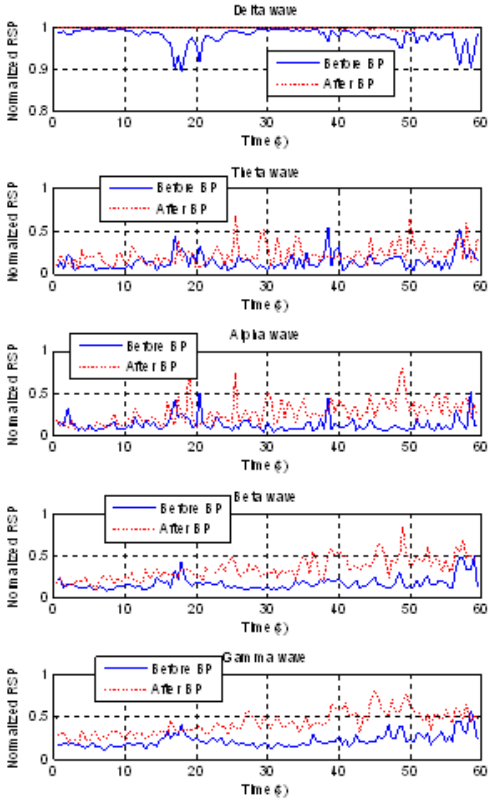

Fig. 10 The temporal variation of RSP in variouous frequency bands of brain wave pattern for before and after BP conditions.

functions, however, we do not have any such results in cause and effect paradigm for BP to confirm scientifically that BP can enhance higher cognitive abilities and of course it needs further studies. The found activation of brain in prefrontal areas was in the frequency range 0-35 Hz. Such symmetric localization of the dipoles in the pre-frontal areas was not found in the pre-BP conditions. The RSP computed from EEG of these areas also show positive changes in different frequency bands.

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