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# Analysis of resting-state fMRI data by CAPA method.


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## SUMMARY


This work describes application of the co-activation patterns analysis (CAPA) method for analyzing resting-state fMRI data obtained in order to detect stable substates. The research involved 25 healthy volunteers. The analysis revealed that inside a resting-state we could distinguish 8 alternating stable substates. Their average duration was estimated at about 20-25 seconds.


## INTRODUCTION

The research aimed at extraction and quantitative assessment of time-changing information contained in resting-state fMRI data provided a new subject for analysis - dynamic functional connectivity (DFC) of a resting-state - as well as corresponding technique. Among known set of DFC techniques, there is an approach radically different from traditional ones, because it analyses separate spatial fMRI-volumes at every time-instance, rather than analysing time series. Such approach concentrates on finding repetitive co-activation patterns (CAPs - i.e. coinciding changes of fMRI signal in a certain spatially separated group of voxels) in brain as well as on their changes in time.

## APPROACH

Due to physiological characteristics of the signal, a smooth change in connectivity between brain regions is assumed. Therefore, the states assessed using the CAPA method do not change quickly and cannot last 1 TR period. Based on these statements, an estimate of the number of "outliers" was introduced when classifying data into states - the number of transition points or single points in which the state lasts one TR period.

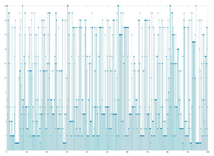


Fig. 1. Temporal scheme of the human brain states changes for an excessive number of states.

## METHODS

The experimental data were obtained at the National Research Center “Kurchatov Institute” on a Magnetom Verio tomograph with a magnetic field strength of 3 T. fMRI data were acquired with scan parameters: 42 slices, repetition time (TR) 2000 ms, echo time (TE) 20 ms, field of view (FOV) 192 × 192 mm2, voxel size 3 × 3 × 3 mm3. As part of the study, 1000 time samples for functional data were scanned, with a total duration of about 33.5 minutes. The total study time was 40 minutes. The study involved 25 healthy volunteers aged from 18 to 31, average age 24.

## RESULTS

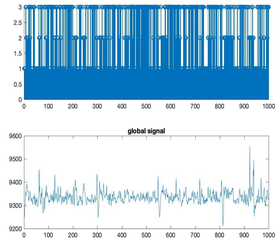
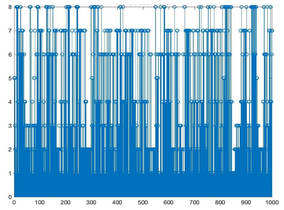



Fig. 2. An example of data decomposition into 3 states. Time diagram of changes in the states of the human brain for an insufficient number of states (top), temporal dynamics of the global signal (bottom).

Fig. 3. The time scheme obtained by decomposing into 8 states (activation code patterns).



## ANALYSIS

The number of outliers in fig. 1 was more than 16% of the total number of points (163 outliers). An excessive number of examined states leads to the fact that some states (obtained with a smaller number of CAP’s) are divided into 2 or more states. Low value of CAP leads to the mixing of all states into one. At this time, the remaining states exhibit abrupt or high-amplitude changes of the global signal.

Thus, we can conclude that the optimal number of states under study can be determined empirically, since if the number is insufficient, the specificity of the selected states disappears, while if they are redundant, the states are blurred. A total of 19 sets of results were calculated (for the number of CAPs from 2 to 20 inclusive) and in each of them the parameter (number of outliers) was estimated, as well as the degree of correlation between the occurrence of a particular state and changes in the global signal.

## DISCUSSION

The average duration of a state, when decomposed into 8 patterns of coactivation, was 22 seconds for the entire set of volunteers. Taking into account the inertia property of the fMRI signal (the period is 15 seconds, while the increase is about 7 seconds), we can conclude that the approximate duration of a state, without taking inertia into account, is about 15 seconds. The duration of a state is about 7-8 time frames, which is physiological and corresponds to the time resolution of the method.

## CONCLUSIONS

1. Empirically, an optimal (with a low number of outliers < 1%) number of CAPs for resting state analysis - 8 - was obtained.
2. The detected states occur with some periodicity and last for a relatively short time - about 20 seconds .
3. The CAP method can be applied not only to fMRI time series, but also to matrices of connectivity between regions and can make it possible to obtain a temporal scheme of connectivity matrices changes.

## ACKNOWLEDGMENTS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