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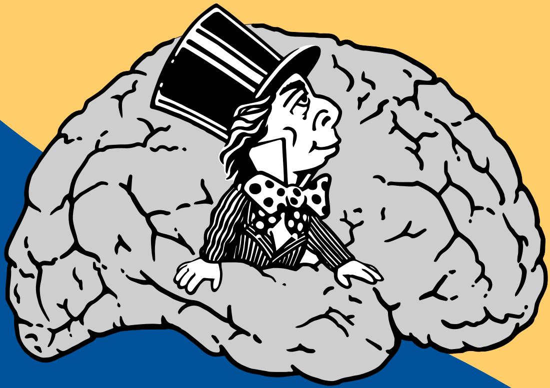

НОВЫЕ ИССЛЕДОВАНИЯ

МАТЕРИАЛЫ КОНФЕРЕНЦИИ 2019

Под ред. Е.В. Печенковой, М.В. Фаликман

УДК 159.9
ББК 88.25
К57

Когнитивная наука в Москве: новые исследования. Материалы конференции 19 июня 2019 г. Под ред. Е. В. Печенковой, М. В. Фаликман. – М.: ООО «Буки Веди», ИППиП. 2019 г. — 656 стр.

ISBN 978-5-4465-2346-7

УДК 159.9
ББК 88.25

ISBN 978-5-4465-2346-7

THE ROLE OF ALPHA OSCILLATIONS IN THE INHIBITION PROCESS DURING WORKING MEMORY: AN EEG-TACS STUDY

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Abstract. One of the principal requirements for successful working memory functioning is the ability to ignore distracting information coming from the environment. This process is thought to be supported by oscillatory brain activity (Jensen et al., 2002). Oscillations in the alpha band (~8-12 Hz) rise in power and synchronization in the parieto-occipital sites prior to the onset of an expected distractor (Bonnefond & Jensen, 2012). In the present study, we explored whether stimulation with tACS over the right parieto-occipital cortex on the participant's individual frequency of alpha would improve performance on a working memory task via improving the inhibition of distractors. We found that alpha activity strengthens prior to the distractor; however, the level of the activation does not change as a function of the distractor's strength. Moreover, tACS did not affect behavioral output. Overall, further research is needed to understand the role of alpha oscillations in the inhibition process.

Keywords: working memory, inhibition, oscillations, alpha range, tACS

The research was supported by the Russian Science Foundation under grant 17-11-01273.

One of the robust features of working memory (WM) is the substantial involvement of attentional processing (Baddeley, 2012; D'Esposito & Postle, 2015; Eriksson et al., 2015). Selective attention is at work during encoding, maintenance as well as processing of information. One of the key functions of selective attention is the protection of the memory from distractors. WM has been shown to have a limited capacity to the amount of information being stored (Baddeley, 2012; Luck & Vogel, 1997), with an increase of the amount resulting in decreased behavioral performance in manipulating this information (Oberauer, 2001; Bays & Husain, 2008). Therefore, it is essential to control and filter what enters memory and what, on the other hand, is ignored as unnecessary noise. A failure to ignore distracting information results in decreased WM performance (Zanto & Gazzaley, 2009). Moreover, the presence of a strong distractor during the period of memory retention results in worse performance as compared to a distractor which is easier to ignore (Bonnefond & Jensen, 2012).

The oscillatory cortical activity in the alpha band over parieto-occipital regions is present during the retention interval in a WM task (Jensen et al., 2002).

When there is a distractor within the retention interval, power of alpha oscillations has been shown to increase prior to the distractor (Freunberger et al., 2009; Sauseng et al., 2009; Bonnefond & Jensen, 2012). In summary, the inhibitory component of working memory is a well-established, however, actively explored to this day phenomenon.

Among other methods, the oscillatory component of cortical activity is researched via active modulation by the means of Transcranial Alternating Current Stimulation (tACS) (Paulus, 2011). Non-invasive stimulation of cortical areas with weak alternating current produces changes in endogenous oscillatory activity and allows to causally verify the role of oscillations in cognitive functioning. In the present study we employed a Sternberg task with distractors and tACS to explore the influence of alpha band activity on the top-down inhibition during working memory.

Methods

Fifteen right-handed, healthy participants from 18 to 30 years old took part in the experiment. One participant was excluded for technical reasons, so 14 participants' data were employed for analysis (9 females, mean age = 22.6, *SD* = 2.33).

In order to avoid pre-established semantic associations, the stimuli for memorization and for "strong" distractors (i.e. the distractors which are relatively hard to ignore) were taken from several ancient alphabets. For the condition with "weak" distractors a set of graphs with thin lines as edges and thick dots as nodes was created.

The experimental paradigm of the study was a modified version of the Sternberg working memory task. In the "strong" condition, six stimuli are presented sequentially at the center of the screen, for 0.033 sec each with 1.1 sec intervals. Subjects were asked to memorize the first four stimuli ("a memory set"), to ignore the fifth one ("a distractor") and to indicate whether the sixth stimulus ("a probe") was a member of the memorized set or not. A distractor was taken from the same category as the other stimuli and was referred to as strong distractor. In the "weak" condition the distractor fell into a visually different category than other stimuli, thereby serving as a weak distractor. In the control condition, instead of having a distractor, participants were asked to memorize all the first five stimuli presented. Accuracy and reaction time (RT) were recorded after each response as behavioral measures of success. The experiment included 180 trials per experimental condition, counterbalanced between blocks.

The experiment was conducted for two consecutive days. During the first day (training) participants completed 3 blocks of each condition. At the beginning of the second day the participants completed 1 block of each condition while the EEG was recorded from the scalp. The recording was done using a standard 64 electrode montage with mastoid electrodes employed for recording electrooculogram. After 1 hour break the participant completed 3 blocks of each condition while the tACS was delivered in an on-line manner throughout the whole trial. The stimulating electrode was placed over right occipito-parietal area (in the position of PO8 electrode according to the international 10 – 20 system) and the returning electrode was positioned on an ipsilateral shoulder. The amplitude of the current was kept at 1000 microA. The protocols of stimulation differed by frequency: subject's individual frequency (in alpha band), individual frequency + 3 Hz (in order to verify the effectiveness of using individualized frequency for stimulation) and sham stimulation (in order to verify the influence of factors unrelated to the alternating current stimulation).

For extraction of the individual frequency of stimulation, power spectral density (PSD) was calculated for the pre-distractor time period from Strong condition in the PO8 electrode (according to the 10 – 20 international system), and the frequency with the highest power was taken as an individual frequency of stimulation.

The behavioral results were statistically tested using 3-way repeated measures ANOVA with factors Stimulation (Individual, Individual + 3 Hz, Sham), Condition (Strong, Weak, Load-5) and Session (1, 2, 3). To explore the differences between conditions, we employed Student's *t*-test for pairwise comparison.

EEG data was analyzed from 14 subjects (the data of 1 subject had technical problems). The analysis was conducted in order to extract individual frequency of activation of alpha oscillations in the pre-distractor period, as well as to verify the stability of the effects induced by the task. The window of −700 ms before the onset of the distractor was chosen. For extraction of the individual frequency, power spectral density (PSD) was calculated for the frequency-resolved data from Strong condition in the PO8 electrode (according to the 10 – 20 international system), and the frequency with the highest power was taken as an individual frequency of stimulation. For further analysis, time-frequency-resolved data of different experimental conditions (Strong, Weak and Load-5) was contrasted against each other.

Results

Stimulation didn't have any significant effect on either of the behavioral measures. However, the analysis of accuracy for the first stimulation session has shown a significant interaction between Condition and Stimulation ($F(4, 24) = 2.88$, $p < .05$). At the same time, the type of stimulation demonstrated no significant effect on accuracy. There was a significant difference between sham and real stimulation for RT ($p < .05$ for individual frequency and $p < .01$ for individual frequency + 3 Hz). Real stimulation, irrespective of the frequency, lead to reduced RT. The same trend was observed for accuracy.

Condition had a significant influence on both the accuracy ($F(2, 28) = 9.63$, $p < .01$) and the reaction time ($F(2, 28) = 8.65$, $p < .01$). Load-5 condition was significantly different from both Strong ($p = .01$) and Weak ($p < .01$) conditions in accuracy. Weak condition was significantly different from both Strong ($p = .01$) and Load-5 ($p < .01$) conditions.

Session had a significant influence on the accuracy ($F(2, 28) = 3.97$, $p < .05$). With the increasing number of session, the accuracy dropped, which might be an effect of fatigue. Interestingly, the reaction time didn't change as a function of session.

The analysis of EEG activity during the task showed an increase in alpha power in bilateral occipito-parietal region irrespective of the condition (Fig. 1B). The

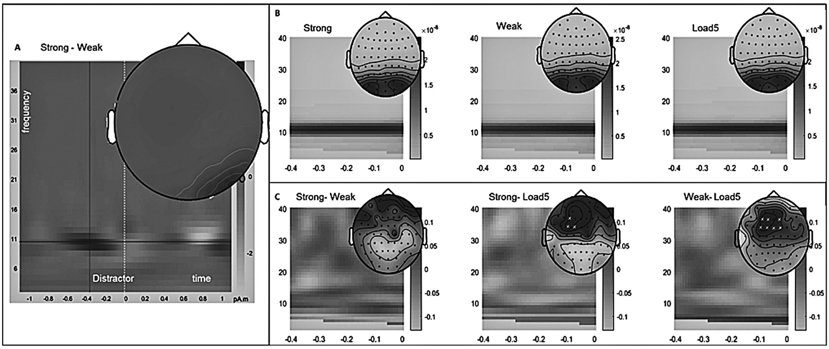

Figure 1. Time-frequency (TF) maps and topographies of a pre-distractor activation. **A.** A contrast of Strong condition against Weak condition. **B.** TF map of PO8 electrode and topography of activation in alpha band, averaged across time — individual conditions. **C.** TF map of PO8 electrode and topography of activation in alpha band — contrasts between conditions, normalized by the sum of conditions.

contrast of power in PO8 electrode between Strong and Weak conditions shows an increase in alpha power in Strong as compared to Weak condition (Fig. 1A). However, the topography of activation, when normalized to the sum of conditions, shows the greater difference between conditions in frontal but not in parietal regions (Fig. 1C).

Discussion and Conclusions

The results of the EEG analysis give evidence to the role of alpha band oscillations in working memory dynamics. Alpha band activity is present in parieto-occipital regions during a pre-distractor period in each experimental condition and this activity is stronger with stronger distractor. However, most of the condition-specific activity is observed in frontal regions. These results give evidence for a fronto-parietal network involved.

Stimulation did not have any effect on the task performance. The possible reason for that is interference between types of stimulation. Results from the first stimulation session gives rise to two possibilities which need to be further explored: (1) stimulation in alpha frequency reduces reaction time during a working memory task, irrespective of the individual frequency of oscillation; (2) individual frequency of oscillation should be extracted in a different way. Another possible reason for the absence of any effect of tACS on the success rate is the fact that the stimulation was delivered throughout the whole trial, including the stages of encoding, maintenance and retrieval. Introduction of the oscillatory activity on the inhibitory frequency may have a differential effect on other stages of WM processing. Restricting the timings of stimulation to memory maintenance periods is a possible path to follow in order to better understand the role of alpha oscillations in the inhibitory activity during WM.

References

Baddeley A. Working memory: Theories, models, and controversies // Annual Review of Psychology. 2012. Vol. 63. No. 1. P. 1 – 29. doi:10.1146/annurev-psych-120710-100422

Bays P. M., Husain M. Dynamic shifts of limited working memory resources in human vision // Science. 2008. Vol. 321. No. 5890. P. 851 – 854. doi:10.1126/science.1158023

Bonnefond M., Jensen O. Report alpha oscillations serve to protect working memory maintenance against anticipated distracters // Current Biology. 2012. Vol. 22. No. 20. P. 1969 – 1974. doi:10.1016/j.cub.2012.08.029

D'Esposito M., Postle B. R. The cognitive neuroscience of working memory // Annual Review of Psychology. 2015. Vol. 66. No. 1. P. 115 – 142. doi:10.1146/annurev-psych-010814-015031

Eriksson J., Vogel E. K., Lansner A., Bergström F., Nyberg L. Neurocognitive architecture of working memory // Neuron. 2015. Vol. 88. No. 1. P. 33 – 46. doi:10.1016/j.neuron.2015.09.020

Freunberger R., Fellinger R., Sauseng P., Klimesch W. G. W. Dissociation between phase-locked and nonphase-locked alpha oscillations in a working memory task // Human Brain Mapping. 2009. Vol. 30. No. 10. P. 3417 – 3425. doi:10.1002/hbm.20766

Jensen O., Gelfand J., Kounios J., Lisman J. E. Oscillations in the alpha band (9-12 Hz) increase with memory load during retention in a short-term memory task // Cerebral Cortex. 2002. Vol. 12. No. 8. P. 877 – 882. doi:10.1093/cercor/12.8.877

Luck S. J., Vogel E. K. The capacity of visual working memory for features and conjunctions // Nature. 1997. Vol. 390. No. 6657. P. 279 – 281. doi:10.1038/36846

Oberauer K. Removing irrelevant information from working memory: A cognitive aging study with the modified Sternberg task // Journal of Experimental Psychology: Learning, Memory, and Cognition. 2001. Vol. 27. No. 4. P. 948 – 957. doi:10.1037/0278-7393.27.4.948

Palva S., Kulashekhar S., Hamalainen M., Palva J. M. Localization of cortical phase and amplitude dynamics during visual working memory encoding and retention // Journal of Neuroscience. 2011. Vol. 31. No. 13. P. 5013 – 5025. doi:10.1523/jneurosci.5592-10.2011

Paulus W. Transcranial electrical stimulation (tES – tDCS; tRNS, tACS) methods // Neuropsychological Rehabilitation. 2011. Vol. 21. No. 5. P. 602 – 617. doi:10.1080/09602011.2011.557292

Sauseng P., Klimesch W., Heise K. F., Gruber W. R., Holz E., Karim A. A., Glennon M., Gerloff C., Birbaumer N., Hummel F. C. Brain oscillatory substrates of visual short-term memory capacity // Current Biology. 2009. Vol. 19. No. 21. P. 1846 – 1852. doi:10.1016/j.cub.2009.08.062

Zanto T. P., Gazzaley A. Neural suppression of irrelevant information underlies optimal working memory performance // Journal of Neuroscience. 2009. Vol. 29. No. 10. P. 3059 – 3066. doi:10.1523/jneurosci.4621-08.2009

РОЛЬ АЛЬФА-ОСЦИЛЛЯЦИЙ В ПРОЦЕССЕ ОТТОРМАЖИВАНИЯ ИНФОРМАЦИИ В РАБОЧЕЙ ПАМЯТИ: ЭЭГ-TACS ИССЛЕДОВАНИЕ

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Аннотация. Одним из важнейших требований для успешного функционирования рабочей памяти является способность игнорировать отвлекающую информацию, поступающую из внешней среды. Данный процесс, вероятно, поддерживается осцилляторной активностью мозга (Jensen et al., 2002). Мощность и синхронизация осцилляций в альфа-диапазоне (~8 – 12 Гц) растут в затылочно-теменных зонах в период подготовки к появлению отвлекающего стимула (дистрактора) (Bonnefond, Jensen, 2012). В данном исследовании была изучена возможность повысить успешность выполнения задания на рабочую память через более эффективное оттормаживание дистракторов. Воздействие на способность к оттормаживанию осуществлялось при помощи транскраниальной стимуляции переменным током (tACS) затылочно-теменной зоны на индивидуальной альфа-частоте испытуемого. Было обнаружено, что альфа-активность усиливается в период ожидания дистрактора; однако, мощность активации не зависит от силы дистрактора. Более того, tACS не оказывала влияния на поведенческие результаты. Таким образом, для понимания роли альфа-осцилляций в процессе оттормаживания необходимы дальнейшие исследования.

Ключевые слова: рабочая память, оттормаживание, осцилляции, альфа-диапазон, tACS