MATHEMATICAL TECHNIQUES FOR STUDY OF EEG DATA RECORDED DURING MEDITATION

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Abstract: Meditation is considered to be an altered state of consciousness associated with heightened cognitive functions and transcendental experiences. The neural dynamics in meditative states needs to be explored and an objective analysis of such states is required. Here, we have investigated the dimensional complexity of electroencephalogram (EEG) signals from the brain of subjects in yogic meditation. Several channels of EEG have been analyzed in terms of compressed spectral array (CSA), running fractal dimension and running attractor dimension during the process of meditation. The CSA yields some interesting features. The running fractal plots show low average fractal dimension values during pre-meditative and post-meditative periods. During meditation there is an increase in the average fractal dimension value. The attractor dimension values also show changes. As the meditation progresses the average attractor dimension rises to a value which is more than that for the premeditative period. It shows a decline during some stages of meditation. The results indicate that the attractor dimension estimation is more effective in depicting the dynamics of the brain in a highly complex state. The investigation reveals that chaotic dynamics provides a mechanism for low dimensional control of neuronal oscillations in meditation.

Next, we have studied the efficacy of neural network approach in differentiating various levels of consciousness using EEG signals. We considered 60 segments of premeditation data, 140 segments of meditation data, 140 segments of deep meditation data and 60 segments of post meditation data. We have chosen 8 features as input to the neural networks. The features we have chosen are mean, variance, fractal dimension, complexity measure, and powers in alpha, beta, theta and delta waves. Four classification algorithms were compared viz., k-neighbors, RBF networks, Support vector machines (SVM) and back propagation networks for different set of features. The obtained accuracies for the back propagation network, RBF network units and support vector machine with RBF kernel are higher than for k-neighbors. We are able to attain optimum accuracy of 99.6% with SVM in case of two-category problem (Meditation and Pre-meditation), 99.6% with SVM in case of three-category problem (Pre-

meditation, Meditation and Post meditation) and 99.38% with SVM in case of four-category problem (Pre-meditation, Meditation, Deep meditation and Post meditation). Thus this work has shown the feasibility of the use of neural networks in the classification of EEG meditation data.

In summary, this work has demonstrated the efficacy of mathematical techniques in establishing that meditative state is indeed a well defined and distinct state of consciousness where clear changes are observed in EEG during meditation. The fact that an automated method like neural network approach can differentiate such states from other states clearly shows that there is no human bias involved in such studies.