

## Abstract

One of the most fundamental problems in brain signal analysis is an absence of reliable measures of certain brain states. For purpose of study and detection of such states (especially the state of the mental relaxation which is still not exactly defined) we decided to investigate the influence of commercially well-known mind machines (light & sound machines) on subject's brain. In this paper we discuss changes in common linear and novel nonlinear measures applied on series of EEG signal recorded before and after mind machine sessions. We will namely discuss linear correlation, mutual information content, spectral entropy, spectral edge frequency and relative power of alpha, beta, delta and theta band.

## Experiment description

The experiment consisted of 25 series (days) of 20 minutes training with the mind machine in a darkened Faraday chamber. There were 6 adult volunteers participating in the experiment. The mind machine was supposed to train subjects' brain to relax more efficiently using light and sound stimulation. The mind machine affected audiovisual nervous sensors by decreasing frequency stimulation from 18 Hz to 2 Hz and back to 18 Hz at the end of each session. Before and after each session the EEG signal was recorded from selected 6 channels according to International 10-20 system: F3C3, F4C4, C3P3, C4P4, P3P1, P4O2. The reference electrode was placed at CZ point and ground electrode at FPZ point. Each EEG record was 3 minute long what gives 90000 samples at the 500 Hz sampling frequency. All records with obvious artefacts or sleep occurrences were excluded from further analysis.

## Results

In neurophysiology the most common indicators of relaxation and sleep are rise of *alpha* frequencies and synchronization of brain activity in both hemispheres. Another indicator is decrease of complexity of EEG signal.

As traditional spectral measures of EEG signal were used the power of *delta*, *theta*, *alpha*, *beta*, *gamma* band and so-called spectral edge. The range of *delta* band is 0.5-4 Hz, *theta* 4-8 Hz, *alpha* 8-12 Hz, *beta* 12-30 Hz and *gamma* 30-45 Hz. Spectral edge is a frequency below which one finds 95% of the signal power.

Clear positive change of *alpha* band in frontal areas and also positive change of *delta-theta* band in right occipital area can be observed. Decrease of spectral edge frequency in both occipital areas implies a gain of power in the lower spectral bands (in this case *delta-theta* band). (Fig. 1, 2)

Entropy and spectral entropy measures were used as nonlinear estimators of the signal complexity. Entropy of simple EEG signal seems to be more accurate than the spectral entropy. Entropy measure shows decrease of complexity in occipital areas but strong increase in frontal areas. (Fig. 1)

As measures of synchronization between left and right hemisphere the linear correlation and mutual information content were used. Both measures show that synchronization significantly decrease in frontal and occipital areas. The mutual information content shows more significant progress in comparison with linear correlation.

In general neither of mentioned measures showed ocular change during the experiment. Therefore partial correlation coefficient (PCC) was used to distinguish significant linear trends from the noise in the signal. Absolute values of PCC were lying between 0.6 and 0.99 for all measures. We could ignore all EEG records where the value of PCC was close to 1.

From subjective point of view only 2 of 6 participants were optimistic about the impact of a mind machine. Nevertheless they described significant increase (45%) of relaxation depth after all training sessions.

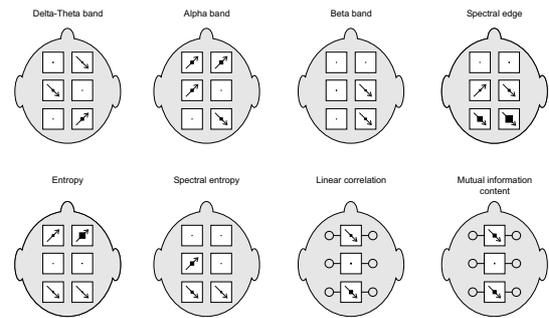


Figure 1: Partial correlation coefficient (black boxes) and average trend in all important points (arrows) of all measures. Included EEG data were recorded before mind machine sessions. Size of black boxes is equal to  $(1 - |PCC|)$ .

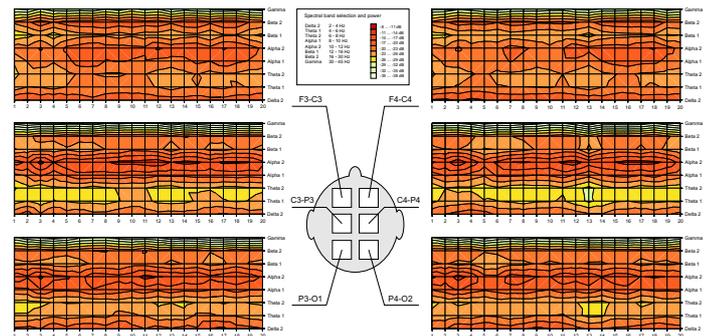


Figure 2: Evolution of the spectral power in selected bands. Analysed EEG data were recorded before mind machine sessions. X axis is session number, Y axis is spectral band. Positive change of *alpha1* (8-10 Hz) and *alpha2* (10-12 Hz) frequencies is evident in both left and right frontal areas. Minor positive change of *delta-theta* frequencies can be observed in the occipital areas.

## Conclusions

The rise of alpha frequencies in frontal areas and delta-theta frequencies in occipital areas can be observed. It may indicate mental state of brain relaxation and thus positive effect of the mind machine. It is also supported by decreasing trend in occipital areas in both entropical measures (*entropy* and *spectral entropy*). Surprisingly we have detected decrease of synchronization between hemispheres in frontal and occipital areas (*linear correlation* and *mutual information content*). This is usually considered as an indicator of the state of alertness.

## References

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