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**STUDY OF THE ACTIVITY OF BASIC EEG RHYTHMS DURING
MEMORIZATION USING THE LOCI METHOD**

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ABSTRACT

This article presents data on changes in the amplitude activity of alpha and beta rhythms of the cortex depending on the method of memorization. The study of the electrical activity of the cerebral cortex in the process of memorizing information by the Loki method remains a hot topic of research in the fields of neuroscience and cognitive psychology. The method of loki, loci is a mnemonic method set forth in ancient Roman treatises on rhetoric. It is based on mental-spatial associations, the purpose of which is to create, organize and further use the entire content of human memory. Understanding how data is stored in students' brains and how Loki's method influences this process can help develop more effective teaching methods, thereby optimizing the learning process. The effect of this memorization method on psychological aspects such as improved concentration, visualization and associative thinking has been

demonstrated. Studying the brain's electrical activity during normal memory processes and using Loki's method can also help identify individual differences in memory abilities and the performance of different memory methods. The study revealed a significant increase in the frequency of alpha and beta rhythms when memorized by the Memory Palace method in the frontal, temporal and occipital lobes. This indicates the activation of the mental process with additional visualization. As for the left location of this activity in the subjects, it can be assumed that the left hemisphere is responsible for the processes of spatial memory, or for purely individual differences in the activity of the hemispheres. Forgetting curve analysis showed a more stable ability to reproduce information using the Loki method compared to controls. This method excites several centers of the brain, which makes it possible to form stronger neural networks, which are necessary for studying various materials. This can be beneficial for all people with poor memory.

Keywords: memory, mnemonics, Loki method, electroencephalography, memory physiology

ИЗУЧЕНИЕ АКТИВНОСТИ ОСНОВНЫХ РИТМОВ ЭЭГ ВО ВРЕМЯ ЗАПОМИНАНИЕ С ИСПОЛЬЗОВАНИЕМ МЕТОДА LOKI.

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АННОТАЦИЯ

В данной статье представлены данные изменения амплитудной активности альфа и бета ритмов коры в зависимости от способа запоминания. Изучение электрической активности коры головного мозга в процессе запоминания информации методом Локи остается горячей темой исследований в областях нейробиологии и когнитивной психологии. Метод локи, локусов — мнемонический метод, изложенный ещё в древнеримских трактатах, посвящённых риторике. Основан на мысленно-пространственных ассоциациях, целью которых является создание, упорядочивание и дальнейшее использование всего содержимого человеческой памяти. Понимание того, как данные хранятся в мозгах студентов и как метод Локи влияет на этот процесс, может помочь в разработке более эффективных методов обучения, тем самым оптимизируя учебный процесс. Продемонстрировано влияние этого метода запоминания на психологические аспекты, такие как улучшение концентрации, визуализации и ассоциативного мышления. Изучение электрической активности мозга во время нормальных процессов памяти и использование метода Локи также может помочь выявить индивидуальные различия в способностях памяти и эффективности различных методов памяти. По результатам исследования был выявлен существенный подъем частоты альфа и бета ритмов при запоминании методом Memory Palace в лобной, височной и затылочной долях. Это указывает на активацию ментального процесса с дополнительной визуализацией. Что касается левого

расположения этой деятельности у испытуемых, то можно предположить, что за процессы пространственной памяти отвечает левое полушарие, или о чисто индивидуальных различиях в активности полушарий. Анализ кривой забывания показал более стабильную способность воспроизводить информацию при использовании метода Локи по сравнению с контролем. Этот метод возбуждает несколько центров мозга, что позволяет формировать более прочные нейронные сети, которые необходимы для изучения различного материала. Это может быть полезно для всех людей с плохой памятью.

Ключевые слова: память, мнемотехника, метод Локи, электроэнцефалография, физиология памяти

YODLASH VAQTIDA LOCI USULI YORDAMIDA ASOSIY EEG RITMLARINING FAOLIGINI O'RGANISH

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ANNOTATSIYA

Ushbu maqolada yodlash usuliga qarab po`stloqning alfa va beta

ritmlarining amplituda faolligidagi o'zgarishlar to'g'risidagi ma'lumotlar keltirilgan. Loki usuli yordamida ma'lumotni eslab qolish jarayonida miya po'stlog'ining elektr faolligini o'rganish neyrobiologiya va kognitiv psixologiya sohasidagi tadqiqotlarning dolzarb mavzusi bo'lib qolmoqda. Loki usuli qadimgi Rim ritorika risolalarida bayon etilgan mnemonik usuldir. Maqsadlari inson xotirasining butun mazmunini yaratish, tartibga solish va undan keyingi foydalanishdan iborat bo'lgan aqliy-fazoviy birlashmalarga asoslanadi. Talabalar miyasida ma'lumotlar qanday saqlanishi va Loki usuli bu jarayonga qanday ta'sir qilishini tushunish samaraliroq o'qitish usullarini ishlab chiqishga yordam beradi va shu orqali o'quv jarayonini optimallashtiradi. Ushbu yodlash usuli diqqatni jamlash, vizualizatsiya va assotsiativ fikrlashni yaxshilash kabi psixologik jihatlarga ta'sir qilishi ko'rsatilgan. Oddiy xotira jarayonlarida miyaning elektr faolligini o'rganish va Loki usulini qo'llash, shuningdek, xotira qobiliyatidagi individual farqlarni va turli xil xotira usullarining samaradorligini aniqlashga yordam beradi. Tadqiqot natijalari peshona, chakka va ensa bo'laklarida Xotira saroyi usulidan foydalangan holda yodlash paytida alfa va beta ritmlarining chastotasining sezilarli darajada oshishini aniqladi. Bu aqliy jarayonning qo'shimcha vizualizatsiya bilan faollashishini ko'rsatadi. Ushbu faoliyatning sub'ektlardagi joylashuviga kelsak, chap yarim sharning fazoviy xotira jarayonlari uchun mas'ul ekanligi yoki yarim sharlar faoliyatida sof individual farqlar mavjudligini taxmin qilish mumkin. Unutish egri chizig'ining tahlili nazorat bilan solishtirganda Loki usulidan foydalanganda ma'lumotni ko'paytirishning barqaror qobiliyatini ko'rsatdi. Ushbu usul miyaning bir nechta markazlarini qo'zg'atadi, bu esa turli xil materiallarni o'rganish uchun zarur bo'lgan kuchli neyron tarmoqlarni shakllantirishga imkon beradi. Bu xotira zaif bo'lgan barcha odamlar uchun foydali bo'lishi mumkin.

Kalit so'zlar: xotira, mnemonika, Loki usuli, elektroensefalografiya, xotira fiziologiyasi

Relevance. Studying the electrical activity of the cerebral cortex during the process of memorization of information using the Loci method (a memory technique based on place) remains a hot topic of research in the fields of neuroscience and cognitive psychology - [1, 2]. This is essential in the context of an ever-changing educational environment and the need for fast and effective learning. Understanding how data is stored in students' brains and how the Loci method influences this process can help in developing more effective teaching methods, thereby optimizing the educational process. The influence of this memorization method on psychological aspects, such as improving concentration, visualization, and associative thinking, is demonstrated. Studying the electrical activity of the brain during normal memory processes and using the Loci method may also help identify individual differences in memory abilities and the effectiveness of various memory techniques. This can lead to personalized learning approaches tailored to students' individual needs. Modern neuroscientific research techniques offer greater insight into which areas of the brain are activated during specific cognitive tasks. Studying the electrical activity of the cerebral cortex using the Loci method may provide insights into the neuronal mechanisms underlying this memory technique.

Spatial memory is a specific part of the mind responsible for accumulating data about location in cognitive psychology and neurobiology - [1, 2]. The purpose of our research is to study the activity of the cerebral cortex during ordinary memory tasks and while using the Loci method among students. This article presents the changes in the amplitude activity of the alpha and beta rhythms of the cortex, depending on the method of memorization.

The aim of the study

To investigate the electrical activity of the cerebral cortex during normal memorization and while using the Loci method in students.

Materials and research methods

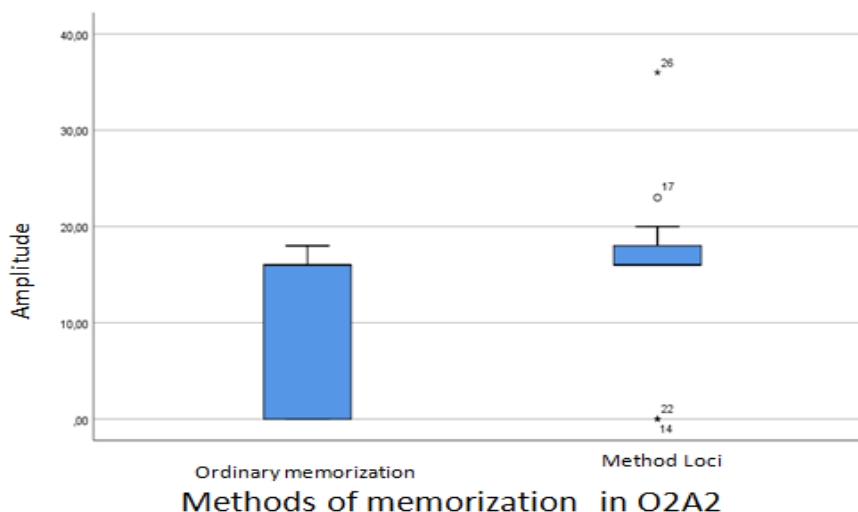
20 students from different years of study participated in the research. Students memorized a number of words in a specific order. When using the Loki method in the process of memorization, at the first step, the subject was asked to choose a place to "build" a memory palace. In the second step, it was proposed to build associative chains for each zone in the palace. When all the suggested words for memorization were translated into associative images and chains, the subject was asked to repeat all the words in the exact order of memorization. The number of memorized words, the order of their memorization and the time of forgetting were estimated in accordance with the Ebbinghaus forgetting curve [3]. The study was carried out in several stages: at the first stage, the respondents recorded an electroencephalogram at rest and while memorizing information. Subsequently, for the next 1, 2, 3 days, as well as after 4 weeks, the survival of memorization was checked (the ability to reproduce information was assessed by counting the number of words that the respondent still remembers). The registration and analysis of the bioelectric activity of the brain was carried out using a 16-channel encephalograph. The signals were processed using a fast Fourier transform, the values of absolute spectral power (MV²), amplitude and frequency for θ — (4 - 7 Hz), α — (8 - 13 Hz) and β — (14 -30 Hz) rhythms were analyzed.

Then, the changes in the activity of the cerebral cortex were assessed on EEG. Differences between two methods of memorization were determined by the Mann-Whitney U Test ($p < 0.05$). The calculation of statistical characteristics was carried out using the SPSS 7.0 software package and Statistica 10.

The results of the study and their discussion

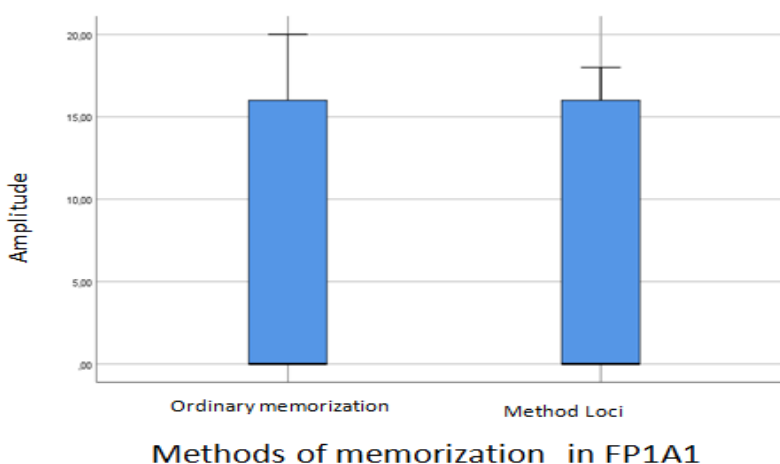
According to the results of statistical calculations, it was revealed that the studied methods of memorization have the following differences

in the structure of the EEG rhythm. The calculation by the Mann-Whitney U Test shows statistically significant differences in the amplitude of the alpha and beta rhythms in FP8A2 and O2A2 electrodes, ($U = -1.089$, $p = 0.0276$), ($U = -1.472$, $p = 0.0141$) (picture 1) for alpha and $U = -1,000$, $p = 0,0317$), ($U = -0,717$; $P = 0,0474$) for beta respectively.



Picture 1

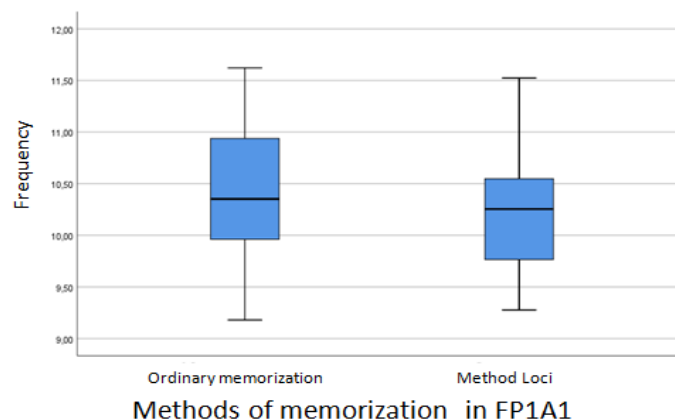
However, there is a significant increase in the amplitude of alpha rhythm in FP1A1 ($U = -0.756$, $p = 0.0450$)(picture 2), while there is no change in beta rhythm.



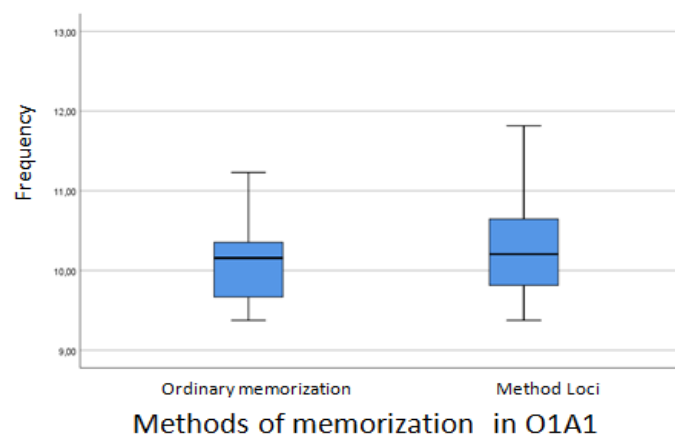
Picture 2

However, statistically significant differences in the mean alpha frequency were revealed when comparing the two memorization methods in FP1A1 (Picture 3), FP4A2 and O1A1 (Picture 4) leads. There is an

increase in the alpha rhythm when using spatial memory ($U = -2.621$, $p = 0.009$), ($U = -1.021$, $p = 0.0307$) ($U = -1.575$, $p = 0.0115$) and ($U = -1.374$, $p = 0.0169$).



Picture 3

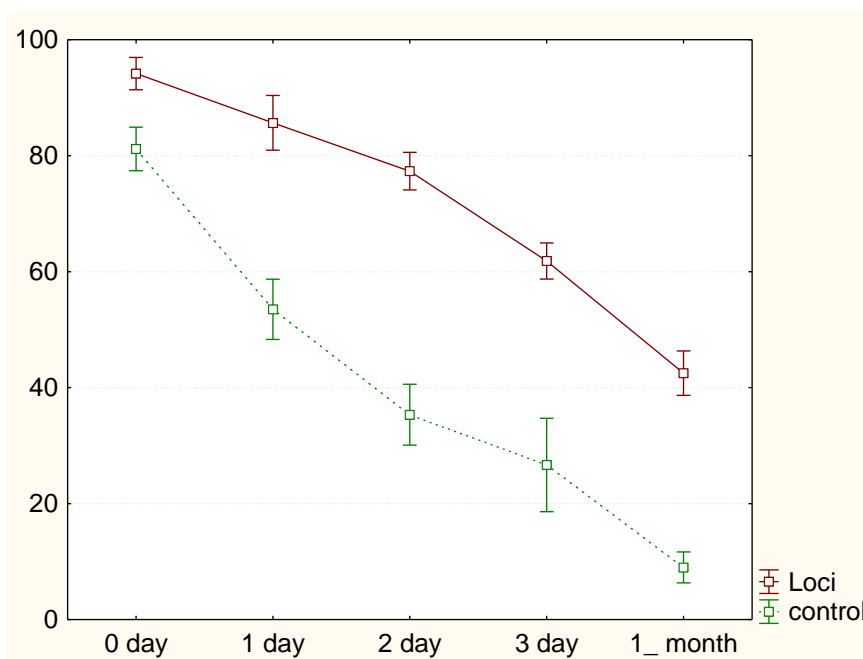


Picture 4

There are differences in the mean alpha rhythm frequency in all frontal leads: FP1A1 ($U = -0.805$, $p = 0.0421$), FP2A2 ($U = -1.779$, $p = 0.0475$), FP3A1 ($U = 0.981$, $p = 0.0327$), FP7A1 ($U = -1.085$, $p = 0.0278$), F8A2 ($U = -2.760$, $p = 0.006$) and occipital leads: O1A1 ($U = -1.503$, $p = 0.133$), O2A2 ($U = -1.119$, $p = 0.263$). There is an increase in the amplitude of the alpha rhythm when memorized by the Palace of Memory method in the following lead: O1A1 ($U = -2.574$, $p = 0.010$). An increase in frequency when memorizing by the Palace of Memory method is available in the

following leads: FP3A1 ($U = -1.084$, $p = 0.0279$), FP7A1 ($U = -3.110$, $p = 0.002$), FP8A2 ($U = -2.760$, $p = 0.006$), O1A1 ($U = -2.970$, $p = 0.003$).

The analysis of the ability to store information showed statistically significant differences in the number of words that the subjects were able to remember at the beginning of the study (Loci: $Me=17$, $Q25=14$, $Q75=20$; control; $Me=12$, $Q25=7$, $Q75=17$; $U=49$, $p=0.000462$). Later, on days 1, 2, 3, the percentage of memorization also had statistically significant differences (picture 5).



picture 5

A study of the process of forgetting for a month (Table 1) revealed a significant effect of the method of memorization on the survival of knowledge over time ($\chi^2=29.48175$, $df=4$, $p=,00000$). The forgetting curve showed more pronounced difficulties of long-term memorization in the control group compared to memorization by Memory Palace. More pronounced statistically significant differences between the methods of memorization were observed 1 month after the study ($U=0.000$, $p=0.000001$).

Table 1 – Memorization rates (%) in the study and control groups during the month.

	Loci - Means	Confidence Interval - 95%	Confidence Interval +95%	Control - Means	Confidence Interval - 95%	Confidence Interval +95%
0 day	94,17	91,39	96,94	81,17	77,41	84,92
1 day	85,67	80,95	90,39	53,50	48,31	58,69
2 day	77,33	74,09	80,58	35,33	30,08	40,59
3 day	61,83	58,71	64,95	26,67	18,61	34,73
1 month	42,50	38,68	46,32	9,00	6,34	11,66

Conclusion

According to the results of the study, an essential climb in the frequency of alpha and beta rhythms were revealed during memorization by Memory Palace method in frontal, temporal and occipital lobes. This indicates the activation of the mental process with additional visualization. As for the left-sided arrangement of this activity in the subjects, it can be assumed that the left hemisphere is responsible for the processes of spatial memory, or about purely individual differences in the activity of the hemispheres. The analysis of the forgetting curve showed a more stable ability to reproduce information when using the Loki method compared with the control.

This method excites several centers of the brain, which allows to form stronger neural networks, which are necessary for studying various material. It might be useful for all people with poor memory [4].

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