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Desempeño escolar, actividad cerebral y estimulación magnética transcraneal repetitiva

Academic Performance, Brain Activity and Repetitive Transcranial Magnetic Stimulation

Desempenho escolar, atividade cerebral e estimulação magnética transcraniana repetitiva

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Resumen

El desempeño escolar universitario depende del funcionamiento de las neuronas y la EMTr es una herramienta de nueva aparición que modifica la función neural. El objetivo de estudio fue identificar la relación entre EMTr y el promedio escolar. Previa firma por conveniencia del consentimiento informado se aplicó EMTr a un grupo de 6 participantes, se registró qEEG al final de 10 sesiones de 40 minutos con trenes pulsantes de tres segundos de estimulación por uno de descanso, frecuencia de 100 Hz e intensidad de seis Gauss, en estado de reposo con ojos cerrados, empleando una bobina de 10 centímetros en la línea media anterior a la mitad de nasión y vertex. Los resultados arrojaron alfa de Cronbach de 0.863; el promedio escolar inicial en el grupo estudiado (8.03) y final (8.55) presentó t de student de -3.253 y p=0.023; La EEG y promedio escolar mostraron correlación de Pearson en: T5HzDB en All Range r= -0.824 con p=0.044, T5HzDB en el rango Delta r=-0.825 y p=0.045 y F3HzDB en la frecuencia Theta r=0.859 y p=0.028. Concluyendo que la aplicación de EMTr modifica el funcionamiento neuronal mejorando el promedio escolar.

Palabras clave: Estimulación magnética transcraneal repetitiva, electroencefalografía cuantitativa, promedio escolar, estudiantes universitarios.

Abstract

University academic performance depends on the functioning of neurons, and rTMS is a newly emerging tool that modifies neural function. The study aimed to identify the relationship between rTMS and academic average. With informed consent obtained for convenience, rTMS was applied to a group of 6 participants. qEEG was recorded at the end of 10 sessions of 40 minutes, with three-second pulsed trains of stimulation followed by one second of rest, a frequency of 100 Hz, and an intensity of six Gauss, in a resting state with eyes closed, using a 10-centimeter coil on the midline anterior to the midpoint of nasion and vertex. The results showed a Cronbach's alpha of 0.863; the initial academic average in the studied group (8.03) and final (8.55) showed a Student's t of -3.253 and p=0.023; EEG and academic average showed Pearson correlation in: T5HzDB in All Range r= -0.824 with p=0.044, T5HzDB in the Delta range r=-0.825 and p=0.045, and F3HzDB in the Theta frequency r=0.859 and p=0.028. Concluding that the application of rTMS modifies neural function, improving academic average.

Keywords: Repetitive Transcranial Magnetic Stimulation, Quantitative Electroencephalography, Academic Average, University Students.

Resumo

O desempenho escolar universitário depende do funcionamento dos neurônios e a EMTr é uma ferramenta emergente que modifica a função neural. O objetivo do estudo foi identificar a relação entre a EMTr e a média escolar. Após assinatura para conveniência do consentimento informado, a EMTr foi aplicada a um grupo de 6 participantes. O qEEG foi registrado ao final de 10 sessões de 40 minutos com trens pulsantes de três segundos de estimulação e um segundo de repouso, frequência de 100 Hz e. intensidade de seis Gauss, em estado de repouso com olhos fechados, utilizando uma bobina de 10 centímetros na linha média anterior ao meio do násio e vértice. Os resultados mostraram alfa de Cronbach de 0,863; A média escolar inicial do grupo estudado (8,03) e final (8,55) apresentou t de Student de -3,253 e p=0,023; O EEG e a média escolar apresentaram correlação de Pearson em: T5HzDB na faixa All r= -0,824 com p=0,044, T5HzDB na faixa Delta r=-0,825 e p=0,045 e F3HzDB na frequência Theta r=0,859 e p= 0,028. Concluindo que a aplicação da EMTr modifica o funcionamento neuronal, melhorando a média escolar.

Palavras-chave: Estimulação magnética transcraniana repetitiva, eletroencefalografia quantitativa, médio escolar, estudantes universitários.

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Introduction

In the statistical yearbooks of the Juárez University of the state of Durango, in the students of the medical surgeon career in the Durango fields (August 2018 to December 2021) a 73% failure rate is recorded (UJED, 2018, 2019, 2021, 2022); which is the reason for this research project seeking to improve the school average by applying repetitive transcranial magnetic stimulation (rTMS).

The UJED has implemented a tutoring program to address failure rates, which began in 2019 without any evidence of results to date (UJED, 2019).

Academic performance is the result that students have in school cycles, normally expressed with numerical grades, frequently averaged, also known as academic performance or school average. (Lamas, 2015).

In a study carried out by the Pedagogical University of Durango in the Faculty of Medicine and Nutrition (FAMEN), a relationship was observed in 635 students aged 18 to 21 years between 2006 and 2018, between academic performance and study time with p = 0.003 in the Kruskal-Wallis test (Arreola & Hernández, 2021).

At the Technological Institute of Sonora, Mexico, 300 participants were studied, finding a Pearson correlation of 0.49 with a p=0.00 between high school grade point average and university academic performance (Vera *et al.*, 2012).

> Neurons connect to each other to organize nervous functions. They are organized into the autonomic and central nervous systems, the latter being responsible for neurocognitive processes through cholinergic (excitatory) and GABAergic (inhibitory) neurons, helping in attention, learning and memory. (Guyton and Hall, 2016) (Reis et al., 2009).

Neurons in response to stimuli produce action potentials generating electric fields that can be quantified in terms of voltage and frequencies with quantitative electroencephalography (qEEG). Action potentials measured by bursts are dependent on N-methyl-D-aspartate, others by means of ephaptic communication and gap junctions (Dorian and Mandar, 2006).

As time passes and the stimulations carried out by the behavioral learning process occur, changes are caused in the modulation of the electrical flow of the neuronal network and in the organization of the electrical activity (Ford, 2009).

In the majority of the population, the left cerebral hemisphere is dominant with a prevalence of right laterality and only 10.6% with left-hand dominance (Herweg et al., 2020).

Cognitive processes are carried out through the interaction of the different lobes of the brain:

The frontal lobe is located in the anterior cranial fossa and controls higher mental functions such as social behaviors ranging from motor tasks, judgment, abstract thinking, and creativity functions. The frontal cortex has four convolutions; prefrontal which is involved in decision making, reasoning, and personality, superior frontal in a dominant area is related to working memory and non-dominant in impulse control, the dominant middle gyrus is related to the alphabetic process and non-dominant in numerical ability, in its caudal portion

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with its interaction with the precentral gyrus is Brodmann's area eight for eye movements for analysis of details in a scene and image, the dominant inferior gyrus has Brocca's area responsible for speech, prospective memory, speeches, and language, connects with the temporal and motor cortex, regulator of personality and decision making (El-Baba et al., 2023).

The parietal lobe is located behind the Rolandic fissure and regulates somatic sensory reception. The temporal lobe, located below the lateral or Sylvian fissure, is responsible for auditory sensory reception and is responsible for language comprehension. The occipital lobe, located at the posterior pole of each cerebral hemisphere, regulates visual sensory function (El-Baba et al., 2023).

Wenicke's area or Brodmann's area 22, located in the left temporal lobe (Javed et al., 2023), is responsible for the process of understanding sounds for speech and phonemic decoding. It connects via the corticocortical pathway for associative and conscious learning, while its other connection with the corticosubcortical pathway is related to habit learning (Castaño, 2003).

Using functional neuroimaging studies, brain areas responsible for cognitive processes for mathematical calculation and arithmetic problems have been located; positive correlations were found between the activity of the left angular gyrus in beta frequencies by functional magnetic resonance (Eimeren et al., 2010).

Electroencephalography is a tool that allows the study of brain electrophysiological activity by placing electrodes on the scalp that receive the information generated by the action potentials of cortical neurons, determining the different rhythms or amplitudes that may be present. (Abdallah and Coleman, 2023) these rhythms are generated by different areas of the brain that constantly change according to how the individual is, state of rest, fight, flight, deep sleep or mental concentration (National Autonomous University of Mexico UNAM and Department of Physiology, 2022) which are described below:

- Alpha: The alpha rhythm is often recorded frequently in the occipital area of the brain during a relaxed state of wakefulness with eyes closed, its frequency is eight to 13 Hertz (Hz) and its amplitude is 30 to 59 microvolts. Clayton et. al. observed that the alpha rhythm from 10 to 13 Hz is related to visual perception, cognitive processes and memorization work, with variations in alpha rhythms in different areas of the brain, as well as whether the recording is made with eyes closed or open (Clayton, 2018).

- Beta: This rhythm is associated with a higher frequency of mental activity, and is located in the frontal area and parietal region. It has a frequency of 13 to 30 Hz and voltage <20 µV. (UNAM and Department of Physiology, 2022).
- Gamma: It is related to higher mental activity and consciousness, its frequency is 30 to 50 Hz (UNAM and Department of Physiology, 2022).
- Theta: This frequency is four to eight Hz, while other authors point out that four to seven Hz are related to stress or disorders, and can be located in the parietal and temporal regions. They are less common than the rest, with amplitude >30 µV. (Mayor L. et al., 2013).

Theta-type waves are related to learning regarding associative memory, in the frontal midline it is related to cognitive and error control, in the occipital parietal junction it is related to spatial coding and memory, in frontoparietal areas with working and episodic memory (Herweg et al., 2020).

- Delta: This frequency of 0.5 to four Hz is related to deep sleep or neuropsychiatric diseases, a record of these can be taken in all areas of the cerebral cortex with a very high voltage of 100 to 200 µV, (UNAM and Department of Physiology, 2022) They are associated with the taste perception of the healthy human brain (Wallroth and Ohla, 2018).

  Michel et al. observed delta and theta rhythms in anterior and deep regions related to generating frequencies related to states of abstract thought and thoughts of visual origin in superficial areas (Michel et al., 1993).

Franco refers that rTMS is based on the principles of electricity and magnetism of Michael Faraday (1831) that applied to the surface of the skull stimulates cortical regions for therapeutic processes, if it is ≤1 Hz it is slow, and >1 Hz it is fast (Franco, 2004).

Magnetism and the treatment of mental illness date back to Egyptian medicine using ferromagnetized stones on the heads of people with cerebrovascular diseases (Franco, 2004).

transcranial magnetic stimulation (TMS) equipment, in 1985 Anthony Barker applied TMS in neurology to noninvasively induce changes in cortical excitability and connectivity allowing research into therapeutic uses (Lopez and Kabar, 2023).

In 2008 John P. O'Reardon helped lead to rTMS being approved by the U.S. Food and Drug Administration for treatment of drug-resistant depression (Hamlin and Garman, 2023), and applied for migraines with aura in 2013, obsessive-compulsive disorder in 2017, smoking cessation in 2020, and anxiety disorder in 2021 (Cohen et al., 2022).

Currently, rTMS is used for the treatment of neuropsychiatric disorders and neurorehabilitation, as it offers neuromodulation processes and plasticity of neural networks (León et al., 2018; Malavera et al., 2014; Frech, 2015).

10Hz to 20Hz rTMS for two to four weeks over the left dorsolateral prefrontal cortex improves cognitive functions of attention, executive functions, learning, memory, and significant processing speed (Guse et al., 2010).

Application of rTMS in healthy women in the left dorsolateral prefrontal cortex at 1 Hz and right 10 Hz for six minutes with 12 trains of five seconds, with a total of 360 pulses showed significant improvement in visuospatial working memory performance and in veridical decision making, prefrontal rTMS improved the neuronal activity of remote cortical regions interconnected with stimulation sites through longitudinal fascicles (Tulviste et al., 2016).

Malavera describes that rTMS can reach deeper areas of the brain according to the capacity of its magnetic field and the postsynaptic connections produced by neurons, encouraging changes in the cerebral cortex (Malavera et al., 2014).

Hou Wentao applied rTMS to mice for 14 days with 1000 pulses per day for 2 hours, with a 14mm circular beret, intensity of 3.6 Tesla and 15 Hz, applied in an area parallel to the parietal bone. He observed improvement in neuronal function by changing the activity of ion channels, optimizing cognitive and electrical functions in the neurons of the dentate gyrus of the hippocampus (Wentao et al., 2023).

In a study involving first semester health sciences students from UJED, 29% of them showed lower academic performance and slow brain activity in the delta range. In addition, in participants with average or higher than average grades, alpha activity was observed in T3 (Ríos et al., 2015).

rTMS is contraindicated for patients with implanted medical devices made of metallic or ferromagnetic materials located in areas of the brain, head and neck, pacemakers , cochlear implants and even dental implants if the coil is applied less than 10 centimeters away from the object (Tikka et al., 2023), active brain disease, alcohol or drug withdrawal due to a predisposition to seizures, the risk rate is less than 1% (Stultz et al., 2020), in a history of epilepsy, contraindications influence according to the intensity of the magnetic pulse and frequency, which currently standardized does not generate complications.

rTMS is even used as a treatment for epilepsy under compliance with safety guidelines (Fitzgerald and Daskalakis, 2013), applied with a frequency of 9.3 to 1 Hz, showing reduction in cortical excitability (Jan, 2017; Mikellides et al., 2021; Starnes et al., 2022).

With rTMS from 1 Hz to 20 Hz the most common adverse effect is mild headache (Bakulin et al., 2023).

Materials and methods

The type of research developed was quasi-experimental, prospective and longitudinal. Using non-probabilistic convenience sampling of a universe of 70 3rd semester FAMEN UJED medical students, of which six participated after signing informed consent.

The study group consisted of three males and three females, aged between 19 and 22 years.

In the study population, neurological and/or psychiatric disorders were ruled out by clinical survey. The initial and final grade point average at the time of rTMS was taken from the institutional Kardex provided by the participant.

Brain activity was obtained by qEEG before starting rTMS during the month of February and at the end of the rTMS sessions (June). For the session, participants came with their hair dry after thorough cleaning, electroencephalography electrodes were placed (16 recording points) according to the international 10/20 standard, recording brain activity in a resting condition with eyes closed for five minutes. The electroencephalographic record obtained was mathematically processed with software for fast Fourier transform, obtaining the different brain rhythms and their respective amplitude and frequency at each of the recording points. With this mathematical data, the database was formed for analysis.

rTMS was applied in a weekly session of 40 minutes, for 10 weeks during semester A 2023, intensity of six gauss and frequency of 100 Hz, in intermittent trains lasting three seconds followed by one second without stimulation, rTMS was applied with a circular coil 10 cm in diameter, on the middle and anterior portion of the skull, positioning it halfway between the cranial vertex and nasion. Without modifications in physical-acoustic phenomena of the conventional environmental environment. The participants attended the sessions in a conventional physiological condition of their personal physical and eating habits.

The database was formed by the sociodemographic characteristics of the group studied, the school average of each participant obtained before and after the rTMS and the electroencephalographic record of the absolute power (microvolts squared), the dominant frequency and the mean frequency in Hertz of each of the recording points (electrodes), using a descriptive, comparative and correlational statistical analysis using the SPSS program version 21.

Ethical considerations

The project was registered and approved by the FAMEN UJED research committee with opinion 002 with approval date of December 3, 2020 and by the FAMEN UJED ethics and research committee with unique registration number CEI-FAMEN 05 dated November 17, 2020.

Limitations

The first limitation in carrying out this study was the lack of interest on the part of the people invited to participate in the study. Secondly, students have difficulties in attending rTMS sessions due to very frequent unforeseen events in their school activities, which required finding time slots where students could come to receive rTMS for the time scheduled for each week. And finally, the lack of furniture with greater comfort for the application of rTMS.

Results

The reliability of the variables corresponding to brain activity was evaluated using Cronbach's Alpha, considering all frequency bands (ALL RANGE) in a first evaluation, as well as divided by each frequency band, see Table 1.

Table 1. Cronbach's alpha.

Frequency bands	Cronbach's alpha
ALL RANGE (8.5 to 30 Hz)	0.867
DELTA (0.5 to 3.9 Hz)	0.901
THETA (4 to 7.9 Hz)	0.926
A LPHA (8 to 12.9 Hz)	0.930
BETA LF (13 to 19.9 Hz)	0.867
BETA HF (20 to 29.9 Hz)	0.863

Source: Own elaboration

The school average before rTMS showed differences with respect to the school average after rTMS (See Table 2) when analyzed using the Student t test showed a t=-3.253 with a p= 0.023.

Table 2. School average.

Initial grade point average	Final grade point average
8.03	8.55

Source: Own elaboration

After the full application of rTMS (Variables identified with a capital letter B at the end), a significant negative correlation was observed between the school average and one of the brain activity variables; T5HzDB, corresponding to ALL RANGE. (See table 3). In this same process of correlational analysis between the school average and each of the specific frequency band groups, significance was observed (see table 3).

Table 3 . Pearson correlation.

Frequency	variable	r	P
ALL RANGE	T5HzDB	-0.824	0.044
DELTA	T5HzDB	-0.825	0.045
THETA	F3HzDB	0.859	0.028

Source: Own elaboration

The other variables of brain activity, both absolute power and dominant frequency and mean frequency, did not present a statistically significant correlation.

Discussion

The initial school average of the study group showed a statistically significant difference at the end of the application of the rTMS.

The strong negative correlation between the school average and T5HzDB, considering that this qEEG recording area is close to Wernicke's area and participates in the understanding of speech sounds and phonetic decoding that are important for learning habits, associative and conscious (Castaño, 2003; Cano, 2019), highlights that the improvement in the school average may be caused by rTMS due to better neurocognitive function.

The correlation with each of the frequency bands with the school average is confirmed with slow Delta and Theta rhythms. Showing that in T5HzDB the lower the dominant Delta frequency, the higher the school average (See table 3).

A strong positive correlation was also observed between the Theta rhythm of F3HzDB and the school average, identifying that the higher the dominant Theta frequency in the described area, the higher the school average (See Table 3).

The dominant theta activity in areas close to F3 is related to learning processes, associative memory, working memory, episodic memory, cognitive and error control (Herweg et al., 2020). Therefore, the application of rTMS can be considered as a tool to promote a better academic average.

Conclusion

When comparing the study group's academic average obtained at the beginning of the school year with that at the end of the same and the total application of the rTMS sessions, a statistically significant increase was shown, so it is possible to recommend the application of rTMS in support and care to improve academic performance in university education.

Future lines of research

Conventionally, for the admission and continuity of students in higher education, educational institutions do not take into consideration the evaluation of the functioning of the organ responsible for learning, which is precisely the brain. Based on the above and derived from the results obtained in this work, it is pertinent that, in addition to the evaluations already used to enter university education, opportunities for new lines of research are opened that support the possibility of promoting improvement in neurocognitive functioning based on the needs that can be identified in this type of research work such as this one; in this way, the suggestion of a line of research is brain electrophysiological evaluation and application of rTMS in those higher education students who may require it according to the results of their cognitive neurophysiological evaluation. On the part of the researchers of this work, it is important to continue the project by increasing the number of participants in the study to verify the replicability of the observed phenomenon.

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