

EEG Characterization of Psycho-Physiological Rest and Relaxation

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Abstract. *EEG correlates of psycho-physiological rest are addressed. Experiment consisted of 88 relaxation sessions of 8 subjects. 6-channel EEG data of 3-minute duration were examined. Firstly EEG characteristics of rest were revealed in a form of linear regression trends. On the contrary to general expectations, during resting conditions of 3-minute session in darkened room in lying position with eyes closed, relative alpha-1 powers were decreasing, followed by increase in theta-1 and decrease in total powers over the whole cortex. EEG features derived from linear regression model were selected according their ability to discern between subjectively more and less successful relaxation. Lower overall power in backward areas as a distinctive characteristic of more successful relaxation was accompanied by increased alpha and beta-1 features in some cortex areas. Potential applications involve clinical, pharmacological, and stress management areas.*

Keywords: EEG, relaxation, signal analysis

1. Introduction

The relaxation response is an integrated body reaction, which has been found to have such benefits as increased mental and physical health and improved ability to deal with tension and stress. In the literature we had found no direct characterization of EEG features of relaxation. However need for characterization of resting status of patients may be relevant for many areas, e.g. stress reduction, sleep deprivation, and testing of pharmacological substances related to hypnotic and sedative drugs. Poor relaxation response is usually connected to problems of stress. Actually, stress is acknowledged as one of the major problems of modern society. While calling for stress reduction, need for monitoring tools for stress may grow.

It might be difficult to define relaxation properly. First of all, it is related to subjectivity and may vary across individuals. Implicitly, under the term relaxation it is usually meant certain positive and beneficial phenomenon. Regular relaxation practice should have more side effects on different physiological and psychical parameters of individuals (related e.g. to aging, digesting, general peace, psycho-somatic deceases). There exist no generally accepted references in a form of other physiological parameters. According to Travis five different categories of physiological variables might be sensitive to level of relaxation [1] including breath and heart rates, and skin conductance. Similar parameters for characterization of stress level are reported by Vavrinský [2]. Physiological components of relaxation response introduced in [3] were decrease in oxygen consumption, decrease in respiratory rate, decrease in heart rate, and increased in alpha brain wave production. Researchers usually consider increased alpha production as a sign occurring during mental and physical rest [4, 5, 3]. According to Ossebaard relaxation is made up of several biological, psychological, and social components [6].

In our previous study we interpreted increased alpha and theta powers during long term audio-visual stimulation as signs of relaxation [7]. The aim of this study was to examine basic EEG characteristics during resting conditions. In particular, two consequent tasks were

addressed: 1) Finding changes in EEG measures during sensori-motorical rest reflecting functioning of the central nervous system. 2) Selecting the most appropriate objective EEG features that are able to distinguish between more and less successful relaxation determined by subjective assessment.

2. Subject and Methods

Eight right-handed healthy subjects (3 females and 5 males, mean age 27 years, st.dev. 7 years) volunteered in the experiment. Subjects were instructed to keep their eyes closed and relax both physically and mentally. The lying position during 3-minute EEG measurements was comfortable enough to avoid unwanted activities and to diminish the occurrence of some artefacts caused by feeble motion. Monopolar EEG montage was realized by EEG cap and comprised eight channels with electrodes placed on F3, F4, C3, C4, P3, P4, O1, and O2 locations according the International 10-20 system. The reference electrode was located at Cz and the ground electrode at Fpz point. A standard cap system (Electro Cap Inc.) with Ag-AgCl electrodes was employed. In order to prevent signal distortions, impedances at each electrode contact with the scalp were kept below 5 k Ω , and balanced within 1 k Ω of each other. EEG recording was realized by unit with the following parameters: no. of channels: 8, amplifying gain: 402, sampling frequency: 500 Hz, A/D converter resolution: 16 bits, input resolution: 0.46 μ V, noise: max 4.1 μ V pp.(0.07 to 234 Hz), low pass filter: 234 Hz (-3dB), high pass filter: 0.07 Hz (-3dB).

From the 8-channel signal between active electrodes and reference electrode six difference signals F3C3, F4C4, C3P3, C4P4, P3O1, and P4O2 were derived by off-line transformation in order to avoid undesirable effects of common reference electrode. The electroencephalograms were analyzed first by online visual control of the ongoing EEG in 8 channels and later by off-line analysis. Sequences contaminated by either subject-related or technical artefact and obvious sleep occurrences were excluded by eye inspection and according to the subject's assessment. Digital high pass FIR filter with cut-off at 0.75 Hz and with 3000 point Blackman window was utilized.

To uncover objective changes from obtained EEG data, we computed the following signal characteristics: total power, relative frequency powers, and magnitude squared coherences in nine bands: delta-1 (0.5-2 Hz), delta-2 (2-4 Hz), theta-1 (4-6 Hz), theta-2 (6-8 Hz), alpha-1 (8-10 Hz), alpha-2 (10-12 Hz), beta-1 (12-16 Hz), beta-2 (16-30 Hz), and gamma (30-45 Hz). Powers and coherences were computed in Matlab environment. Time subwindows were 2 seconds long with 0.75 overlap.

From each of 8 subjects we obtained 24 recording sessions. For the first task we chose 11 artefact-free recordings from each participant. From them, in the second task we chose 4 least and 4 most successful relaxation sessions for each subject. Choice was done according to answers to the following task: "Assess a level of your relief accomplished during 3-minute resting period." Subjective measure was rated on 7-point bipolar scale.

3. Results

We identified evolutions of various measures during 3-minute intervals. Most of them could be reasonably interpolated by linear regression. For evaluation of trend magnitudes we constructed index out of absolute difference obtained by measure's trend according to linear model (Δ_{abs}) divided by standard deviation of residuals in respect to linear regression:

$$\Delta_{res} = \frac{\Delta_{abs}}{std(res)}$$

This index is reasonable alternative to p-value from testing whether regression slope differs from flat one by F-test and they are in mutual unambiguous nonlinear correspondence.

In order to discover general features of the resting process, we focused on strong nonzero trends from average ($n = 88$) course of each measure, that should reflect certain changes in physiological functioning. In Fig. 1 samples of averaged behaviour of measures with cortex location identification during resting conditions are presented.

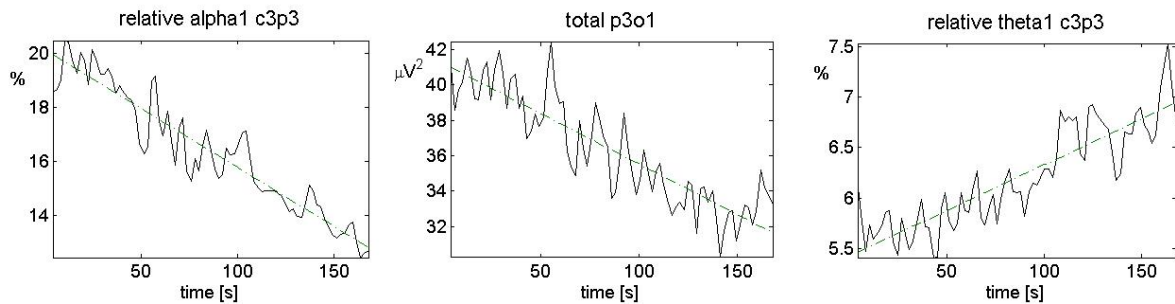


Fig. 1: Strongest trends of averaged behaviour of EEG measures in particular cortex locations during resting conditions.

Sensori-motorical rest can be characterized by trends of the following EEG measures. The strongest changes were observed across all six cortex regions by decrease of relative alpha-1 power (cortex average $\Delta^{\text{res}} = -8.9$), further by increase in theta-1 relative power ($\Delta^{\text{res}} = -6.1$) and by global decrease in total power ($\Delta^{\text{res}} = -4.8$). The strongest combination of alpha decrease and theta increase was observed in C3P3 area (Fig. 1), where alpha-1 relative power was diminished by 40 % from its initial values (typical st.dev. 15 % for average points in graph).

Further goal was to find out special EEG features bound to 'successful' relaxation expressed on the contrast of 'less successful' relaxation. Recordings were divided into two groups according their subjective evaluation of general well-being during the relaxation period. For each subject groups were formed separately; four artefact-free sessions were taken with the lowest scoring and four with the highest one.

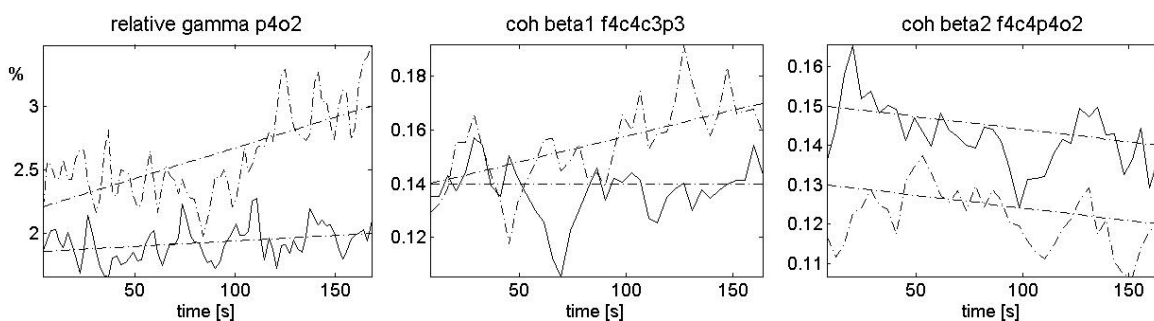


Fig. 2: Samples of average curves for more and less (dashed) successful relaxation differing by either initial values, slopes or terminal values.

For each individual data (32 cases from 8 persons in each group) linear regression model was counted. Two relaxation categories might differ by three types of features related to linear regression: initial values, trends (Δ^{res}), and terminal values. In order to find distinct features of two relaxation categories, two-sample heteroscedastic student's t-test was utilized for data that did not violate normality in Shapiro-Wilk test ($p > 0.05$) and nonparametric Kruskal-Wallis test for those data where normality was refused (both $p < 0.002$ after involving Bonferroni correction). More successful relaxation was characterized by lower final levels of total power

in parieto-occipital areas, overall higher relative alpha powers, and higher terminal relative beta-1 powers in backward regions. Further significant changes were observed in beta coherence (in both relation directions) mostly interhemispherically through all three types of features.

4. Discussion

Decrease of total power over the whole cortex implies that overall brain activity was gradually diminished during the resting process, with the strongest contribution on this change realized by alpha-1 band. In spite of the fact that during our resting conditions we detected no increase in appearance of alpha waves during 3 minutes, consistent increase of alpha waves in our data could be found: Focus on shorter time windows shows that relative power in alpha-2 band in average increased during the first 30 seconds in all cortex regions. In the literature commonly accepted fact on alpha wave increase during rest and relaxation [3] should be rather related to eye closing phenomenon, by which resting is usually initiated, and to kind of lighter rest - rest with shorter time span and perhaps to sitting position. Moreover we have shown that in principle discrimination of two relaxation categories from EEG data is possible. In further work referencing to more physiological outcomes (e.g. cardio-vascular, respiratory, muscular, blood secretion) is suggested.

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References

- [1] Travis, F. Autonomic and EEG patterns distinguish transcending from other experiences during Transcendental meditation, *Int. J. Psychophysiol.*, 42: 1–9, 2001.
- [2] Vavrinský, E. Tenkovrstvové mikroelektródy pre elektrochemické vodivostné senzory aplikované v biomedicínskom monitorovaní stresu, PhD thesis, Slovak Technical University in Bratislava, Faculty of Electrical Engineering and Informatics, Department of microelectronics, 2005.
- [3] Foster, D. EEG and subjective correlates of alpha-frequency binaural-beat stimulation combined with alpha biofeedback. Memphis State University, 1990.
- [4] Lindsley, D. Psychological phenomena and the electroencephalogram, *Electroenceph. Clin. Neurophysiol.*, 4: 443, 1952.
- [5] Brown, B. Recognition of aspects of consciousness through association with EEG Alpha activity represented by a light signal, *Psychophysiology*, 6: 442–452, 1970.
- [6] Ossebaard, H. Stress reduction by technology? An experimental study into the effects of brainmachines on burnout and state anxiety, *Applied psychophysiology and biofeedback*, 25: 93–101, 2000.
- [7] Teplan M. et al. EEG responses to long-term audio-visual stimulation. *Int. J. Psychophysiol.*, 59: 81-90, 2006.