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Cross-sectional study on electroencephalographic oscillations when achieving heart coherence in medical students at the Technological University of Pereira

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ABSTRACT

Heart coherence is a technique that consists of synchronizing breathing with heart rate, which produces physiological and psychological benefits. The aim of this cross-sectional study is to analyze the characteristics of electroencephalographic oscillations during the implementation of the cardiac coherence strategy in medical students. The target population are the active students of the medical program of the Universidad Tecnológica de Pereira in 2023, aged between 18 and 30 years. A sample of 20 students will be selected by a non-probabilistic convenience sampling. The variables of frontal alpha asymmetry (FAA), relative theta power (RTP), relative beta power (RBP), frontal beta asymmetry (FBA), delta coherence (DC) and theta/beta ratio (TBR) will be measured before and after the intervention. Matlab software and different toolboxes will be used for processing the information collected by a heart rate variability (HRV) sensor and skin electrodes. It is expected that cardiac coherence will produce significant changes in electroencephalographic variables, which could reflect a state of greater balance and harmony between the nervous and cardiovascular systems. These results could contribute to research in the field of neuroscience, which may lead to advances in the development of new techniques for the management of various psychiatric disorders.

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Electroencephalographic correlates of cardiac coherence in a cross-sectional sample of medical students from the Technological University of Pereira

INTRODUCTION

2 JUSTIFICATION

Heart rate variability (HRV) is the variation in time between heartbeats, expressed in milliseconds. This fluctuation reflects the interaction between the autonomic nervous system and the cardiovascular system. Cardiac coherence is a state in which the HRV is around 0.1hz, a value associated with positive emotions and sought in various therapeutic interventions (Thayer et al., 2009). Cardiac coherence implies a regular synchronization between various physiological functions, such as blood pressure, respiratory rate and heart rate (Shaffer and Ginsberg, 2017). Electroencephalography (EEG) is a technique that measures the electrical activity of the brain and has acquired great relevance in the clinical field of psychiatry. For example, alpha asymmetry has been related to positive or negative emotions depending on the predominance in the left or right hemisphere, respectively (Davidson, 1992). However, studies on the cardiovascular system and the central nervous system are often fragmented, addressing these systems in isolation. Currently, little is known about the electrophysiological processes involved in cardiac coherence and what electroencephalographic variables are affected by this technique.

To understand pathological states, it is necessary to understand normal physiology, as it is on it that therapeutic interventions are based. In this context, electroconvulsive therapy and transcranial magnetic stimulation stand out as strategies that have shown that modulating brain electrical activity can be an important goal in addressing mental disorders (lefорcheur, 2020). Moreover, experimental studies using brain-computer interfaces (BCI) have demonstrated that frontal alpha asymmetry can be modulated by cognitive strategies (Krogmeier et al., 2022). EEG has multiple current and potential clinical applications in psychiatry, and it is a promising field that aims to increase objectivity. Therefore, it is essential to explore, identify and characterize more electrophysiological variables that have clinical relevance and can be targeted by different techniques.

An integrative perspective that adheres to the positivist approach of the scientific method requires a continual pursuit of knowledge to enhance the comprehensive understanding of various physiological phenomena (Chakravarthy, 2020). Historically, the concept of "emotional well-being" has been associated with a dualistic epistemology that has impeded the empirical and monistic investigation of emotions in science (Damasio, 1994). For instance, the WHO defines mental health as "a state of well-being in which the individual realizes his or her abilities, can cope with the normal stresses of life, can work productively and fruitfully, and is able to make a contribution to his or her community" (World Health Organization, n.d.). This definition specifies the capabilities of an individual with mental well-being but does not delineate well-being itself. Despite the extensive literature on the impact of heart coherence on emotional self-regulation, anxiety reduction, and psychosocial well-being (McCraty, 2017), the relationship between heart coherence and electroencephalographic oscillations remains poorly understood and warrants further exploration. As suggested, frontal alpha asymmetry can be altered by neurofeedback, and other electrophysiological variables with clinical relevance may be amenable to different interventions. However, prior to that, it is essential to locate, identify and characterize them (Aftanas & Golocheikine, 2001). The electroencephalogram enables the assessment of various parameters, such as the degree of asymmetry between bands, relative power

3 ¿What are the characteristics of electroencephalographic oscillations during the application of the cardiac coherence strategy?

4 **OBJECTIVES**

General:
To examine the effects of the heart coherence strategy on electroencephalographic oscillations in medical students at the Technological University of Pereira.

Specific:
- To describe the socio-demographic characteristics of the participants.
- To measure the frontal alpha asymmetry, relative theta power, relative beta power, frontal beta asymmetry, delta coherence, and theta/beta ratio before and after the heart coherence strategy.
- To compare the changes in the electroencephalographic variables between the pre- and post-intervention conditions.

SUMMARY

5 SUMMARY

Heart coherence is a technique that consists of synchronizing breathing with heart rate, which produces physiological and psychological benefits. The aim of this cross-sectional study is to analyze the characteristics of electroencephalographic oscillations during the implementation of the cardiac coherence strategy in medical students. The target population are the active students of the medical program of the Universidad Tecnológica de Pereira in 2023, aged between 18 and 30 years. A sample of 20 students will be selected by a non-probabilistic

convenience sampling. The variables of frontal alpha asymmetry (FAA), relative theta power (RTP), relative beta power (RBP), frontal beta asymmetry (FBA), delta coherence (DC) and theta/beta ratio (TBR) will be measured before and after the intervention. Matlab software and different toolboxes will be used for processing the information collected by a heart rate variability (HRV) sensor and skin electrodes. It is expected that cardiac coherence will produce significant changes in electroencephalographic variables, which could reflect a state of greater balance and harmony between the nervous and cardiovascular systems. These results could contribute to research in the field of neuroscience, which may lead to advances in the development of new techniques for the management of various psychiatric disorders.

SUMMARY TABBLE

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A	B
Background	The project provides a literature review on the concepts of emotional well-being, heart coherence, and electroencephalographic oscillations, and their interrelations. It also discusses the gaps and limitations of previous studies on these topics.
Rationale	The project aims to contribute to the understanding of the neurophysiological mechanisms underlying heart coherence.
Objectives	The main objective of the project is to examine the characteristics of electroencephalographic oscillations during the implementation of the heart coherence strategy in medical students at the Technological University of Pereira. The specific objectives are: - To characterize the study participants socio-demographically. - To compare the variables of frontal alpha asymmetry, relative theta power, relative beta power, frontal beta asymmetry, delta coherence, and theta/beta ratio before and after the implementation of the heart coherence strategy. |
Hypotheses	The project formulates the following hypotheses: - There will be a significant increase in frontal alpha asymmetry after the implementation of the heart coherence strategy compared to before. - There will be a significant decrease in relative theta power after the implementation of the heart coherence strategy compared to before. - There will be a significant decrease in relative beta power after the implementation of the heart coherence strategy compared to before. - There will be a significant increase in frontal beta asymmetry after the implementation of the heart coherence strategy compared to before. - There will be a significant increase in delta coherence after the implementation of the heart coherence strategy compared to before. - There will be a significant decrease in theta/beta ratio after the implementation of the heart coherence strategy compared to before

A	B
Methods	The project describes the design, participants, procedures, measures, and data analysis plan of the study. The design is a transversal , observational, exploratory study with a control group. The participants are 20 medical students from the Technological University of Pereira who meet the inclusion and exclusion criteria. The procedures consist of four sessions: an initial evaluation, two training sessions on heart coherence, and a final evaluation. The measures include socio-demographic data and electroencephalographic recordings. The data analysis plan involves descriptive statistics, normality tests, reliability tests, and paired t-tests for each electroencephalographic variable.
Proposed analyses	The project specifies the statistical tests that will be used to test the hypotheses: - To compare frontal alpha asymmetry before and after the intervention, a paired t-test will be performed on the difference between left and right alpha power (ln F4 - ln F3). - To compare relative theta power before and after the intervention, a paired t-test will be performed on the ratio between theta power and total power (ln T4 / ln TP4). - To compare relative beta power before and after the intervention, a paired t-test will be performed on the ratio between beta power and total power (ln B4 / ln TP4). - To compare frontal beta asymmetry before and after the intervention, a paired t-test will be performed on the difference between left and right beta power (ln F4 - ln F3). - To compare delta coherence before and after the intervention, a paired t-test will be performed on the correlation coefficient between left and right delta power (r D3 D4). - To compare theta/beta ratio before and after the intervention, a paired t-test will be performed on the ratio between theta power and beta power (ln T4 / ln B4).
Expected outcomes	The project indicates what results are expected to find and how they will support or reject the hypotheses: - It is expected that frontal alpha asymmetry will increase after the intervention, indicating a greater activation of the left prefrontal cortex associated with positive affect. This would support the first hypothesis. - It is expected that relative theta power will decrease after the intervention, indicating a lower level of drowsiness or relaxation. This would support the second hypothesis. - It is expected that relative beta power will decrease after the intervention, indicating a lower level of anxiety or stress. This would support the third hypothesis. It is expected that frontal beta asymmetry will increase after the intervention, indicating a greater activation of the right prefrontal cortex associated with cognitive control and emotional regulation. This would support the fourth hypothesis. - It is expected that delta coherence will increase after the intervention, indicating a higher synchronization of brain activity and a better integration of information. This would support the fifth hypothesis. - It is expected that theta/beta ratio will decrease after the intervention, indicating a lower level of attentional problems or hyperactivity. This would support the sixth hypothesis
Potential implications	The project discusses how the findings will contribute to the scientific knowledge and have practical applications: - The findings will provide evidence for the effects of heart coherence on electroencephalographic oscillations in medical students. - The findings will suggest new avenues for future research on the neurophysiological mechanisms and clinical benefits of heart coherence and modifying certain eeg parameters.

MATERIALS AND METHODS

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Research Type:

A cross-sectional, observational, and descriptive exploratory study will be conducted.

Population:
The target population is active medical students in 2023 at the Technological University of Pereira.

Sample:
A sample of 20 medical students will be selected through non-probabilistic convenience sampling, taking into account their availability and willingness to participate in the study. Participants will be divided into two groups, one control (n=10) and one intervention (n=10).

Unit of Analysis:
The unit of analysis will be the records of the cardiac variability and electroencephalographic tracing of the participants.

Inclusion Criteria:
The inclusion criteria are: being a medical student at the Technological University of Pereira, aged between 18 and 30 years, having given written informed consent, having a normal body mass index (BMI) within the range of 18.5-24.9, and being right-handed.

Exclusion Criteria:
The exclusion criteria are: having a history or current diagnosis of any mental disorder listed in the DSM-5R, having a history or current diagnosis of neurological or cardiovascular diseases, having a history or current diagnosis of any chronic disease regardless of the compromised system, having consumed psychoactive substances in the last 48 hours, having received medications that affect the central nervous system in the last 48 hours (corticosteroids, beta-blockers, calcium channel blockers, anti-seizure medications), being pregnant or lactating.

Variables and Operationalization:
Socio-demographic characteristics of the participants: age, gender, socioeconomic status, marital status, occupation, educational level, among others.
Cardiac coherence: Independent variable. HRV with a range of 0.1-0.14 Hz.
Frontal alpha asymmetry: Difference between alpha power measurements obtained at electrodes located at F3 and F4. The reference value is: -0.3-0.3.
Relative theta power: Proportion of power in the theta frequency range divided by total power in the spectrum. The reference value is: 20-30.
Relative beta power: Proportion of power in the beta frequency range divided by total power in the spectrum. The reference value is: 10-20%.
Frontal beta asymmetry: Difference between beta power measurements obtained at electrodes located at F3 and F4. The reference value is: -1.5-1.5.
Delta coherence: Phase coherence coefficient between electrodes located at F3 and F4 in the delta frequency range. The reference value is: 0.5-0.8.
Theta/beta ratio: Proportion of power in the theta frequency range divided by power in the beta frequency range. The reference value is: 2.5-3.5, (Ortiz, 2020).

Source type: Primary sources will be used through direct contact with the study subjects.

Information collection techniques:
A prior interview will be conducted to explore disorders included in the DSM-5R, as well as the Matlab software and different subscribed toolboxes for processing the information collected through a VFC sensor and cutaneous electrodes for measuring electroencephalographic activity.

Biological variable measurement process: Once participants have given their informed consent, they will be invited to the laboratory of the Faculty of Medicine at the Technological University of Pereira (UTP). EEG measurements will be taken before and during the application of the heart coherence technique, with participants comfortably seated in a chair with their eyes closed. During the measurement, a mobile application designed for this purpose will provide instructions for breathing, following a specific pattern. The intervention will last between 5-15 minutes and will be performed in an individual session in a quiet and distraction-free environment. Heart coherence will be measured using a portable heart rate sensor. The control group will remain in the same space for the same amount of time, without being exposed to the strategy. Electrodes will be placed on specific points on the participant's head using the international 10/20 system manual, measuring activity in the central, parietal, temporal, occipital, and ocular signals. An electrooculogram (EOG) and ground electrode will be applied to the forehead, and exfoliating gel will be used to reduce skin resistance. All electrodes will be fixed with conductive paste, ensuring that impedances do not exceed 5 kΩ. An initial EEG measurement will be recorded in the absence of heart coherence at the start of the session (measuring VFC). Then, participants will be asked to sit in front of a monitor displaying a visual feedback signal (heart rate variability) based on real-time analysis of their electrofisiological data. Participants will follow the breathing and cursor on screen until obtaining a sinusoidal pattern registration, considered to have achieved heart coherence. At this point, they will be asked to close their eyes and maintain heart coherence for a second measurement. Data collection will be performed using a computer with an EEG amplifier. The signal will be processed and analyzed using the EEGLAB toolkit of MATLAB, defining four frequency bands for subsequent analysis: delta (1-4 Hz), theta (4-8 Hz), alpha (8-12 Hz), beta (12-30 Hz), and gamma (30-50 Hz). The spectral power of EEG data will be calculated using the fast Fourier transformation, using the "spectrogram" function of EEGLAB, and absolute power will be averaged over all time windows and frequency bands for subsequent analysis.

ANALYSIS

8 Before conducting the descriptive and comparative analysis of the study variables, potential outliers that may affect the validity and reliability of the results will be detected and treated. The boxplot method will be used to identify extreme values in each variable, considering those above or below the upper and lower limits of the boxplot as outliers, respectively. Once the outliers are detected, a replacement strategy will be used by substituting extreme values with

the closest value within the interquartile range. This will maintain the size and shape of the data distribution, minimizing the effect of outliers. In addition, a sensitivity analysis will be performed to evaluate the impact of outliers on the results, comparing analyses performed with and without the replacement of extreme values.
A descriptive analysis of all variables included in the study will be carried out, calculating measures of central tendency (mean, median) and dispersion (standard deviation, range) for quantitative variables, and presenting frequencies and percentages for categorical variables.
Regarding the comparative analysis, various variables will be compared between the experimental group (subjected to the coherence cardiac strategy) and the control group (not subjected to the strategy) before and after the intervention. Appropriate statistical tests will be applied according to the data distribution and variable type (t-Student for continuous variables with normal distribution and Wilcoxon non-parametric test). A significance level of $p<0.05$ will be considered.
Furthermore, a correlation analysis will be conducted between coherence cardiac and variables of interest (frontal alpha asymmetry, relative theta power, relative beta power, frontal beta asymmetry, and theta/beta ratio), using the Pearson or Spearman correlation coefficient depending on the data distribution. A significance level of $p<0.05$ will also be considered.
Effect size will be calculated for variables that show significant differences between the experimental and control groups. Cohen's d coefficient will be used for continuous variables, and the phi correlation coefficient for categorical variables.
Finally, an ANOVA analysis will be performed, evaluating the difference in dependent variables between intervention and control groups in both measurements (before and after the intervention). A repeated measures ANOVA model with two factors (group and time) will be used, and post-hoc tests will be carried out if a significant interaction between the factors is found. A one-way ANOVA analysis will also be conducted to evaluate differences between groups in each measurement separately if no significant interaction is found. A significance level of $p<0.05$ will be considered, and relevant descriptive statistics and results of statistical tests will be presented.

EXPECTED OUTCOMES AND POTENTIAL IMPLICATIONS

9 The objective of this study is to examine the effects of the heart coherence strategy on electroencephalographic oscillations in medical students. The hypotheses posit that heart coherence will produce significant changes in EEG variables, such as increased frontal alpha asymmetry, decreased relative theta power, decreased relative beta power, increased frontal beta asymmetry, and increased EEG coherence. These changes would reflect enhanced parasympathetic nervous system activity, relaxation, reduced anxiety, and improved inter-regional brain synchronization. These outcomes are consistent with previous literature that has shown the benefits of heart coherence for physical and mental health.
However, alternative results are also possible. For instance, there may be no significant differences between the experimental and control groups in any EEG variables, indicating that heart coherence does not affect brain activity or that the effect is weak or inconsistent. This result could be attributed to poor adherence or effectiveness of the synchronized breathing technique,

an inadequate or heterogeneous sample size, or uncontrolled confounding or moderating factors. Alternatively, there may be significant differences between the experimental and control groups in EEG variables, but in the opposite direction to that hypothesized, suggesting that heart coherence elicits negative changes in brain activity, such as reduced frontal alpha asymmetry, reduced relative theta power, increased relative beta power, increased frontal beta asymmetry, and reduced EEG coherence. These changes would indicate enhanced sympathetic nervous system activity, tension, elevated anxiety, and impaired inter-regional brain synchronization. This result would be highly unexpected and inconsistent with existing literature and would necessitate an alternative explanation or a replication of the study.

These are some potential scenarios and their implications. In any case, the results should be compared with previous studies on the topic and potential limitations and biases that could affect their validity and generalizability should be discussed.

In terms of other areas of impact, this study could enhance the quality of life of medical students participating in the study by offering them a stress management technique that could reduce symptoms related to stress and anxiety. This study could also advance research in the field of neuroscience, leading to innovations in the development of new techniques for managing psychiatric disorders. Furthermore, the use of mobile technology for measuring electroencephalographic activity could facilitate the adoption of more advanced and accessible medical technology.

APPENDICES

10 Ethical considerations

This study will be conducted in accordance with the ethical principles established in the Declaration of Helsinki and the current regulations in Colombia for research with human beings. The protocol has been approved by the Ethics and Research Committee of the Technological University of Pereira, with the code ".......". All participants will be informed about the objectives, procedures, benefits and risks of the study, and will have to sign an informed consent form before participating. Participants will be able to withdraw from the study at any time without negative consequences. The data collected will be treated confidentially and anonymously, and will only be used for research purposes.

11 Informed consent

Dear participant:

We invite you to participate in a study on the effects of cardiac coherence on electroencephalographic oscillations. The aim of this study is to evaluate whether the practice of cardiac coherence induces changes in brain electrical activity. The study is led by Dr Paula Hernandez, a teacher and researcher at the Technological University of Pereira. If you agree to participate, you will be asked to attend a session at the university's neuroscience laboratory.

There you will be interviewed to collect your personal data and you will be fitted with electrodes on your scalp to measure your brain activity. Subsequently, you will be taught how to practice cardiac coherence using a mobile application and a heart rate sensor. After achieving cardiac coherence, another electroencephalographic measurement will be performed.

Your participation in this study is voluntary and you can withdraw at any time without any negative consequences. The data obtained will be treated confidentially and anonymously, and will only be used for research purposes. The results of the study may be published in scientific journals or presented at conferences, but without revealing your identity.

The possible benefits of your participation are learning a relaxation technique that can improve your psychological well-being and contributing to the advancement of scientific knowledge about the relationship between the heart and the brain. The possible risks are minimal and include discomfort from the use of the electrodes or from exposure to stressful stimuli during the cognitive task.

If you have any questions or doubts about the study, you can contact j.morales10@utp.edu.co

If you agree to participate, please sign the following document:

I, ____ have read and understood the above information and agree to participate voluntarily in this study:

Signature:______________
Date:_____________________