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Evaluation of long-term memory through electroencephalographic techniques

Avaliação da memória de longo prazo por meio de técnicas eletroencefalográficas

Evaluación de la memoria a largo plazo mediante técnicas electroencefalográficas

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Abstract
This study aimed to evaluate the long term memory through electroencephalographic techniques. Were evaluated, in individuals from the human and exact sciences groups, during the following cognitive activities: task: 1 – MEMORIZING WORDS; 2 – REMEMBER THE WORDS OF ACTIVITY 1; 3 – MEMORIZING FIGURES; 4 REMEMBER THE FIGURES OF THE ACTIVITY 3. The gamma rhythm was recorded through the electroencephalogram (EEG), according to the 10-20 system. Thus, the tasks aimed to analyze the capacity for long-term memorization. EEG signals were monitored during the reading and response of the tasks and the means and standard deviation of the gamma rhythm were calculated. The statistical model was BioEstat 5.0, T test for paired samples ($p<0.05$), Mann-Witney non-parametric test - independent samples and Excel. The results of the intragroup and intergroup analysis in human and exact subjects showed a significant difference in processing brain, through the gamma rhythm, during activities. Individuals in the humanities area used the anterior left quadrant more, while individuals in the exact sciences area used the posterior right quadrant more, as evidenced in the tasks of memorizing pictures and evoking pictures. It seems that there is an association of the gamma rhythm with the states of greater activation of the cerebral cortex during the programming and execution of cognitive activities.
Keywords: Electroencephalography; EEG; Memory, Long-term; Assessment.

Resumo
Este estudo teve como objetivo avaliar a memória de longo prazo por meio de técnicas eletroencefalográficas. Foram avaliadas, em indivíduos dos grupos de ciências humanas e exatas, durante as seguintes atividades cognitivas: tarefa: 1 – MEMORIZAR PALAVRAS; 2 – LEMBRE-SE DAS PALAVRAS DA ATIVIDADE 1; 3 – MEMORIZAÇÃO DE FIGURAS; 4 LEMBRE-SE DAS NÚMEROS DA ATIVIDADE 3. O ritmo gama foi registrado através do eletroencefalograma (EEG), de acordo com o sistema 10-20. Assim, as tarefas visavam analisar a capacidade de memorização de longo prazo. Os sinais de EEG foram monitorados durante a leitura e resposta das tarefas e as médias e desvio padrão do ritmo gama foram calculados. O modelo estatístico utilizado foi o BioEstat 5.0, teste T para amostras pareadas ($p<0,05$), teste não paramétrico de Mann-Whitney - amostras independentes e Excel. Os resultados da análise intragrupo e intergrupo em humanos e exatos mostraram uma diferença significativa no processamento cerebral, através do ritmo gama, durante as atividades, quadrante posterior direito mais, como evidenciado nas tarefas de memorizar figuras e evocar figuras. Parece haver uma associação do ritmo gama com os estados de maior ativação do córtex cerebral durante a programação e execução de atividades cognitivas.
Palavras-chave: Eletroencefalografia; EEG; Memória de longo prazo; Avaliação.

Resumen
Su estudio tuvo como objetivo evaluar la memoria a largo plazo a través de técnicas electroencefalográficas. Fueron evaluadas, en individuos de los grupos de ciencias humanas y exactas, durante las siguientes actividades cognitivas: tarea: 1 - MEMORIZACIÓN DE PALABRAS; 2 – RECORDAR LAS PALABRAS DE LA ACTIVIDAD 1; 3 – MEMORIZACIÓN DE CIFRAS; 4 RECORDAR LAS CIFRAS DE LA ACTIVIDAD 3. Se registró el ritmo gamma a

través del electroencefalograma (EEG), según el sistema 10-20. Así, las tareas tenían como objetivo analizar la capacidad de memorización a largo plazo. Las señales de EEG se monitorearon durante la lectura y respuesta de las tareas y se calcularon las medias y la desviación estándar del ritmo gamma. El modelo estadístico fue BioEstat 5.0, prueba T para muestras apareadas (p<0,05), prueba no paramétrica de Mann-Witney - muestras independientes y Excel. Los resultados del análisis intragrupo e intergrupo en sujetos humanos y exactos mostraron una diferencia significativa en el procesamiento cerebral, a través del ritmo gamma, durante las actividades. Los individuos del área de humanidades utilizaron más el cuadrante anterior izquierdo, mientras que los individuos del área de ciencias exactas utilizaron el cuadrante posterior derecho más, como se evidencia en las tareas de memorización de imágenes y evocación de imágenes. Parece que existe una asociación del ritmo gamma con los estados de mayor activación de la corteza cerebral durante la programación y ejecución de actividades cognitivas.
Palabras clave: Electroencefalografía; EEG; Memoria a largo plazo; Evaluación.

1. Introduction

The organization of human memory consists of the existence of at least two systems with different durations: a short-term memory (MCP) and a long-term memory (MLP) (Abenna et al, 2022). The formation of memories begins primarily with the acquisition of information in sensory systems (vision, hearing, touch, etc.) in the form of stimuli (Alazrai et al., 2018; Almouloud, 2010). Long-term memory is more stable and long-lasting, and can be evoked in the future by stimuli somehow related. Long-term memory is believed to result from structural changes in signal conduction. MLP introduces the file formation process, in which the process that converts MCP information into MLP is done through consolidation (Cosenza & Guerra, 2009; Brown et al., 2007).

The electroencephalogram (EEG) presents a traditional quantitative study, being evidenced through calculations of the spectral power distribution of long-term recordings, that is, the relative amplitudes, or "energies" of the various frequencies that make up the EEG or other recorded signal. extracellularly (Cosenza & Guerra, 2009; Cowan, 1988; Dori et al., 2022; Guarda & Goulart, 2018; Gruneberg, 1970).

EEG frequency variations are grouped into five categories; alpha, beta, theta, delta and gamma (Gruneberg, 1970). Individuals belonging to the area of exact sciences have exalted their logical-mathematical abilities, while individuals belonging to the area of humanities develop their linguistic abilities (Buzsáki & Watson, 2022). Thus, it would be interesting, using electroencephalographic mapping and coherence analysis, to assess whether there are differences in verbal brain processing during the execution of cognitive activities in the language area between individuals belonging to these two areas.

The present study aimed to evaluate the long term memory through electroencephalographic techniques between individuals in the human and exact areas, through an intragroup analysis.

2. Methodology

Statistical Method

Sample size calculation

The sample size was calculated using the Epi-Info version 6 statistics program, taking into account a 95% confidence interval, a statistical power of 80% and an α risk of 0.05. Being determined in 20 volunteers (10 volunteers from exact sciences and 10 volunteers from humanities). The research was authorized according to: CAAE: 20373813.6.0000.5012 and Opinion Number: 660.031.

Statistical analysis

Descriptive statistics techniques were applied, including tables and graphs. The BioEstat 5.0 statistical model, T test for paired samples, Mann - Witney non-parametric test - independent samples and Excel 2020 were also used to determine the existence of correlations and differences between the two study groups. A significance level of 0.05 was accepted.

Primary Variables:

Academic background: nominal qualitative variable that can be characterized as: humanities or exact.

Secondary variables:

Topographic analysis of cerebral frequency: quantitative variable that will be measured by the percentage of cerebral electroencephalographic rhythms (beta, alpha, theta, delta and gamma) in each cerebral lobe.

Search location:

The research was carried out at the physiology and pharmacology laboratory at the physiology laboratory of UNCISAL (State University of Health Sciences of Alagoas - Brazil). Rua Doctor Jorge de Lima, 113 - Trapiche da Barra - 57010-300 - Maceio/AL - BR.

Sample

Inclusion criteria: Individuals from the humanities and exact sciences aged between 18 and 30 years old and who carry out labor activities in the humanities and exact sciences areas.

Exclusion criteria: Individuals who, despite having university education in the areas of humanities or exact sciences, do not carry out activities congruent with their education, who are using psychotropic drugs or who have behavioral changes.

Sampling

The sample consisted of 20 individuals from the areas of humanities and exact sciences aged between 18 and 30 years old and who were carrying out work activities consistent with their academic training. These volunteers were recruited by the researchers among professionals and students, in the last periods of university courses, in the areas of humanities and exact sciences. Through telephone contact. Volunteers were randomly recruited at the Federal University of Alagoas - UFAL.

Procedures:

Research participants were recruited according to the inclusion and exclusion criteria. After a clear explanation of what was done during the research and the application of the free and informed consent, the individuals were submitted to a brief anamnesis with the objective of identifying whether they perform the work function congruent with their training. Some personal information will be raised, as the use of some types of drugs, recreational or otherwise, may interfere with the research results.

The 20 selected individuals were distributed according to their academic background into two groups: Group H: 10 individuals with academic training in the areas of humanities and Group E: 10 individuals with academic training in the areas of exact sciences.

Participants in both groups underwent long-term memory tests during the electroencephalogram.

To perform the electroencephalographic record, an EMSA model 320 serial electroencephalograph with 20 electrodes was used, which were placed on the scalp of the volunteers according to the international 10-20 system. To place the electrodes, a conductive concrete paste and masking tape were used. The electroencephalographic signals were amplified, digitized and the brain mapping information was analyzed. All information obtained was archived on CDs.

Electroencephalographic examinations were always performed in the morning between 08:00 and 12:00. Each session initially consisted of five minutes of baseline recording during wakefulness. Then the electroencephalographic recording was continued simultaneously with:

Presentation of the verbal long-term memory stimulus for thirty seconds;

This memory stimulus consists of a list of 10 words, according to the CERAD Word Test, in which the individual will have 30 seconds to memorize the words;

Ten seconds of distracting tasks (count backwards from 1 to 20);

In an experimental sequence, another visual memory test was carried out, which consisted of 10 pictures of different semantic categories: pencil, apple, chair, bag, shoe, tree, ice cream, church, house and ball;

Then, the individuals read the book A “brunette” by MACEDO, Joaquim Manuel de. Brunette (Macedo, 2008).

Individuals were presented with two lists of words and in the two lists that contained words from the list shown initially and new words that were not there, and the individual was asked to show which words were in the first list;

Individuals were presented with two sets of pictures containing the initial pictures and new pictures and the individual will be asked to show which were among the ten shown initially.

3. Results

Intragroup analysis of individuals in the humanities area

The comparison between the anterior left (AE), anterior right (AD), posterior left (LP) and posterior right (PD) areas before and during the execution of: activity 1 (memorizing words) showed that there was a significant difference in the anterior left areas ($p<0.04$) and in the right posterior area ($p>0.01$), activity 2 (remembering the words from activity 1) showed that there was a significant increase in the gamma rhythm, in the left anterior area ($p<0.05$) , in human subjects, activity 3 (memorizing pictures) showed that there was a significant difference only in the posterior left area ($p=0.05$), in human subjects and activity 4 (remembering the pictures from activity 3) showed that there was no difference significant in human subjects (Table 1).

Table 1 - Intragroup analysis of individuals in the humanities area.

	REST				ACTIVITY 1				REST				ACTIVITY 2				REST				ACTIVITY 3				REST				ACTIVITY 4			
AREA	AE	AD	PE	PD	AE	AD	PE	PD	AE	AD	PE	PD	AE	AD	PE	PD	AE	AD	PE	PD	AE	AD	PE	PD	AE	AD	PE	PD	AE	AD	PE	PD
AVERAGE	26,9	26,7	26,8	26,6	27,6*	26,7	27,4	28,1*	27.4	27.6	27.0	27.0	26,5*	26,3	26,8	26,5	27.4	27.6	27.0	27.0	26,6	26,6	26,4*	26,6	27.4	27.6	27.0	27.0	27,2	26,4	27,3	26,7
PAD DEVIATION	0,8	0,7	0,6	0,4	1,4	0,5	1,2	1,8	1.5	1.4	1.1	0.9	0,4	0,2	0,7	0,3	1.5	1.4	1.1	0.9	0,7	0,4	0,3	0,5	1.5	1.4	1.1	0.9	1,3	0,2	1,1	0,5

*significant Source: Research authors

Intragroup analysis of individuals in the area of exact sciences

The comparison between the areas AE, AD, PE and PD, before and during the execution of: activity 1 (memorizing words) showed that there was no significant difference in individuals of exact sciences, activity 2 (remembering the words of activity 1) showed that no there was a significant difference, in exact sciences individuals, activity 3 (memorizing pictures) showed that there was no significant difference, in exacting individuals and activity 4 (recalling the figures from activity 4) showed that there was a significant difference only in the right posterior area ($p \leq 0.01$). In this area, a decrease in the gamma rhythm was observed in individuals with exact sciences (Table 2).

Table 2 - Intragroup analysis of individuals in the exact sciences area.

	REST				ACTIVITY 1				REST				ACTIVITY 2				REST				ACTIVITY 3				REST				ACTIVITY 4			
AREA	AE	AD	PE	PD	AE	AD	PE	PD	AE	AD	PE	PD	AE	AD	PE	PD	AE	AD	PE	PD	AE	AD	PE	PD	AE	AD	PE	PD	AE	AD	PE	PD
AVERAGE	26.85	26.98	26.61	27.65	26.79	26.44	27.17	27.17	26.85	26.98	26.61	27.65	27.24	26.75	27.35	27.04	26.85	26.98	26.61	27.65	26.65	26.82	26.65	26,6	26.85	26.98	26.61	27.65	26.37	26.63	26.58	26.77*
PAD DEVIATION	01.06	0.82	0.66	1.25	0.93	0.44	1.18	1.34	01.06	0.82	0.66	1.25	1.22	0.87	1.52	1.15	01.06	0.82	0.66	1.25	01.07	0.95	0.82	0,5	01.06	0.82	0.66	1.25	0.35	01.04	0.76	0.53

*significant. Source: Research authors.

Intergroup analysis between individuals in the humanities and exact sciences

The analysis of intergroup data between individuals in the humanities and exact sciences areas obtained during: activity 1 (memorizing words) did not show a significant difference in gamma rhythm, activity 2 (evoking words from activity 1), between the did not show a significant difference in gamma rhythm in individuals from the humanities and exact sciences area, activity 3 (picture memorization), between the humanities and exact sciences groups showed a significant increase in the gamma rhythm in individuals from the humanities area in the left anterior area ($p \leq 0.006$) on the other hand side, an increase in the exact gamma rhythm was observed in the right posterior area ($p \leq 0.007$) and activity 4 (recall the figures from activity 4) between the human and exact science groups showed a significant increase in the gamma rhythm in the individuals in the area of human in the left anterior area ($p \leq 0.00006$), right anterior area ($p \leq 0.001$), left posterior area ($p \leq 0.003$). On the other hand, an increase in the gamma rhythm was observed in the exact sciences group in the right posterior area ($p \leq 0.01$) (table 3).

Table 3 - Intergroup analysis between individuals in the humanities and exact sciences.

	HUMAN				EXACT				HUMAN				EXACT				HUMAN				EXACT				HUMAN				EXACT			
	ACTIVITY 1				ACTIVITY 1				ACTIVITY 2				ACTIVITY 2				ACTIVITY				ACTIVITY 3				ACTIVITY 4				ACTIVITY 4			
AREA	AE	AD	PE	PD	AE	AD	PE	PD	AE	AD	PE	PD	AE	AD	PE	PD	AE	AD	PE	PD	AE	AD	PE	PD	AE	AD	PE	PD	AE	AD	PE	PD
AVERAGE	27,6	26,7	27,4	28,1	27,33	27,31	26,98	26,92	26.8	26.9	26.5	26.8	27.24	26.75	27.35	27.04	26.6	26.5	26.5*	26.4	26.65	26.82	26.65	27.21**	26.8*	27.0*	27.2*	27.0	26.37	26.63	26.58	26.77**
PAD DEVIATION	1,4	0,5	1,2	1,8	1,89	1,76	1,44	0,88	1.1	1.2	0.6	0.9	1.22	0.87	1.52	1.15	1.1	0.6	0.4	0.3	01.07	0.95	0.82	1.31	0.9	1.1	1.0	0.7	0.35	01.04	0.76	0.53

Source: Research authors.

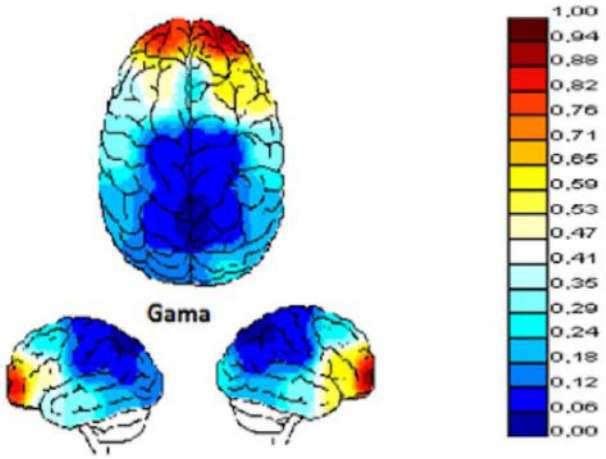
Figure 1 - EEG laboratory, placement of electrodes.

Source: Research authors.

Figure 2 - EEG laboratory, volunteer performing the activity.

Source: Research authors.

Figure 3 - Captured EEG image Regions with gamma rhythm predominance and gamma rhythm intensity range (the brighter , the greater the amount of gamma rhythm).



Source: Research authors.

4. Discussion

This research demonstrated that in the activity of: memorization of words, it was demonstrated that there was a significant difference in the anterior left areas and in the posterior right area, remembering the words of the previous activity demonstrated that there was a significant increase of the gamma rhythm, in the anterior left area, when evaluated for

memorization of figures, it was demonstrated that there was a significant difference only in the posterior region. However, when individuals from the area of exact sciences were exposed to these activities, it was demonstrated that only the activity of remembering the activity numbers made a significant difference only in the right posterior area. On the other hand, when intergroup analysis of individuals from humanities and exact sciences in the activity of memorizing figures, between humanities and exact sciences groups showed a significant increase in gamma rhythm in individuals from the humanities area in the anterior left area on the other hand and posterior right, in the activity of remembering the numbers from the previous activity, the humanities and exact sciences groups showed a significant increase in the gamma rhythm in the individuals in the area of humanities in the anterior left area. On the other hand, an increase in the gamma rhythm was observed in the exact exact sciences group in the right posterior region. In view of the data reported above, it appears that individuals in the humanities and exact areas, depending on the activity they are exposed to, have different brain activities.

As far as we know, this cross-sectional EEG research seems to be a pioneer in the assessment of long-term memory (PLM) in an intragroup and intergroup manner in a population with academic training and work activity in the humanities and exact sciences.

Furthermore, in a meta-analysis, it was evaluated whether musicians and non-musicians performed better in MLP activities, demonstrating a slight superiority of musicians over non-musicians, with moderate variability between studies (Jonides et al., 2008) Another meta-analysis also reported EEG analysis of brain activity in healthy adults (Niedermeyer & da Silva, 2005) demonstrating the EEG as the tool of choice for analyzing brain electrical activity.

MLP seems to be related to didactic preferences based on neuroeducational principles and may contribute to the acquisition, formation and evocation of Long-Term Memory (Norris, 2017). Still memory can be classified into short-term memory, responsible for maintaining recent events; and the long-term, where long-lasting and/or permanent records are stored (Oberauer, 2009).

Theoretical representations of arithmetic facts are associated with long-term memory - association distribution model (Siegler, 1984) and seem to indicate that the learning process in simple arithmetic depends on the retrieval of long-term memory (Perry, 2002). Suggest that children with learning difficulties in mathematics do not have a solution memory production process (Russell, 2019). as they have difficulty accessing the facts of the MLP (Perry, 2002)

However, there is controversy, as several authors claim that there is only one memory system responsible for short-term and long-term storage (Siegler, 1984; Da Silva, 2022; Surprenant & Neath, 2009). Some authors report that long-term memory is nothing more than activated short-term memory (Swanson & Rhine, 1985), (Swanson & Jerman, 2006), (Talamini et al., 2017). However, it is necessary to carry out studies that deepen this theme, in order to clarify.

This research presents as a limitation the number of evaluated participants, so we suggest that studies be carried out with a greater recruitment of a greater number of participants.

The main implication for future research is that long-term memory assessment associations in people from the humanities and exact academic areas should be reported, as well as intragroup analysis during rest and activities.

The implication for the clinical practice of the present research is that it seems that depending on the academic area, different brain regions are activated and are associated with the gamma rhythm, this rhythm comprises frequencies above 30 Hz and is physiologically related to waking states and especially during sleep concentration to perform tasks (Vanhollebeke et al., 2022; Liu et al.,2022).

As studies are carried out in this perspective, brain areas that are neglected in the learning process can be identified, so that therapeutic pedagogical strategies can be developed for efficient brain stimulation.

5. Conclusion

Individuals in the humanities area used the anterior left quadrant more, while individuals in the exact sciences area used the posterior right quadrant more, as evidenced in the tasks of memorizing pictures and evoking pictures. Our results seem to demonstrate that there is an association between the gamma rhythm and the states of greater activation of the cerebral cortex during the programming and execution of cognitive activities.

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