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Designing the Neuropsychological Experimental Studies in a Developing Country: An EEG-Based Study on the Emotional Self-Regulation

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Abstract

This short article discusses the research trend on emotional self-regulation based on EEG signals in a developing country: Vietnam. Based on the evidence of the potential of a psychology laboratory with experimental equipment that meets the requirements for an experiment measuring EEG signals related to emotional self-regulation in students, we propose a procedure for conducting an EEG-based study on emotional self-regulation. This proposed research design will be an important evidence for us to continue to verify and develop future research.

Keywords: EEG-based research, emotional self-regulation, brain signal, mindfulness, neuropsychological research.

Background on EEG-based Study on Emotional Self-Regulation

Emotional self-regulation (ESR), which refers to the understanding, acceptance, and regulation of emotional responses, is a process that children and adolescents undertake to adapt to their psychosocial environment, orient themselves toward achieving evolutionary goals, and support their own mental health (Van Lissa et al., 2019). The acquisition of ESR allows progress toward greater autonomy, and it is associated with the development of adequate self-esteem and a sense of self-efficacy, which facilitate social and school adjustment. Sabatier et al. (2017) pointed out that, in the last 15 years of research in the field of emotional development, findings regarding neurobiological and environmental factors influencing the acquisition of emotion regulation skills have been highlighted, with a consensus that, with age, people improve in controlling their emotions. However, fewer studies have been observed to analyze these regulatory processes during adolescence, and many of these studies correspond to Western and developed countries. In addition, there is a need to document the development of emotion regulation processes in different economic and social contexts (Alarcón-Espinoza et al., 2022). When studying ESR, neuropsychological and neuroscientific approaches are often used by many researchers because of their potential to provide important information about how the brain processes emotional and neural signals related to external stimuli.

Globally, there have been many important studies such as: Zotev et al. (2014)'s about the self-regulation of human brain activity using simultaneous real-time fMRI and electroencephalography (EEG) neurofeedback, Anique et al. (2023)'s about cognitive load and self-regulation theory, Li et al. (2023)'s about EEG neurofeedback-guided cognitive reappraisal training for emotional regulation, etc. The study of Barros et al. (2021) designed an exploratory study on ESR through the response of electroencephalographic signals to experimental games. This study demonstrated that the use of serious games with virtual reality and electroencephalography, to treat anxiety disorders, although promising, is still relatively young and just beginning to develop. Alarcón-Espinoza et al. (2022) used a systematic review method performed in the Web of Science, Scopus, and PsycINFO databases and in Google Academic from inception until May 2020. Several criteria of the studies met the survey's objectives: (a) Their goal was to investigate self-regulation/emotion regulation; (b) Primary studies did not include theoretical works, systematic reviews, and meta-analyses; (c) Observed everyday relationships/communication patterns in naturalistic settings; (d) Primary participants were people under 18 years of age (regardless of whether parents or teachers were also involved); (e) Studied a general population (normal evolutionary development); (f) Written in English or Spanish; (g) Had access to the full text. The results show that ESR in adolescence as well as in adulthood has gradually received certain attention from the scientific community in the past 20 years. ESR has been conducted using many different methods, increasing the multidimensionality of the approach to this topic, the advantages of previous studies are shown through the methods of data collection and analysis based on neuroscience.

However, in developing countries, the field of study on ESR according to neuroscience or neuropsychology approaches is very limited and mainly based on self-assessment of participants. In general, ESR is gradually being considered an essential factor and researchers spend a lot of time to invest in studying it in depth from multidimensional perspectives. Research methods on ESR go from theoretical research to the concretization of the portrait of this factor through the processing of electroencephalography technology to confirm its measurability, from which it can be affirmed that research methods on ESR are limitless. New approaches can contribute to enriching the archive of collected data on the influence of ESR to be able to develop appropriate intervention or support methods to promote the ability of ESR in humans.

In Vietnam, a developing country, ESR has not been focused on. ESR has often been studied as one of the components or indicators of emotional management, social emotional competence, or emotional intelligence (Huynh et al., 2021; Giang et al., 2023). Moreover, Vietnam has certain limitations in studies on neuroscience and neuropsychology, so the studies related to ESR brain structure has limited, ether. The use of EEG to assess ESR or to assess components and indicators is still a research gap.

Designing the current EEG-based study on the Emotional Self-Regulation in Vietnam

The main method of the current proposed study was the laboratory experiment. We used an EEG machine in the Psychology Lab, under the management of the Educational Psychology Research Group, Ho Chi Minh City University of Education, to conduct experiments measuring the EEG signals of the participants before and after practicing mindfulness exercises that the group developed to affect the participants' ability to self-regulate emotions.

EEG Signal Evaluation

EEG brain signal assessment has been widely used to understand human behavioral, cognitive, and emotional mechanisms by measuring physiological changes in the brain in an objective, non-invasive, and continuous manner (Jalaudin & Amin, 2019). In contrast to neuroimaging tools such as MRI/fMRI scanners that may potentially induce anxiety disorders in participants, EEG is considered more feasible and cost-effective. It is a non-invasive clinical neurophysiological research method to passively monitor and record electrical activity in the brain. Most activities in some parts and regions of the brain can be assessed and examined by EEG. The EEG spectrum can be separated into five specific wavebands/sub-bands according to the oscillation frequency: Delta (<4 Hz) - dreamless sleep state; Theta (4–8 Hz) - meditative state; Alpha (8–12 Hz) - relaxed state; Beta (12–38 Hz) - active state; and Gamma (38–42 Hz) - high activity state. Spectral analysis of EEG signals, corresponding to the signal characteristics in the frequency domain, is mostly used in studies on mindfulness, or meditation (Gupta et al., 2021). Among the brain waves, alpha, theta, and beta waves have been recognized as important brain activities correlated with mindful awareness or, in short, the neural correlates of mindfulness. One line of research has actually found increased activity in the alpha and theta frequency bands during mindfulness meditation and in the post-meditation resting state. On the other hand, decreased beta activity during mindfulness meditation has been widely reported, which may be due to reduced anxiety and stress due to mindfulness (Jalaudin & Amin, 2019). Beta waves have been reported to appear noticeably in people who are feeling anxious and stressed due to external stimuli.

In cognitive neuroscience studies, the ability to regulate emotions is associated with a set of prefrontal brain regions involved in cognitive control and executive function that have been shown to mature later in development. As a result, children and adolescents may have more difficulty regulating their emotions. However, because the ability to regulate emotions can develop significantly during adolescence, treatment strategies are needed to help students with depression, or other mental health problems, improve their quality of life. Mindfulness, a highly flexible and simple (in terms of time, place, and mechanism) yet effective approach to meditation, may be one of the best options. In this study, the electrode channels related to emotional self-regulation were selected for EEG measurement, the frontal electrodes F3 (left) and F4 (right) were used to provide EEG data based on the frontal EEG asymmetry in the alpha and high-beta brain wave bands. The FCz channel was used as a reference for comparison with the two electrodes (See Figure 1).

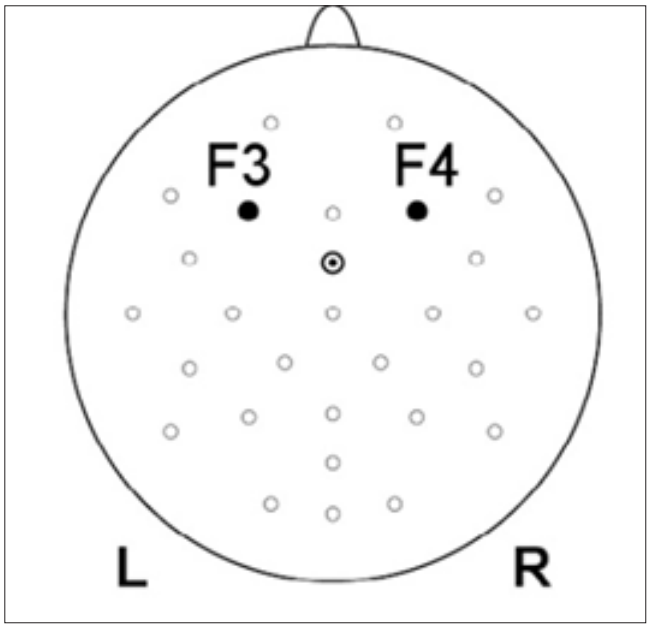

Figure 1: Description of electrode F3 and F4 measuring emotional self-regulation signals

Resources that generate brainwave stimulation for emotional self-regulation

Emotional video clip

In this study, we selected emotional video clips as stimuli to evoke/trigger unpleasant emotions in the research participants. Descriptions of the video clips are given in Table 1.

No	Video clip name	Main content	Emotions evoked
1	City of Angels	Maggie (Meg Ryan) passes away in Seth's (Nicolas Cage) arms.	Sad
2	Schindler's List	A concentration camp commandant shot prisoners randomly from his balcony.	Angry
3	Dangerous Mind	Students in a class are informed that one of their classmates has passed away.	Sad
4	Sleepers	Child sexual abuse	Angry

Table 1: Emotionally evocative video clips:

The video clips were selected from a well-established and validated study in emotion research (Schaefer et al., 2010). A total of 10 emotional video clips were used for the experiments to arouse participants' emotions: 2 videos at the pre-intervention stage and 2 videos at the post-intervention stage. The participants' state when watching these videos was assumed to be similar to their state when facing stressful life situations. The arousal value ranged from excited (9) to calm (1), while the valence value ranged from pleasant (9) to unpleasant (1). According to the Circumplex Model of Affect (Russell, 1980), the emotional arousal from the videos was defined as "happy" when the valence and emotional arousal were above 5. "Calm" when the valence was above 5, while the emotional arousal was below 5. "Sad" when the valence and emotional arousal were both below 5. "Fearful" when the valence was below 5, while the emotional arousal was above 5. Although different video clips were used before and after the mindfulness-based intervention phases, similar mean values for valence, emotional arousal, and length were maintained. The difference between the video clips in the two phases was not significant, with $p = 0.913$, indicating high similarity between the videos. This was necessary to ensure that the hypothesized changes in participants were caused solely by the mindfulness exercises that develop ESR.

Mindfulness exercises improve emotional self-regulation

The 8-week mindfulness-based intervention exercises were synthesized, inherited and built by the authors to suit the Vietnamese context and culture from the research of (Coholic & Eys, 2016). Accordingly, Coholic and Eys (2016) proposed a Holistic Arts-Based Program, a comprehensive practice program based on the study of mindfulness practices to develop the ability to Self-regulate emotions in high school students. In addition, the research subjects were also instructed on how to practice original mindfulness: thinking, feeling their emotions come and go without making any judgments or reactions to them. Focusing on the breath improves the subject's cognitive awareness, allowing them to be non-judgmental without much effort.

The Current Study Procedure

EEG data collection was conducted twice: (1) pre-intervention (i.e., phases I and II) and (2) post-intervention (i.e., phase III). Phase II included training and practice of mindfulness exercises.

Phase I: 60-90 minutes/participants

In phase I, we collected pre-intervention data for the mindfulness exercise, including recording of the subjects' EEG and physiological responses. The experiment began with 5 minutes of eyes open followed by 5 minutes of eyes closed, which served as a baseline/rest condition, i.e., data from participants in a neutral condition with no task-required brain activity. This was a necessary step to account for subjective variability. During eyes closed, subjects were instructed to close their eyes while awake, while with eyes open, subjects were instructed to look at a fixation point that appeared in the center of the screen. The baseline condition was followed by 5 experiments, and each experiment contained two consecutive stimuli: a video clip and a mindfulness task (listening to a mindfulness bell that produces white noise stimulation that increases the focus of the alpha wavelength). For this bell, the research team used the "Be mindful" application, which is also the application the research team introduced to the subjects to have an interactive tool at home to support improving the effectiveness of Mindfulness practice.

Each experiment began with a 30-second fixation to allow for synchronization with the physiological sensors, while discarding the first 5 seconds that might contain noisy data about participants getting ready (or performing mindful breathing, phase III). This was followed by viewing a video clip that averaged 4.35 minutes in length. This was followed by another 10 seconds of fixation, followed by listening to a mindfulness bell to assess the impact of negative emotions on participants' cognitions for 2 minutes.

In summary, each experiment had a baseline followed by 5 trials, where each trial consisted of 30 seconds of fixation, followed by viewing a video clip, followed by 2 minutes of calming while listening to a mindfulness bell, followed by task assessment. To avoid fatigue in participants, they were given a few minutes of rest between each trial. Participants' feedback on their ability to self-regulate emotions while watching the video clip. This experimental procedure was performed in the pre-mindfulness intervention and post-mindfulness intervention phases. At the end of the pre-intervention data recording, the instructor explained information and instructions related to the mindfulness-based intervention that would be implemented in phase II.

Phase II: 8 weeks of mindfulness practice

In phase II of the study, all participants underwent a 8-week mindfulness training session, both online and in-person, at a mutually agreed upon schedule between the research team and the participants.

After completing the introductory training session, the participants were instructed on how to practice mindfulness exercises for a minimum of 5 minutes daily, which they were required to adhere to. During the study, all participants were added to a social network group created so that the research team could send them daily reminders for individual mindfulness exercises. This was done once a day to ensure that the participants adhered to the mindfulness exercises with as little distraction as possible.

Once a week, the research team met directly with the participant group once on Saturday morning to assess the participant's mindfulness practice and experience during the mindfulness practice week in phase II.

Phase III: Evaluation and analysis of EEG and behavioral data

After the 8-week experimental course of mindfulness exercises to develop ESR, the participants were asked to return to the Psychology Laboratory to record data for Phase III, using the same procedure as that used in Phase I. The video clips were changed in Phase III, while the same valence, arousal, and length were maintained. This was necessary to ensure that the hypothesized improvement in ESR was not affected by the repetition of stimulation.

Before and during the experiment/data collection in phase III, participants were asked to practice mindfulness as comfortably as possible. By phase III, it is expected that participants will be familiar and comfortable with practicing mindful breathing at their pace.

EEG Data Analysis

EEG data help identify brain regions affected by mindfulness. EEG recordings, as described earlier, were performed twice, at phase I (before mindfulness practice) and at phase II (after mindfulness practice). Each participant was recorded at baseline and 5 trials: eyes closed and eyes open, and 5 short videos to induce negative emotions, followed by listening to a bell.

To study the variability of EEG data, signal power was used. The raw EEG data was filtered for gamma, beta, alpha, theta and delta frequencies respectively. The raw EEG data was pre-processed using EEGLAB which is used in MATLAB software. The drift in the acquired EEG data was corrected and a 50 Hz notch filter was applied to remove line noise. The data was then filtered using an FIR filter with a low pass of 0.5 Hz and a high pass of 47 Hz. The data was then down-sampled from 500 Hz to 250 Hz, as this provided accurate analysis within half the analysis time required for 500 Hz. The cleaned EEG data was then exported to MATLAB and frequency analysis was performed.

In this study, we will record the total measurement data for 10 minutes. Of which, the time for the measuring devices to stabilize the transmission is 30 seconds, the average short video is 4 minutes 35 seconds and finally 5 minutes focusing on the "+" point in the middle of the screen when the short video ends to self-regulate emotions after watching the sad and angry videos. Through the raw recorded data, we mainly process the last recorded segment, specifically 05 minutes of self-regulating emotions after watching the short video because this is the time when customers will self-regulate the emotions originating from the short video they just watched. We perform the steps to collect, process and analyze the recorded data as follows:

- First, we will get the raw recording which includes noise elements, over-processed high and low frequencies.
- Second, we process the data to achieve the best requirements with alpha wave levels (7.5Hz – 12.7Hz) and Beta (21Hz – 32Hz) through adding filters and processing the sampling frequency to 250Hz. Cut the first 10 seconds of recorded data due to unstable transmission through the Reject tool.
- Third, we compared the recorded EEG at electrodes F3 and F4 to see if there was any similarity to further process or reject the recorded data if necessary.
- Fourth, after having processed data, we proceed to run spectral analysis to find energy data. From there, we rely on this energy data to analyze the meanings from the numbers.

Research Prospects and Conclusions

In the process of studying ESR in students, the organization and selection of research methods play an important role in gaining a deeper understanding of this issue. The ESR of students or adolescents is a research problem that should be considered in a laboratory setting, with designs measuring EEG signals to obtain important evidence findings. The field of ESR currently has changed a lot compared to previous generations due to the impact of social context and the development of science and technology, so the application of neuroscience to experimental psychology research is a sustainable trend for countries with a young psychology industry like Vietnam.

From the above proposals on the design and implementation process of an EEG study on ESR in a developing country, Vietnam, we will continue to improve and publish important findings when initially implementing this research direction. The expected results in the near future, in developing countries, will initially invest and promote experimental psychology research combined with neuroscience to have important practical and theoretical evidence for psychological research in these countries. This is both a challenge and a potential for the research trend on neuropsychology in developing countries, including Vietnam.

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