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Research Article

EEG MACHINE AND THE NEURO-SCIENCE RESEARCH IN VIETNAM

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ABSTRACT

The article introduces an electroencephalogram (EEG) and the steps to conduct an EEG experiment. The features and the technical structure of the machine are presented. The paper lists the nine steps of an experiment as a guideline for designing a similar experiment. The maintenance of the machine after an experiment is also discussed. This is a foundation for conducting experiments in the field of neuro-science in Vietnam.

Keywords: electroencephalogram (EEG); neuro-science; practical experience; scientific research

1. Introduction

An electroencephalogram (EEG) machine is a device used to create a picture of the electrical activity of the brain. It has been used for both medical diagnosis and neurobiological research, especially in cognitive science research (Abhang et al., 2016). The essential components of an EEG machine include electrodes, amplifiers, a computer control module, and a display device (Cooper et al., 2014).

The function of an EEG machine depends on the fact that the nerve cells in the brain are constantly producing tiny electrical signals. Nerve cells, or neurons, transmit information throughout the body electrically. They create electrical impulses by the diffusion of calcium, sodium, and potassium ions across the cell membranes (Luck, 2005). When a person is thinking, reading, or watching the experiment screen, different parts of the brain are stimulated. This creates different electrical signals that can be monitored by an EEG.

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The electrodes on the EEG machine are affixed to the scalp so they can pick up the small electrical brainwaves produced by the nerves. It has long been known that different mind states lead to different EEG displays. Four mind states—alertness, rest, sleep, and dreaming—have associated brain waves named alpha, beta, theta, and delta. Each of these brain wave patterns have different frequencies and amplitudes of waves. As the signals travel through the machine, they run through amplifiers that make them big enough to be displayed. The amplifiers work just as amplifiers in a home stereo system. One pair of electrodes makes up a channel. EEG machines have anywhere from 8 to 64 channels (Alix, 2017). Depending on the design, the EEG machine then either prints out the wave activity on paper or stores it on a computer hard drive for display on a monitor.

With the data collected from the EEG experiment, researchers can conduct many different types of applied research. In education, EEG has been used to assess student academic achievement (Babiker et al., 2019) or support e-Learning and online courses (Nandi et al., 2021). In applied psychology, EEG has been used quite diversely with many different research and practice purposes. Of particular importance are the assessment of human cognitive levels (Antonenko et al., 2010), exploring memory and emotional responses (Ramirez, & Vamvakousis, 2012; Schneider et al., 2020), brain characteristics and brain responses of people with psychological disorders (Huang et al., 2019) or children with disabilities (Ünal et al., 2019), mental health (Price, & Budzynski, 2009), sexual orientation (Amezcua-Gutiérrez et al., 2021), or learning tendency (Alwedaie et al., 2018). It can be seen that the application of EEG machines in experiments and practices in the fields of education and psychology are topics of great interest in the world. The potential of EEG machines can be said to be unlimited because each era, each context, and each different individual have differences in EEG when placed in the same problem.

In this article, we introduce the technical structure of the EEG machine, the steps to perform a simple experiment, and the lessons learned to guide research in the field of applied psychology and neuroscience.

2. Study design

An EEG measures electricity that your brain makes; it does NOT measure thoughts or feelings, and it does not send any electricity into your brain (Abhang et al., 2016). It is most often used to determine the type and origin of seizures. In EEG machine's experiment, there is a technique that help to calculate the electricity of the brain by figuring out the progress of the brain between the timing of stimulus and response, called ERP (event-related potential) (Nidal, & Malik, 2014). The ERP technique provides a powerful method for exploring the human mind and brain, that will help you conduct great brainwave research.

EEG can also detect abnormal brain waves after a head injury, stroke, or brain tumor (Alix et al., 2017). Other conditions such as dizziness, headache, dementia, and sleeping problems may show abnormal brain patterns (Ianof, & Anghinah, 2017; Siuly, Li, & Zhang, 2016). It can also be used to confirm brain death (Szurhaj et al., 2015).

There are five basic types of an EEG experiment (Malik, & Amin, 2017):

- Emotional-face detection: how we detect the different emotions (sad and happy) on people's face (through eyes and mouth).
- Memory stimulation: how we remember the familiar face that the executor showed me on the screen.
- Face recognition: how we recognize the face that familiar from another angle.
- Photo-recognition stimulation: how we recognize the up-side and reverse-side of the pictures.
- Photic-stimulation: how we were able to recognize the different color signal from a series of continuous-changing photos.

To conduct an EEG experiment, it is necessary to first outline the research idea, determine the purpose of the experiment, and design indicators related to brain electricity (Malik, & Amin, 2017). Then, input the indicators into the EEG system management software to complete the experimental content. After that, prepare the necessary specifications to start the experiment. In the next section, we do not refer to a specific experiment, but present general procedures for an EEG experiment, including the basic steps to prepare an experiment.

In this paper, we applied a specific experimental case study method: Conduct an EEG experiment on emotional-face detection. Then, learn from and induct into general procedures for a basic experiment. The experimental data were recorded and systematized with the supervision of two Taiwanese experts. The results presented in this article have been validated for practical use on an experimental basis.

3. Findings and discussion

3.1. Findings

The findings are presented on the technical structure of the EEG machine (components), steps to conduct a basic EEG experiment, and post-experiment steps.

3.1.1. EEG machine's components

The different parts of an EEG machine are produced separately and then assembled by the primary manufacturer prior to packaging. These components, including the electrodes, the amplifier, and the storage and output devices, can be supplied by outside manufacturers or made in-house (Davidson et al., 2000). The cost of each product is expensive, so when you use it, you must extremely care and save the resources.

Electrodes

1 - The EEG electrodes are typically received from outside suppliers and checked to see if they conform to set specifications. One type of electrode commonly used for the EEG

machine is a needle electrode. These can be made from a bar of stainless steel. The bar is heated until it becomes soft and then extruded to form a seamless tube.

2 - The tube is then drawn out to produce a fine hollow tube. These tubes are cut to the desired length, and then conically sharpened to produce a point.

3 - To ensure easy insertion, the tube is passed through a bath of polytetrafluoroethylene (Teflon) to provide a slick, chemical resistant coating. As the tube exits the bath it is warmed to evaporate the solvent and allow the coating to adhere.

4 - The tube is then mechanically placed in a plastic adapter piece that is made with an injection molding machine. This piece allows the disposable, individually packaged needles to hook up to the lead wire.

5 - The shielded lead wire is fitted with an adapter that can be hooked up to the primary unit.

Internal electronics

6 - The amplifiers and computer control module are assembled just like other electronic equipment. The electronic configurations are first printed on circuit boards. The boards can be fitted with chips, capacitors, diodes, fuses, and other electronic parts by hand or passed through an automated machine. This machine works like a labeling machine. It is loaded with numerous spools of electronic components and placing heads. A computer controls the motion of the board through the machine. When a board is moved under one of the component spools, a placing head stamps the electronic piece on the board in the appropriate positions. When completed the boards are sent to the next step for wave soldering.

7 - In the next step, a wave-soldering machine affixes the electronic components to the board. As the boards enter this machine, they are washed with flux to remove contaminants that might cause short circuits.

8 - Boards are then heated using infrared heat. The underside of the board is passed over a vat of molten solder. The solder fills into the needed areas through capillary action.

9 - As the boards cool, the solder hardens and the electronics are held into place. Visual inspection is typically done at this point to ensure that defective boards get rejected.

Amplifier

10 - The electronic boards for the amplifier are pieced together and affixed to a housing. This is typically done by line operators who physically place the pieces on pre-fabricated boards.

11 - The housing is made of a sturdy plastic that is constructed through typical injection molding processes. In this process, a two-piece mold is created that has the inverse shape of the desired part. Molten plastic is injected into the mold and when it cools, the part is formed. For some EEG models, the amplifier is a separate box about the size of a textbook.

The outer sides of the box have connectors where the electrodes and the computer connection lines are plugged in.

Computer control box

12 - An EEG station consists of the amplifier and a computer control station. This control station typically has a desktop computer, a keyboard and mouse, a color printer, and a video monitor. These devices are all produced by outside manufacturers and assembled by the EEG manufacturer.

Final assembly

13 - Each of the components of the EEG machine are brought together and placed into an appropriate metal frame. This process is done by line operators working in extremely clean conditions. When the components are assembled, they are typically put on a sturdy, steel cart to make the device portable.

14 - The finished devices are then put into final packaging along with accessories such as electrodes, computer software, printout paper, and manuals.

3.1.2. Conducting a basic EEG experiment

Step 1. Make sure you have all these items for the experiments. These items will support you in the preparation and washing procedure (see Table 1):

Table 1. *Preparation items for an EEG experiment*

Towel	Comb	Hair dryer	Small washbasin	Toilet paper	Garbage bag
Gel	Needle	Scrub	Alcohol	Cotton swab	Questionnaire and consent

Step 2. Wash clearly your hair before the EEG experiment, and don not put any products (like sprays or gels) in your hair. It makes the conductive cream spread easily and the results will be more accurate.

Step 3. Avoid eating or drinking anything containing caffeine for at least eight hours before the test. Feel relax. Maybe you can take a nap to refresh your mental state. You must be comfortable and not under pressure before taking the experiment.

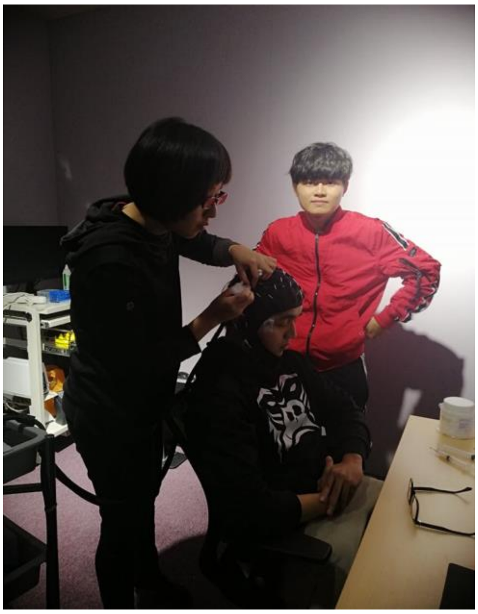
Step 4. Take an emotional test about your current mental state *(Different experimental tools and purposes will use different secondary data sources).*

Step 5. They will then begin to measure the head with a regular cloth tape measure and make marks on the head with a wax pencil. These marks are very specific to each individual’s head size and are the places that the electrodes will be applied onto. This system is used internationally and is called the 10-20 system of electrode placement.

Step 6. The test is run on a computer that looks like the ones you have in your own homes and schools. The electrodes are a disc or cup on the end that is attached to the scalp by an adhesive method. This small disc is made of pure silver with gold plating over it. These electrodes are plugged into a jack box that has a cable attached to the computer. In looking at EEG patterns, we compare the left side of the brain to the right side, so these electrodes must be placed very precisely. The application can take between 30 and 40 minutes.

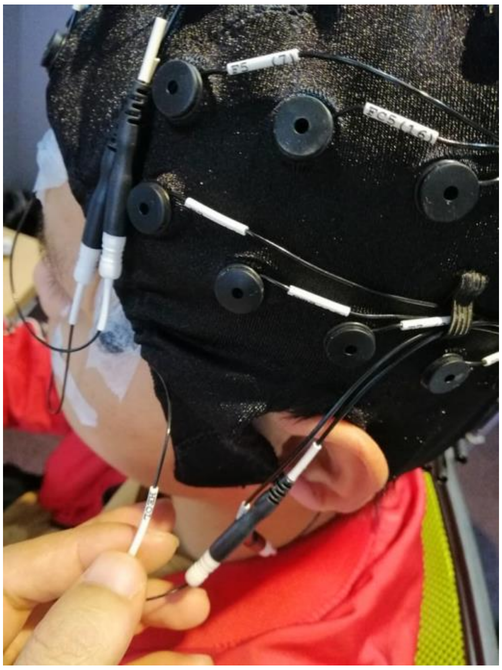
We want to familiarize you also with the electrode application techniques that we may be using. This is called the "paste" method. The technologist will first rub a small amount of skin preparation gel on the measured spot using a q-tip. Next, we will fill the cup of the electrode with a paste substance that has the consistency of tooth paste and, and then adhere it to the scalp with a cotton ball. The electrodes are more easily displaced with this method if head movement occurs.

Next, we must squirt a small amount of conductive cream into the small opening in the top of each electrode disc to help in the flow of the electrical activity of the brain. This may seem a bit scary to some since we must use a syringe to squirt in the lotion, but the syringe is only for squirting purposes. We use a blunt tipped needle attached to the end of the syringe, but once again the needle is blunt with no sharpness to it and has to be used because the hole is very small. It is harmless! (See Picture 1)



Picture 1. *Injecting the conductive cream*

After injecting the conductive cream to the electrode disc (or your scalp), you must make sure that the cream spread all over the scalp and the electrode signals on the screen turn from red to blue. This color changing situation mean that you can begin the experiment (see Picture 2). If the color is still red, or orange, or green, you must make sure the conductive cream spreading particularly.



Picture 2. *The completed scalp with conductive cream*

Step 7. After all this preparation, we are now ready to run the EEG. The room will be made dark, quiet, and door closed to promote relaxation. The tech will tell you everything that will happen before it is performed (on the screen). Just make sure you are relaxed and ready.

Or the executor can stay with the client to explain the meaning of the experiment test and take care of the unpredictable situations.

Step 8. Now we can begin with the lead removal and clean-up process.

We make every effort to remove all remnants of any of the adhesives used from the hair and scalp. If we used the paste and cotton ball method, the clean-up is rather easy. This paste is water soluble and we wash it out with a cloth using warm water and combing through the hair. Shampooing will further remove it once you are home.

Step 9. Again, take an emotional test about the current mental state of yours.

Note: One test before you take part in experiment and one after you finish.

3.1.3. Post-experiment procedure

After the test is performed, you need to clean the electrodes and the cap to get it ready for the next patient to be tested. Cleaning EEG electrodes is simple when you know the proper procedure.

Preparing the Electrodes and Cap

Step 1. Remove the electrodes from the cap using the removal tool. Hold the cap with one hand and use the tool to pop the electrodes off. Work from the front of the electrodes to avoid damaging the tails. Never pull the electrodes out by tugging on the wires, as this can cause electrical damage to the sensors.

Step 2. Place each electrode on the hanger to keep them from tangling. Most labs will have a splitter box hanger on which you can place the electrodes. Be sure to keep the wires separate and dangle the electrode over the edge of the hanger. When placing the electrodes, be careful not to bump or drop them, as this can cause damage to the sensors. Avoid holding the electrodes in the air by the wires.

Step 3. Place the hanger near the sink for easy access. Some labs will have an insert near the sink for placing the hanger to clean electrodes. Gently slide it onto the insert and be sure that it is secure before you begin working. If your lab doesn't have an insert for the hanger, place the hanger on a flat surface near the sink and carefully carry the electrodes to the sink two at a time. Be sure not to place the electrodes in the bowl of the sink. If the lab has a colander available, use that to avoid excess water getting into the electrodes.

Removing the EEG Gel

Step 4. Use a toothbrush to gently scrub the gel from the electrodes and caps. The gel used for an EEG is very sticky, so scrub the entire electrode with the toothbrush carefully under running water. Inspect the outside of the electrode for any excess gel, and if you see some, place it back into the water and continue scrubbing. Removing the gel from the caps will be easier, but still might require some scrubbing from the toothbrush to remove stubborn gel.

Step 5. Clear the tubular space of the electrodes using a needle or toothpick. There may be some excess gel within the electrode. Look inside the tube of the electrode and use a toothpick or needle to carefully clear the space by scraping out the gel. If there is no gel visible in the tube, do a pass with a needle or toothpick just to be safe.

Step 6. Wipe the wires of the electrodes once per day with a baby wipe. At the beginning or end of the day, you can clean gel from the electrode wires by wiping them down. Since this part of the electrode doesn't normally come into contact with the gel, it'll be pretty clean. Be very gentle when wiping the wires because they can be easily damaged by pulling and tugging.

Step 7. Rinse the electrodes one time with distilled water for 30 seconds. After they're clear of gel, rinse the electrodes with a wash of distilled water to prepare them for disinfecting. This will remove any loosened gel that wasn't scrubbed or scraped off. After rinsing, you can hang the electrodes again for safe keeping while you prepare the disinfecting solution.

Disinfecting

Step 8. Prepare disinfectant by mixing antiseptic and water. There are many different brands of antiseptic that can be used. If your solution isn't already diluted, adding 960 mL (32 fl oz) of water to 40 mL (1.4 fl oz) of antiseptic will create an effective disinfectant. Always wear gloves and proper safety gear when working with chemicals like antiseptic.

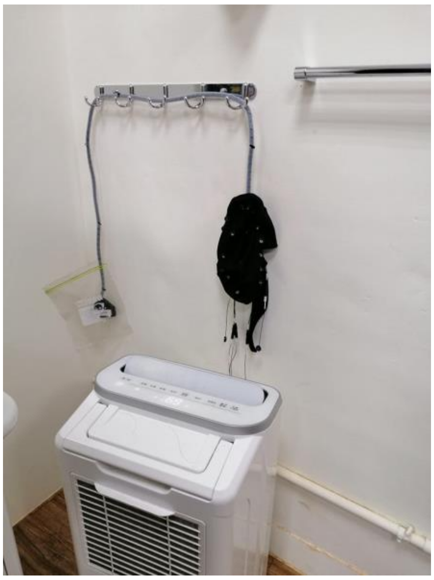
Once you make this solution, you can reuse it throughout the day for disinfecting the electrodes. After the day is over, discard of the solution and make a new one the following day.

Step 9. Soak the caps and electrodes in the solution for 12 minutes. This will remove any bacteria from the caps and the electrodes and prepare them for use on the next patient. Keep the solution at around 20 °C (68 °F) while the electrodes are soaking. Avoid keeping the electrodes in the solution for longer than 15 minutes because this can cause damage to the sensors. If you need a reminder to remove the electrodes, set a timer as soon as you place them in the solution.

Step 10. Rinse electrodes with tap water for 1 minute, repeating 3 times. After all of the electrodes have been removed from the solution, run each of them under the tap water for 1 minute. To do this, you can rinse the electrodes a few at a time, finish the first round of rinsing while they dry, and then repeat the process 2 more times. For higher efficiency, you can hold multiple electrodes under the stream of water at one time but be careful that each electrode is being rinsed thoroughly to avoid damage to the sensors.

Step 11. Rinse the caps with tap water for 1 minute. The disinfectant is irritating to the skin, so be sure to rinse the caps thoroughly before reusing them. About 1 minute under tap water for each cap will be enough to remove the disinfectant. If you have a patient that is known to have sensitive skin, rinse the cap for an extra minute before hanging to dry.

Step 12. Hang the electrodes and caps to dry. Place the electrodes back on the hanger and allow them to dry completely until no moisture remains. Hang the caps to dry as well, allowing excess water to drip off of them. This should take about 5-10 minutes. If you have a patient immediately after cleaning the caps, you can use a hair dryer on the lowest setting and medium heat to quicken drying times for the caps only. Try not to do this often as it can reduce elasticity in the caps. Do not use a hair dryer on the electrodes as it can cause damage to the sensors. Allow them to dry completely in the air (See Picture 3).



Picture 3. *Completed washing and maintaining procedure*

3.2. Discussion

Recent advancements in computer hardware and processor technology have enabled researchers all around the globe to vastly expand the existing knowledge about the complexity of the human brain and gain deeper insights into brain processes and structures. Now that this cornerstone has been set, EEG (Electroencephalography) can be used for various applications. After performing a basic EEG experiment, we discuss some orientations on the application of this technology in Vietnamese psychological science, especially neuroscience. Below is a list of the six most common applications of EEG technology:

Neuroscience: Most generally, psychological studies utilize EEG to study the brain processes underlying attention, learning, and memory. How do we perceive the world? How do our expectations shape the way we see our surroundings? Based on massive trial repetition, event-related potentials (ERPs) are extracted from the continuous stream of EEG data, which allows characterizing brain processes triggered by the events on a very detailed timescale (tens of milliseconds). ERPs can be characterized by their amplitude (in millivolts, with positive and negative going waves labeled “P” and “N”, respectively), timing (in ms relative to event onset), and voltage distribution across all electrodes (topography) (Ibanez et al., 2012). Specific ERPs have been identified for the processing of faces, words and meaning, surprise, or memory recall. In neuroscience research, ERP constitutes a millisecond-by-millisecond record of neural information processing, which can be associated with particular operations such as sensory encoding, inhibitory responses and updating working memory (Song et al., 2020). Thus it provides a noninvasive means to evaluate brain functioning in patients with cognitive disorders and is of prognostic value in few cases. ERP is a method of neuropsychiatric research which holds great promise for the future.

In addition, there are some other research directions to apply data from EEG:

Neuromarketing: In the field of neuromarketing, psychologists use EEG research to detect brain processes that drive consumer decisions, brain areas that are active when we purchase a product/service, and mental states that the respective person is in when exploring physical or virtual stores (Yadava et al., 2017). Studies can be conducted in mobile setups to gain insights into shopping habits and decision-making in real-world scenarios.

Human Factors: Originating from Psychology, the field of Human Factors focuses on workplace optimization; both with respect to tools and interfaces as well as social interaction. In this area, EEG research is used to identify brain processes related to specific personality traits such as intro-/extroversion or social anxiety (Liu et al., 2017). Additionally, brain processes reflecting cognitive and attentional states during human-machine-interaction are heavily studied using EEG, primarily using wireless headsets with long-term monitoring capabilities.

Social Interaction: In social interaction research, brain processes related to social perception, self-evaluation, and social behavior are investigated (Horat et al., 2018). Importantly, social interactions and communication are not passive forms of processing incoming stimuli. Whenever we talk to others or solve problems together, we have to “sync up” with our partners. To study the brain processes underlying the synchronization of conversations and actions, EEG researchers use a method referred to as “hyperscanning” to record data from multiple people at once, allowing them to gain deeper insights into leadership and team interactions.

Clinical and Psychiatric Studies: Whenever brain processes are impaired (e.g., lesions, genetic dysfunctions, diseases), deficits in behavioral, attentional and cognitive processing can be observed. Clinical and psychiatric fields use EEG to evaluate the patients’ cognitive states, determine lesion sites, and classify symptoms (Clarke et al., 2020). Also, EEG is heavily used to evaluate the effect of medical and psychological treatment (e.g., in cognitive-behavioral therapy). More and more therapies utilize virtual reality technology and record EEG data to monitor how the patients’ brains improve over time.

Brain Computer Interfaces (BCI): A relatively new but emergent field for EEG is brain-computer interfaces (Padfield et al., 2019). We know in much more detail which brain areas are active when we perceive stimuli, when we prepare and execute bodily movements, or when we learn and memorize things. This gives rise to very powerful and targeted EEG applications to steer devices using brain activity. This can, for instance, help paralyzed patients steer their wheelchairs or move a cursor on a screen, but BCI technology is also used for military scenarios where soldiers are equipped with an exoskeleton and EEG cap, allowing them to move, lift and carry very heavy items simply based on brain activity.

4. Conclusion

With this EEG experiment, we will learn about the “broad communication” among hundreds of millions of neurons, and we will observe this through the alpha rhythm of our visual cortex in the presence or absence of light. We will glimpse the electrical activity of our brain.

As can be seen, there are many ways to use the EEG method and design an EEG experiment in cognitive science research. Clearly, determining whether EEG is worth the time, effort, and cost is important to consider prior to incorporating this technique into an existing research program. An EEG research is definitely the most useful and convenient methodology to study about not only the brainwave, but also the neuron system activity.

Through the experience in the EEG experiment, we realized that to be able to design experiments and practice EEGs in a smooth and efficient way, it is necessary to practice continuous monitoring for a long time. In addition, it is necessary to understand the theoretical basis and the doctrines of cognitive neuroscience, as well as documents on brainwave analysis, EEG, and ERP.

With this learning experience, we hope to support the operation of the EEG laboratory in Vietnam. Our expectation in the near future is to practice EEG more, on the one hand, to research, on the other hand, to increase practical experience to help guide students to practice experiments in future.

❖ ***Conflict of Interest:*** *Authors have no conflict of interest to declare.*

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MÁY ĐO ĐIỆN NÃO ĐỒ (EEG) VÀ ĐỊNH HƯỚNG NGHIÊN CỨU VỀ LĨNH VỰC KHOA HỌC THẦN KINH

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TÓM TẮT

Bài viết giới thiệu về máy đo điện não đồ (EEG) và các bước tiến hành một thí nghiệm đo điện não đồ. Các tính năng cũng như kết cấu kĩ thuật của máy được trình bày một cách chi tiết. Thông qua 9 bước thực hiện một thí nghiệm, có thể đưa ra định hướng một cách rõ ràng để người đọc tham khảo và thiết kế một thí nghiệm tương ứng. Các bước bảo trì máy sau khi hoàn thành thí nghiệm cũng được đề cập trong bài viết này để cung cấp cho người đọc cái nhìn tổng quát và ứng dụng khi sử dụng máy EEG thực hiện thí nghiệm. Như vậy, nền tảng ban đầu về việc tiến hành thí nghiệm, hoặc thực nghiệm các nghiên cứu về lĩnh vực khoa học thần kinh đang bắt đầu được quan tâm, đầu tư và phát triển tại Việt Nam.

Từ khóa: máy đo điện não đồ; khoa học thần kinh; kinh nghiệm thực tiễn; nghiên cứu khoa học