Audiovisual Stimulation of Human Brain. Linear and Nonlinear Measures.

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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.

1 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 (Fig. 1). 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.

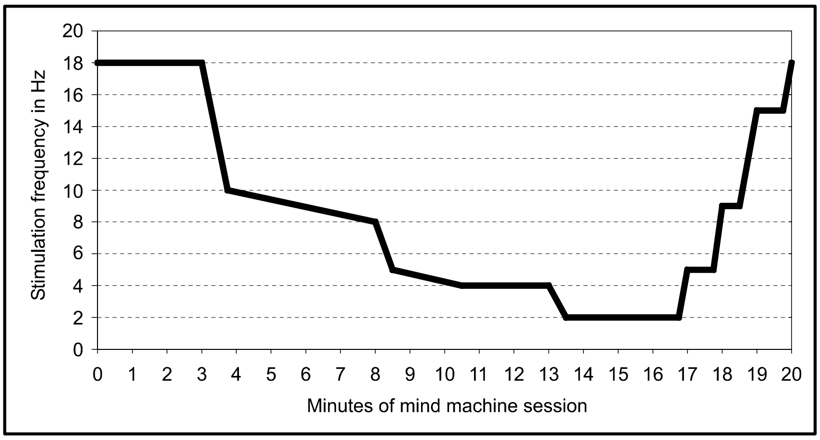

Figure 1: Evolution of the stimulation frequency during mind machine session.

2 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 a measures of traditional spectral features of EEG signal the power of *alpha, beta, delta-theta* band and so-called spectral edge were used. The range of *alpha* band is 8-12 Hz, *beta* 12-25 Hz, *delta-theta* 0.5-8 Hz. Spectral edge is a frequency below which one finds 95% of the EEG 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 (especially *delta-theta* band). (Fig. 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. 2)

To measure 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. (Fig. 2)

In general neither of mentioned measures showed ocular change during the experiment. Therefore partial correlation coefficient (PCC) was used to distinguish significant changes from the noise in 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. (Fig. 2)

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.

3 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 entropic 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.

But how to understand the state of ”alert relaxation”?

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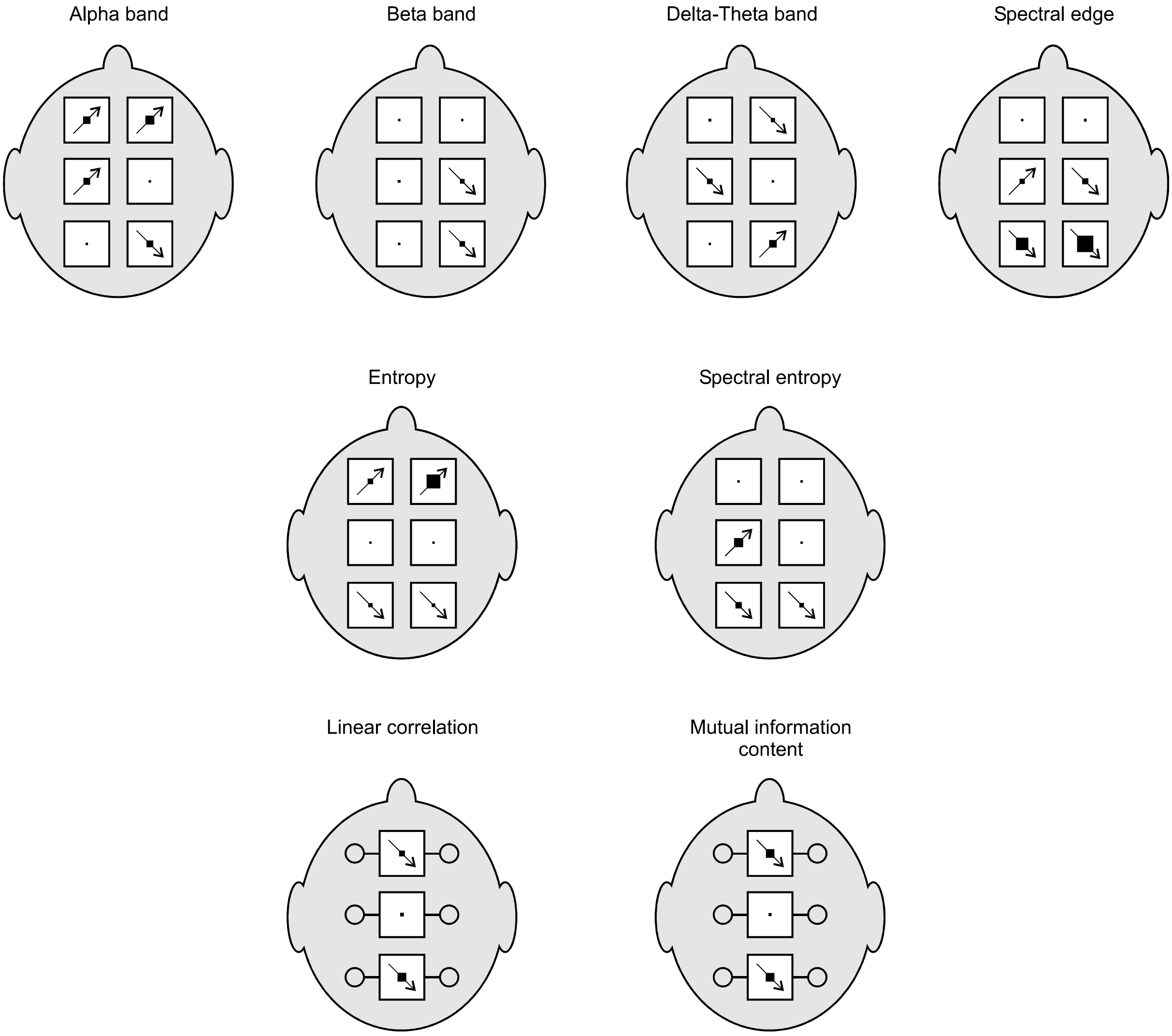

Figure 2: Partial correlation coefficient (black boxes) and trend in all important points (arrows) of all measures. Source EEG signal was recorded before mind machine session. Size of black boxes is equal to (1 - |*PCC*|).