

Introduction of Virtual Reality Therapy Exposure for Undergraduate Students with Anxiety during the Covid-19 Pandemic based on EEG Signals

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Abstract

Social changes in education caused by the Covid-19 pandemic have caused the online learning process to be more intensive which has led to an increased sense of isolation and independence, thus becoming a source of pressure for students. Continuous pressure can lead to generalized anxiety disorder (GAD), a serious mental illness that causes loss of work productivity and decreased quality of life. This mental disorder is most common in individuals with an age range of 18 to 24 years who are at the university level. The most common treatment technique used for GAD is cognitive behavioural therapy (CBT), as technology develops, this therapy has evolved into virtual reality exposure therapy (VRET). The combination of exposure therapy and VR allows users to experience digital versions of anxious real situations. In the diagnosis of GAD, psychologists use standard psychometric questionnaires as measurement methods such as the State-Trait Anxiety Inventory (STAI) and Generalized Anxiety Disorder Assessment (GAD-7) questionnaires. Recently, another incipient and imperative method of valuation of anxiety has been formed by considering the use of physiological constructs such as EEG. Through EEG monitoring, the level of anxiety in individuals can be detected and measured efficiently. In this study, there are two groups of subjects one of which received two anxiety management techniques by VRET (mindfulness and imagery) called treatment group and the other received one anxiety management technique by VRET (imagery) called control group. The results of this study indicate that the two EEG channels used such as AF7 and AF8 channels in the treatment group and control group showed a significant decrease in power spectrum after receiving treatment using VRET. The use of the STAI psychometric questionnaire in this study was carried out to validate measurements with EEG which showed that in the treatment group before VRET as many as 63% of the questionnaire results were subjects with high anxiety, and after receiving VRET the level experienced a significant decrease which was dominated by subjects with low anxiety as much as 53%. In the control group before VRET had questionnaire results as much as 72% of the subjects had low anxiety and the rest had moderate anxiety, then after receiving VRET the subject experienced a decrease in anxiety which all subjects had low or minimal anxiety.

Keywords

EEG, Virtual Reality Exposure Therapy, Generalized Anxiety Disorder

1. Introduction

The national health report in Indonesia, Riset Kesehatan Dasar (riskesmas), in 2013 showed the prevalence of emotional mental disorders as indicated by anxiety and symptoms of depression at the age of 15 years and over reached 6% (Kementrian Kesehatan, 2013). In 2018 there was an increase in prevalence of 9.8% which was marked by an increase in the number of cases from 42,236 to 69,255 people who experienced mental emotional disorders (Kementrian Kesehatan, 2019). Emotional mental disorder is a condition in individuals indicated by emotional

changes that can develop into a pathological state so that anticipation is needed so that individual mental health is maintained (Idaiani, et al., 2009). Mental-emotional disorders often appear when individuals reach the age of 18 to 25 years, this period is a vulnerable developmental time in a person's life (Kessler, et al., 2007). Most individuals in the age range of 18 to 25 years spend their time at university (McLafferty, et al., 2017). When compared with other groups of students such as elementary school students or high school students, the general view shows that students bear more stress and have more serious physical and mental health problems (Gao, et al., 2020).

Social changes in education caused by the Covid-19 pandemic have caused the online learning process to be more intensive which has led to an increased sense of alienation and independence so that it becomes a source of pressure for students. The existence of pressure or stress conditions continuously is the beginning of an anxiety disorder (Faravelli, et al., 1989). The most common treatment technique used in treating anxiety disorders is cognitive behavioural therapy (CBT) (Safir, et al., 2012). Along with the development of technology, cognitive therapy has developed into virtual reality exposure therapy (VRET). The combination of exposure therapy and VR allows users to face digital versions of feared real situations (Scozzari, et al., 2011).

Diagnosis of anxiety disorders is important to explain the clinical symptoms and signs experienced by a person as well as to distinguish it from other similar conditions. According to Farah Muhammad, 2022, psychologists use standard psychometric questionnaires as a method of measuring anxiety. Psychometric questionnaires commonly used to measure anxiety, especially in GAD, are the State-Trait Anxiety Inventory (STAI) questionnaire and the Generalized Anxiety Disorder Assessment (GAD-7). Thus, a new anxiety assessment method was formed by considering the use of physiological constructs such as EEG. Through EEG monitoring, the level of anxiety in individuals can be detected and measured efficiently.

With the support of modern computer computing and memory that can store a lot of data, the collected EEG signals will be processed and analyzed using EEGLAB. The EEG signal is still a type of electrical signal that is prone to noise, artifacts, and interference, so by using EEGLAB, deficiencies in the EEG signal can be easily overcome by applying signal filtering algorithms, such as removing low-frequency components in the frequency domain of the signal (Keong, et al., 2015). Prior to the use of VRET, an initial diagnosis was carried out using a GAD-7 scale questionnaire to measure anxiety levels including minimal, mild, moderate, and severe anxiety (Vignola, et al., 2014). Furthermore, the measurement of the State-Trait Anxiety Inventory (STAI) questionnaire to measure anxiety before and after undergoing the VRET session was carried out by measuring EEG signals in participants.

1.1 Objectives

Along with the increase in anxiety disorders that indicate GAD in college students during the Covid-19 pandemic and technological developments in the field of medicine supported by new methods of measuring anxiety, this study is expected to introduce the use of VRET for students with anxiety especially GAD based on EEG signals. Measurement of anxiety levels based on EEG signals and the use of VRET was focused on students at Sebelas Maret University, Surakarta. Prior to the use of VRET, an initial diagnosis was made using the GAD-7 questionnaire. Furthermore, the State-Trait Anxiety Inventory Form Y (STAI Y) questionnaire and EEG signal measurements were used to measure the participants' anxiety before and after the VRET session.

2. Literature Review

According to Spitzer, 2006 generalized anxiety disorder is defined as one of the most common mental disorders encountered in the population as well as in medical practice. Generalized anxiety disorder is a serious mental illness that causes loss of work productivity and decreased quality of life (Szkodny, Jacobson, C., Llera, & Newman, 2013).

GAD-7 is one of the measuring tools of the Patient Health Questionnaire module to detect and screen for anxiety disorders, as well as being the first questionnaire developed for primary care in helping the diagnostic process of specific disorders (Toussaint, et al., 2020). This measuring instrument was compiled by Robert L. Spitzer in 2006 based on the GAD criteria in the Diagnostic and Statistical Manual for Mental Disorders (DSM-IV) which consists of 7 statement items with the highest correlation value.

STAI Y is a commonly used measuring tool to detect trait anxiety and state anxiety (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983). This self-report questionnaire is used in clinical practice to diagnose anxiety and differentiate

it from depressive syndromes. The use of the STAI Y questionnaire is recommended to measure a person's level of anxiety before and after VRET (Repetto & Riva, 2011).

VRET is an exposure therapy used for evidence-based treatment that supports the treatment of OCD, posttraumatic stress disorder (PTSD), panic disorder (PD), social anxiety disorder (SAD), and specific phobias (American Psychological Association, 2006). In research by Repetto, et al. (2011) stated that VRET can also be used to treat GAD. Virtual reality (VR) technology provides a unique opportunity to expand the utilization of exposure therapy. VR technology for therapy has excellent image quality and lower costs than traditional psychotherapy (Miloff, et al., 2016).

EEG headband is a technology with brain sensors that have a critical point where the device attaches directly to the scalp (Stockman, 2020). The EEG headband used in this study is the headband from InteraXon, MUSE 2. MUSE 2 has a sampling frequency of 256 Hz which can monitor the state of the brain and measure EEG signals in frontal and temporal locations. The electrodes in this device conform to the international 10-20 electrode system (Wilkinson, et al., 2020). EEG brain waves are divided into 4 signals, namely delta, theta, alpha, and beta (Pathirana, Asirvatham, & Johar, 2018). In this study, the type of wave that will be studied is beta waves because beta waves have a higher value than alpha and theta waves when humans are under stress. An increase in beta waves and a decrease in alpha waves is an indication that a person is under stress due to various events, this difference can be found by minimizing the two waves (Jun & Smitha, 2016).

EEGLAB is a programming platform that uses a matrix-based language so it is generally used to analyze data, create algorithms, and create models and applications. EEGLAB often used in processing EEG signals to simplify signal processing and analysis (Gurumurthy, Mahit, & Ghosh, 2013). Electrodes on the EEG are placed on the subject's head which are connected by wires to transmit all electrical activity to the computer. However, the EEG signal is still a type of electrical signal, where it is highly susceptible to noise, artifacts, and interference. With the help of EEGLAB, this problem can be easily solved by applying signal filtering algorithms, such as removing low frequency components in the frequency domain of the signal.

3. Methods

Measurement of the effectiveness of VRET on GAD students was carried out in 2 stages, namely data collection and data processing. In data collection, the first is the identification of anxiety levels by distributing the GAD-7 questionnaire through social media to students with inclusion criteria, including, students with active status at Sebelas Maret University, age range from 18 to 24 years, and have never received any therapy related to her anxiety disorder. Of the 48 students who received the questionnaire, there were 44 students who were willing to participate in filling out the GAD-7 questionnaire (Figure 1).

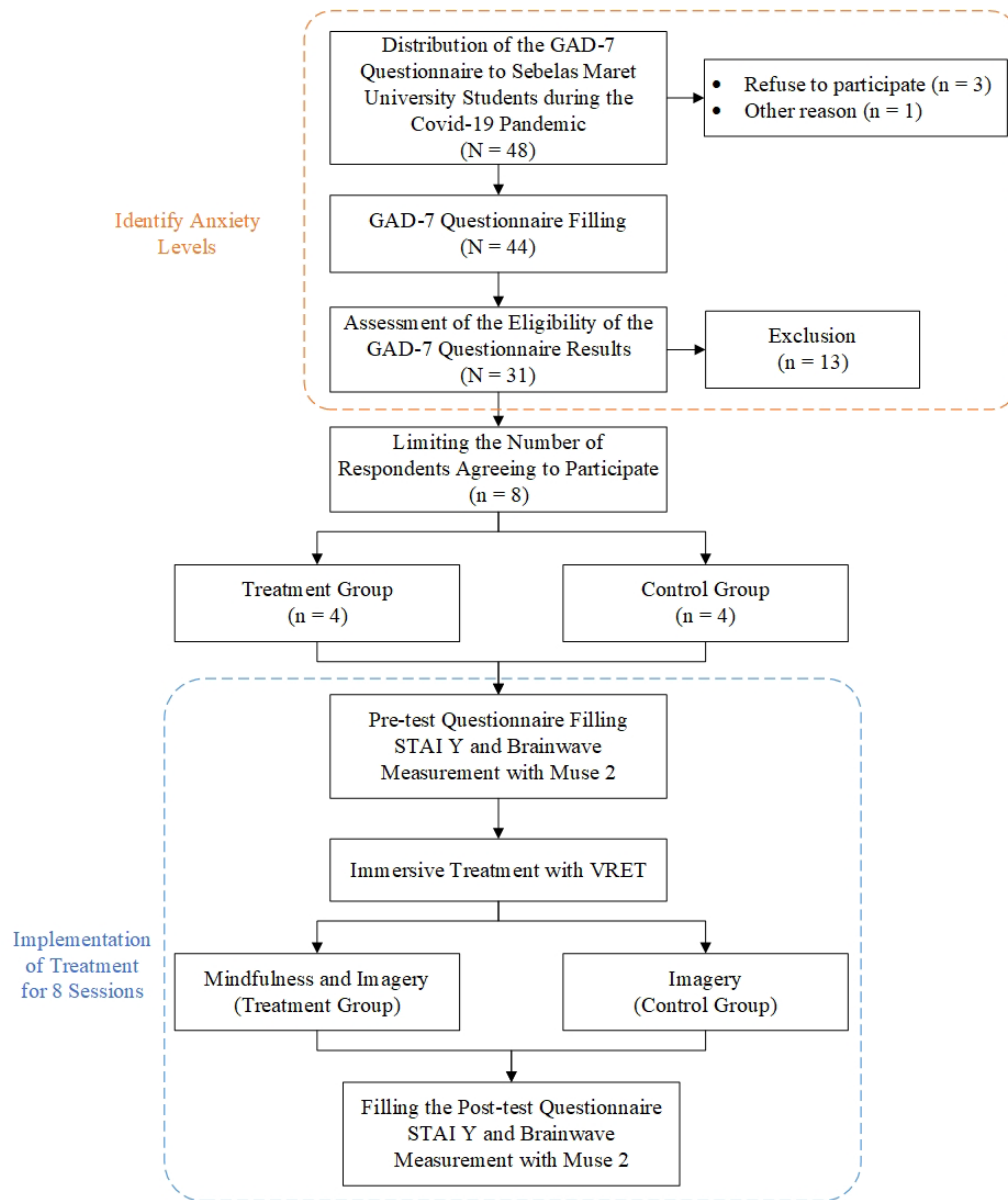


Figure 1. Research Protocol Flowchart

Furthermore, the results of the GAD-7 questionnaire were assessed for feasibility, so that 31 out of 44 respondents met the inclusion criteria. Then the number of respondents who meet the criteria is limited to 8 people as subjects. Limiting the number of subjects is done so that the research runs efficiently considering the limited time and data collection that takes a long time. Although there is a limitation on the number of subjects, the data needs needed for data processing are still met. The following is the data of the subjects selected as samples. Subjects of 8 students were divided into two groups where each group had subjects with balanced characteristics. In the treatment group with 4 subjects experiencing moderate or severe anxiety, they received VRET sessions in the form of mindfulness and imagery. While the control group with 4 subjects who experienced mild or minimal anxiety received a VRET session in the form of imagery (Figure 2 and Table 1).

Table 1. Subject Classification

No	Subject Code	Anxiety Level	Group
1	S1	Severe Anxiety	Treatment Group
2	S2	Severe Anxiety	
3	S3	Moderate Anxiety	
4	S4	Severe Anxiety	
5	S5	Mild Anxiety	Control Group
6	S6	Minimal Anxiety	
7	S7	Mild Anxiety	
8	S8	Minimal Anxiety	

The second stage of data collection is the implementation of VRET sessions for 4 weeks with 2 sessions per week. Here are some stages of treatment and anxiety level checks carried out for 38 minutes 15 seconds:

Step 1: State-Trait Anxiety Inventory Form Y (STAI Y) is a 20-item questionnaire that measures anxiety in adults. Subjects filled out the STAI Y questionnaire to measure the level of anxiety before the VRET session (Repetto, et al., 2011). Then measured brain waves for 6 minutes (Muhammad, et al., 2022).

Step 2: Immersive treatment in the treatment group with mindfulness and imagery anxiety management techniques where sessions 1 to 6 subjects learn relaxation techniques to reduce anxiety using mindfulness applications in VR. This application will help the subject to apply relaxation techniques through breathing exercises and focus training with games in which the subject controls an object with head movements to navigate an approaching challenge. The use of this application will convince, refute, oppose, or ignore brain reactions that cause anxiety. Then in sessions 7 and 8, the subject will practice anxiety management skills with imagery techniques. The subject will be faced with a pre-selected image or video related to the thing that makes him anxious. Visual images and videos that are present through VR make it easier for subjects to use any anxiety management skills to be able to tolerate anxiety rather than avoid or fight it mentally (Repetto, et al., 2011). In the control group for 8 sessions received imagery anxiety management techniques.

Step 3: Filling out the questionnaire by the subject was again carried out to measure the level of anxiety after the VRET session (Repetto, et al., 2011). Then measured brain waves for 6 minutes (Muhammad, et al., 2022) to determine the change in waves after the VRET session.

4. Data Collection

The researchers have conducted a review of related literature, direct observations. Measurement of anxiety levels using the GAD-7 questionnaire as a form of identification of anxiety in Sebelas Maret University undergraduate students during the Covid-19 pandemic is shown on the anxiety scale Figure 2.

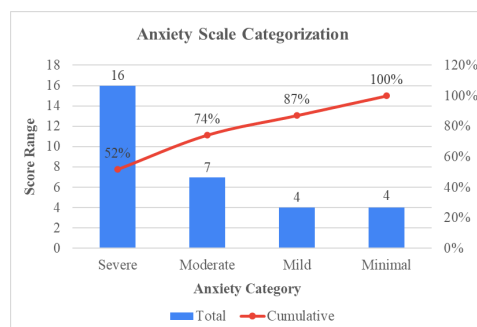


Figure 2. Anxiety Scale Categorization

Anxiety scale categorization on 31 respondents showed 4 respondents (13%) experienced minimal anxiety, 4 respondents (13%) experienced mild anxiety, 7 respondents (23%) experienced moderate anxiety, and 16 respondents experienced severe anxiety (52%). So, it can be concluded that the majority of respondents with a percentage of 52% experienced severe anxiety.

After all the EEG signal data is obtained, processing is carried out using EEGLAB as shown in figure 3 with the first step which is data acquisition. The acquisition of the EEG signal consists of several stages, namely storing the signal in CSV from the Mind-Monitor into a personal computer (PC), naming the signal data, and entering the sampling rate value of 256 Hz according to the EEG headband MUSE 2. Step 2 is processing data, among others, removing the epoch baseline, applying the finite impulse response (FIR) filter, data decomposition using Independent Component Analysis (ICA), and rejecting data. Then post-processing which consists of making STUDY and processing data with STUDY design.

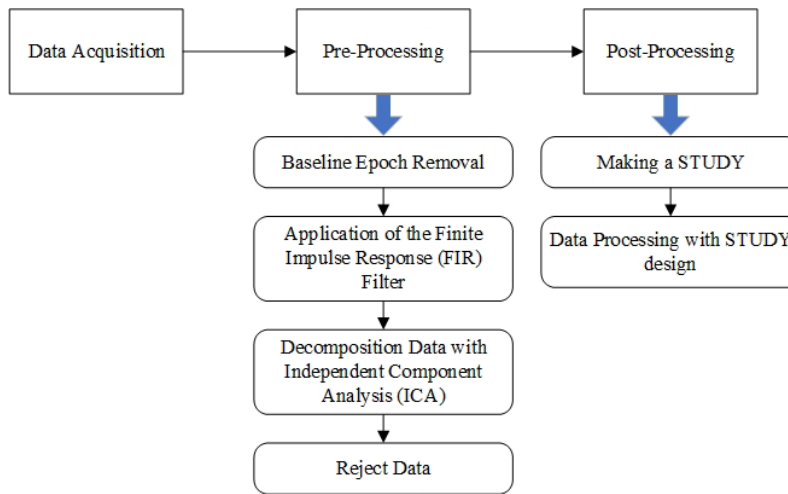


Figure 3. Step by Step Data Processing with EEGLAB

5. Results and Discussion

The results of data processing using EEGLAB provide output in the form of a spectrogram. The spectrogram in this study describes the overall brain wave data which is characterized by the rise and fall of log power (μ^2) at each frequency (Hz) and is used to compare brain waves in subjects before and after using VRET. The comparisons made include comparisons of power spectrum, and AUC which will be explained below.

5.1 Numerical Results

Comparison of EEG signals in the treatment group and control group before and after the first VRET session, namely the power spectrum using parametric statistics. Parametric statistics were carried out to determine the difference in log power in the treatment group and control group before and after running the VRET session. The EEG channel that was compared consisted of 2 channels, including the left frontal lobe (AF7) and right frontal lobe (AF8).

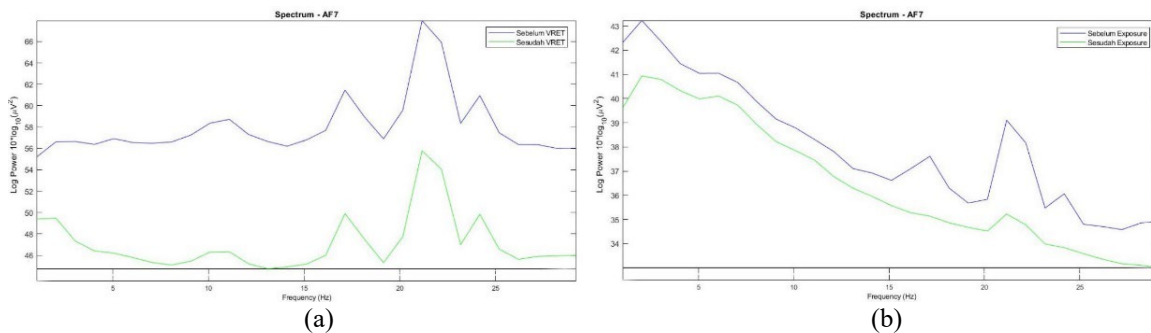


Figure 4. AF7 Power Spectrum Comparison (a) Treatment Group; (b) Control Group

Figure 4 (a) shows that the AF7 treatment group before VRET (blue color) has a maximum point at 21 Hz with a power of 67.96 logs and decreases from 22 Hz with a power of 65,93 logs to a minimum point at 28 Hz with a power of 56 logs. Then the treatment group after VRET (green color) shows a lower power spectrum, namely the minimum point at 13 Hz with a power of 44,74 logs and a maximum point at 21 Hz with a power of 55,78 logs after which it decreases until it reaches a power of 45,63 logs at 26 Hz. Furthermore, AF7 control group in Figure 4 (b) before VRET (blue color) has a maximum point at 21 Hz with a power of 39.11 logs and decreases from 22 Hz with a power of 38.16 logs to a minimum point at 27 Hz with a power of 34, 59 logs. Then the control group after VRET (green color) has a maximum point at 12 Hz with a power of 36.77 logs and decreases from 13 Hz with a power of 36,30 logs to a minimum point at 29 Hz with a power of 33 logs.

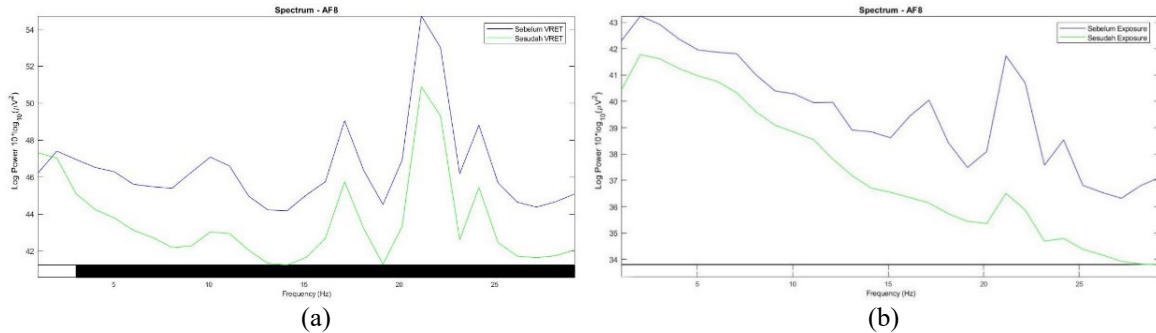


Figure 5. AF8 Power Spectrum Comparison (a) Treatment Group; (b) Control Group

Figure 5 (a) shows that the AF8 treatment group before VRET (blue color) has a minimum point at 14 Hz with a power of 44.18 logs and a maximum point at 21 Hz with a power of 54.72 logs after which it decreases until it reaches a power of 44.38 logs at 27 Hz. Then the treatment group after VRET (green color) shows a lower power spectrum, namely the minimum point at 13 Hz with a power of 41.25 logs and a maximum point at 21 Hz with a power of 50.89 logs after which it decreases until it reaches a power of 41.65 logs at 27 Hz. Furthermore, the AF8 control group in Figure 5 (b) before VRET (blue color) has a maximum point at 21 Hz with a power of 41.73 logs and decreases from 22 Hz with a power of 40.70 logs to a minimum point at 27 Hz with a power of 36, 32 logs. Then the control group after VRET (green) has a maximum point at 12 Hz with a power of 37.81 logs and decreases from 13 Hz with a power of 37.18 logs to a minimum point at 29 Hz with a power of 33.80 logs.

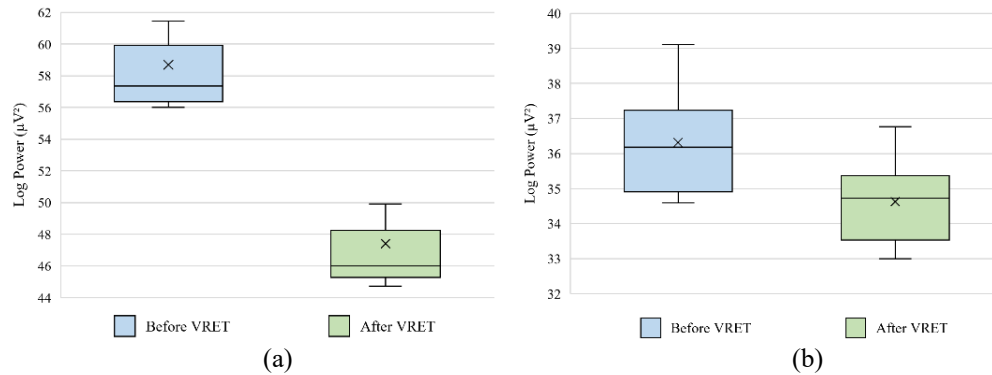


Figure 6. AF7 Mean Comparison (a) Treatment Group; (b) Control Group

The second comparison is the average log power on each EEG channel which is explained through the boxplot Figure 6. The first mean is that the AF7 treatment group before VRET has a mean log power of 58.72 V^2 and after undergoing a VRET session the average log power becomes 47.40 V^2 . Then the AF7 control group before VRET had a mean log power of 36.32 V^2 and after undergoing a VRET session the average log power was 34.62 V^2 .

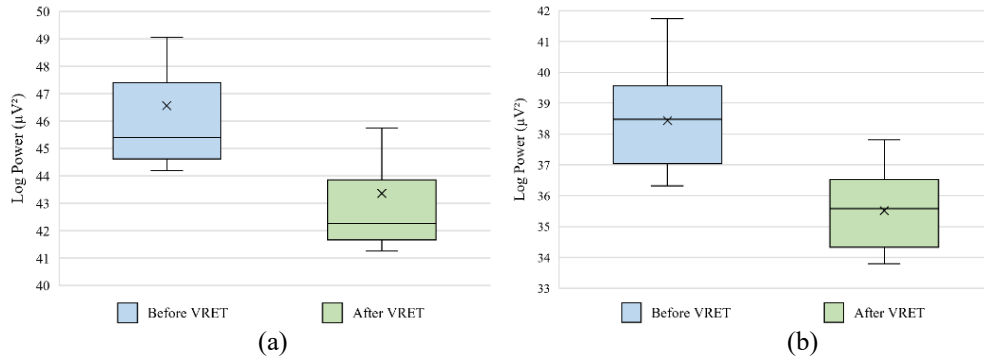


Figure 7. AF8 Mean Comparison (a) Treatment Group; (b) Control Group

The second mean is that the AF8 treatment group before VRET has a mean log power of 46.57 V² and after undergoing the VRET session the average log power is 43.36 V². Then the AF8 control group before VRET had a mean log power of 38.44 V² and after undergoing a VRET session the average log power was 35.51 V².

In addition to using EEG, to measure the subject's level of anxiety during the VRET session, the STAI Y psychometric questionnaire was used. The results of the STAI Y questionnaire in the treatment group are shown in Figure 6. Distribution of STAI Y scores in the treatment group that in the pre-test there were 5 questionnaire results (16%) subjects stated low anxiety, 7 questionnaire results (22%) subjects stated moderate anxiety, and 20 questionnaire results (63%) subjects stated high anxiety. The results of the post-test on the treatment group showed that there were 17 questionnaire results (53%) subjects stated low anxiety, 9 questionnaire results (28%) subjects stated moderate anxiety, and 6 questionnaire results (19%) subjects stated high anxiety (Table 2 and table 3).

Table 2. STAI Y Questionnaire Results on Treatment Group

Category	Anxiety Level	Frequency
<i>Pre-Test</i>	Mild	5 (16%)
	Moderate	7 (22%)
	Severe	20 (63%)
<i>Post-Test</i>	Mild	17 (53%)
	Moderate	9 (28%)
	Severe	6 (19%)

The results of the STAI Y questionnaire in the treatment group are shown in Figure 7. Distribution of the score of STAI Y control group that in the pre-test there were 23 questionnaire results (72%) subjects stated low anxiety and 9 questionnaire results (28%) subjects stated moderate anxiety. The results of the post-test on the treatment group showed that 32 of the questionnaire results (100%) had low anxiety.

Table 3. STAI Y Questionnaire Results on Control Group

Category	Anxiety Level	Frequency
<i>Pre-Test</i>	Mild	23 (72%)
	Moderate	9 (28%)
	Severe	0
<i>Post-Test</i>	Mild	32 (100%)

	Moderate	0
	Severe	0

5.2 Graphical Results

The result of the graph in this study is a AUC (Area Under Curve) which obtained from the power log on the AF7 and AF8 spectrograms. AUC in the spectrogram of the treatment group and the control group before and after running the VRET session shown in Figure 8 and Figure 9.

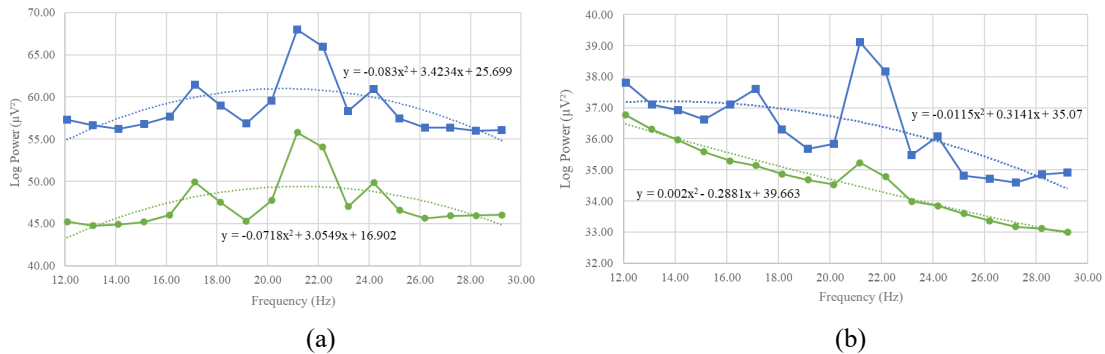


Figure 8. AF7 AUC Comparison (a) Treatment Group; (b) Control Group

AUC in Figure 8 (a) shows AF7 treatment group before VRET (blue color) has an area under the curve of 1.011 V²/Hz and after VRET (green color) has an area under the curve of 816 V²/Hz. Furthermore, the AUC in Figure 8 (b) shows that AF7 control group before VRET (blue color) has an area under the curve of 623 V²/Hz and after VRET (green color) has an area under the curve of 593 V²/Hz.

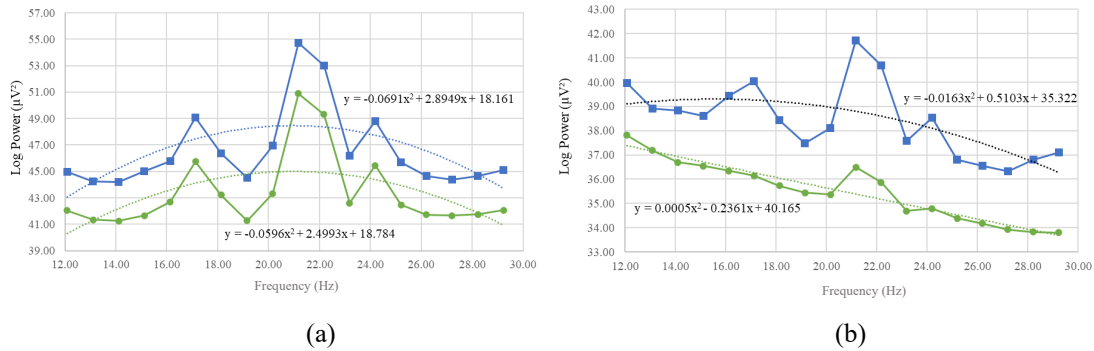


Figure 9. AF8 AUC Comparison (a) Treatment Group; (b) Control Group

The AUC on the channel AF8 treatment group before VRET (blue color) has an area under the curve of 802 V²/Hz and after VRET (green color) has an area under the curve of 746 V²/Hz. Furthermore, the AUC on channel AF8 control group before VRET (blue color) has an area under the curve of 660 V²/Hz and after VRET (green color) has an area under the curve of 609 V²/Hz.

6. Conclusion

The study offers interesting results. On the one hand, it confirms the possibility of using VR in the treatment of GAD in that both experimental groups improved clinical outcomes after the end of treatment. This is indicated by a physiological response in the form of a decrease in power on the spectrogram which indicates that the subject experienced a decrease in anxiety after undergoing a VRET session. In addition, the results of the STAI Y psychometric questionnaire showed that the subject experienced a significant decrease in anxiety. In conclusion, this study shows that VRET can be used also in the treatment of GAD.

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Biographies

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Pringgo Widyo Laksono is a Doctor in Industrial Engineering. Since 2005, He joined as researcher at Production System Laboratory, Faculty of Engineering, Universitas Sebelas Maret, Indonesia. He was received degree Doctor of Engineering from Gifu University, Japan, in 2021. His research interests are automation and production development systems engineering, human-machine interaction, intelligent machine, human factors engineering, robotics, control system engineering, and currently conducting research in Human-Automation Interaction based on bio-signal.