Mental Effort While Conceptual Tasks Solving: an EEG Study

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INTRODUCTION. We studied functional brain state dynamics as indicators of mental effort while solving conceptual tasks of various types. This study is mostly focused on correlations between brain activation and success in solving conceptual tasks of various types. Conceptual task solving is one of the most difficult types of intellectual activity. Mental operations upon concepts require energy consumption. We hypothesized that the functional state patterns differ during various types of verbal tasks solving, because this requires mental operations of various types to be performed.

PSYCHOLOGICAL METHODS:

1. “To Put Together The Three Concepts”” (by M.A. Kholodnaya, 2012) (CC)

The recipient is presented 3 concrete concepts and the task is to name a more general concept which is common for all of them.

Ex.: trap – fence – plug – ?

Answer: barrier.

All in all, there are 10 triads of concrete concepts. The answers are rated 0, 1 and 2 points .

2. “Metagrams” (by O.V. Shcherbakova, 2009) (MS)

Metagrams are the rhymed verbal riddles with more than one word encoded within each of them. All words differ in only one letter. The task is to find out all three words.

Ex.: With “g” it shines
And banks save it
With “m” it spoils
Bread in a week.

Answer: gold – mold.

All in all, there are 6 metagrams. The answers are rated 0, 1 and 2 points.

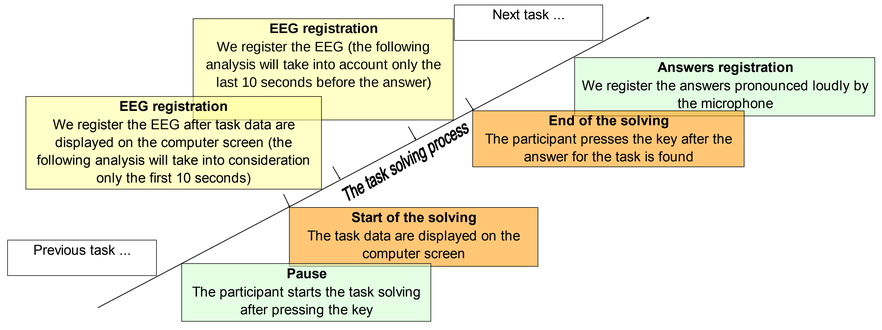
3. “Opposite statements” (by T. Woodjack, 1996) (OS).

The recipient is presented one general and poorly reasoned statement.

Ex.: “The murders often happen on Sundays”. The task is to produce arguments for it. Then the statement is changed to the opposite.

Ex.: “The murders rarely happen on Sundays”. And the task is to produce arguments for this new statement.

All in all, there are 3 pairs of statements. The answers are rated 0 or 1 points.



The sequence of the experimental events while solving the task of each type

STATISTICS. We used MANOVA repeated measures for assessing the differences in the EEG power recorded in all conditions.

We assessed the effect of the following factors:

- Repeated measures factors:
  - Stage of the task solving (two levels: the beginning of the solving process, the end of the solving process)
  - EEG band ranges (six levels: Δ, Θ, α, β1, β2 , γ)
  - EEG channels (19 levels)
- Between groups factors:
  - Correctness of the task solving (three levels: incorrect (0), partially correct (1), and correct (2))
  - Type of the task (three levels: CC, MC, OC)
  - Total correctness for the task of the concrete type.

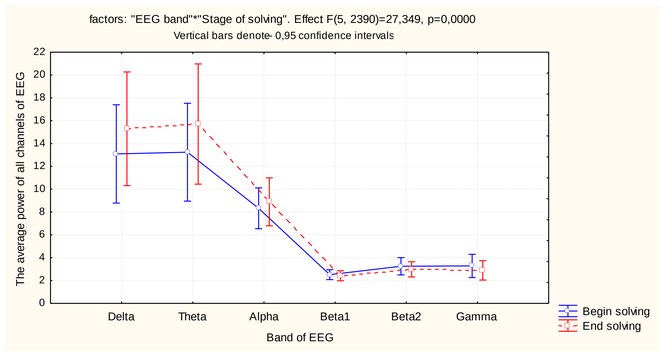
EXPERIMENT:

34 healthy volunteers (male and female aged 17 – 33) participated in our study after informed consent. The procedure included 3 types of intellectual tasks, each of them required operating upon concepts: each participant solved 10 tasks of the type CC, 5 tasks of the type MS and 16 tasks of the type OS.

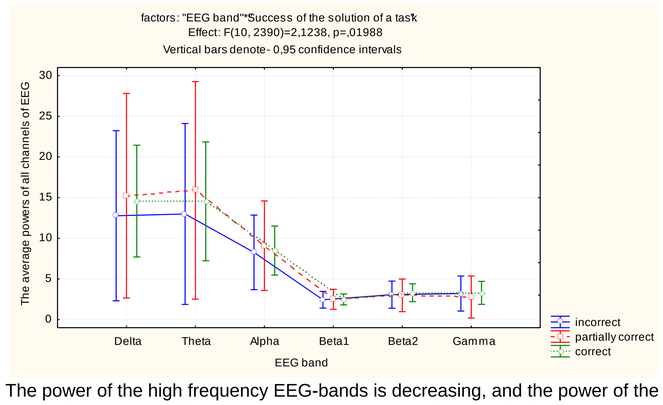
The EEG, ECG and GSR had been recorded during solving. The instruction for the task displayed on the computer screen, the participant pressed the key and after that the record started (see the fig. in the center). We asked all the participants to solve the tasks silently, without saying a word. When the participant finished solving, he/she pressed the button which stopped the record and gave the answer for the task aloud. Three experts assessed their answers using the following rates: incorrect answer (0), partially correct (1), and correct answer (2). We analyzed the EEG fragments representing the first 10 seconds and the last 10 seconds of the task solving process.

EEG activity was recorded with 19 active electrodes (according to the 10-20 international system). The 19 EEG traces were digitized online at 250 Hz. 2244 EEG tests and 1122 responses on the cognitive tasks were registered. We used the low-pass filter (1.6 Hz), the high-pass filter (75 Hz) and the band-pass filter (45-55 Hz).

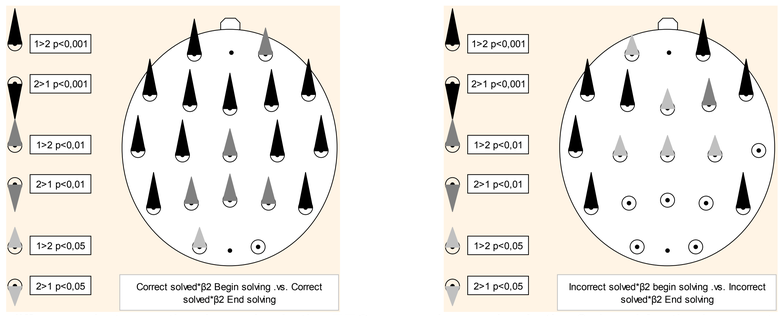
We calculated the EEG power in the main frequency ranges: Δ, Θ, α, β1, β2 , γ. We excluded all the data which were beyond the boundaries of the three standard deviations from the mean. We also calculated the mean frequency of the heart rate (ECG) and its deviation of the baseline state (before solving) and the power of the galvanic skin reactions (GSR).



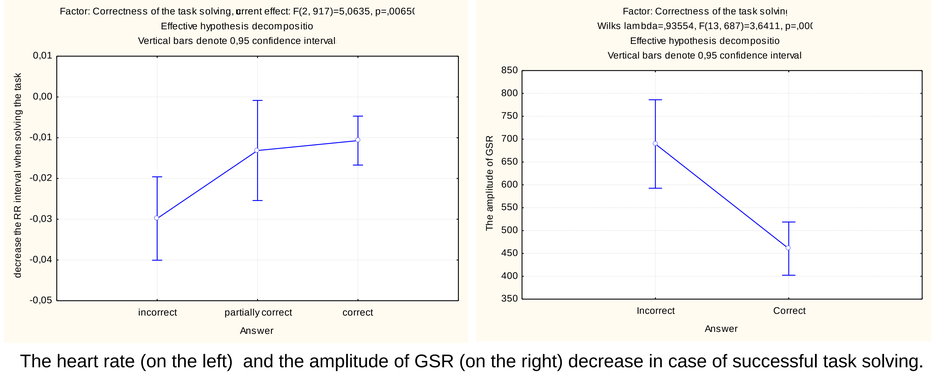
The power of the high frequency EEG-bands is decreasing, and the power of the low frequency EEG-bands is increasing from the beginning of the task solving till the end of it.



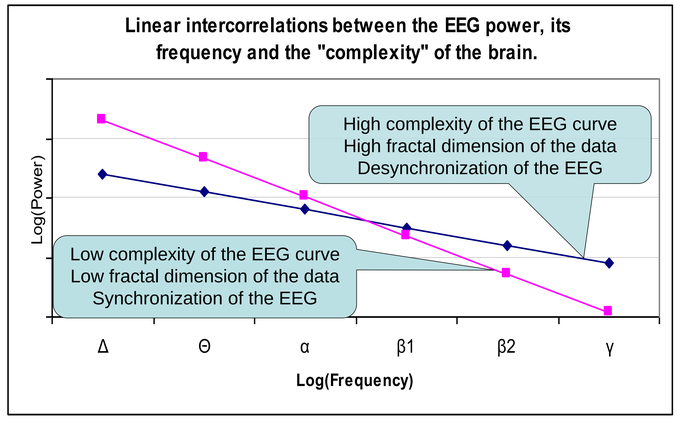
The power of the high frequency EEG-bands is decreasing, and the power of the low frequency EEG-bands is increasing in case of successful task solving.



The difference between the dynamics in the EEG-power decreasing in the β_2 band for the incorrect and correct task solving (Post Hoc criterion – Fisher LSD)



The heart rate (on the left) and the amplitude of GSR (on the right) decrease in case of successful task solving.



The model explaining the observed phenomena