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Investigation of the Music's Effect on Human Brain Activity Using Electrical Capacitance Volume Tomography Brain Scanner and Electroencephalo-Graphy

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In this study, ECVT brain scanner is used to measure electrical signals generated by the activity of the human brain to the audio response. The basic principle of ECVT is the permittivity distribution mapping of objects based on data measured capacitance. Data capacitance is a response to changes in the permittivity distribution in the brain which are affected by brain electrical potential. ECVT system consists of shaped-helmet sensors, 32-channel data acquisition system, and a computer for image reconstruction process and display the results of scanning. Based on the experimental results, the electrical signals from the electrode capacitance shows a clear distinction, when subjects listened to classical, pop and rock music. Furthermore, it also showed that the brain electrical signal of right hemisphere is higher than the left hemisphere when listening to music. These results from ECVT are consistent with the results of measurement using EEG. Analysis of the reconstructed image show that there is an increase in brain activity in the temporal lobe when listening to rock music when compared to the classical music. ECVT brain scanners can be used to observe the electrical activity of the brain that includes auditory activity.

Keywords: ECVT Brain Scanner, Music, Image Reconstruction.

1. INTRODUCTION

Imaging of human brain activity is one of the most interesting topics in the field of neuroscience research to study how the brain works. Imaging of brain activity can also be used in the prevention and treatment of neurological disfunction. Therefore, a brain imaging technique has to be safe, non-invasive, and has a high accuracy. There are several methods in imaging brain activity. Nowadays, the method of measurement is divided into two categories, namely hemodynamic and electromagnetic methods. Hemodynamic methods measure brain activity indirectly, by observing changes in the nature of blood flow while the electromagnetic method to measure directly the electric and magnetic properties as the result of neural activities.[1] Imaging technique using hemodynamic method is Positron Emission Tomography (PET) and functional Magnetic Resonance Imaging (fMRI). While the imaging technique that uses electromagnetic method is Electroencephalo-graphy (EEG) and Magneto Encephalography (MEG).[2]

Since several years, there is an alternative method for imaging the brain namely Electrical Capacitance Volume Tomography (ECVT). ECVT was known as multimodal imaging, non-ionizing radiation technology and has a rapid reconstruction. ECVT technique utilizes non-linear changes in the distribution of the electric field to determine the permittivity distribution in the sensing region. ECVT measures the capacitance data as result of a change in the permittivity distribution between a pairs of electrodes are caused by changes in brain electrical potential. Permittivity is associated with the charge distribution that is directly related to neuronal activity in the brain.[3,4]

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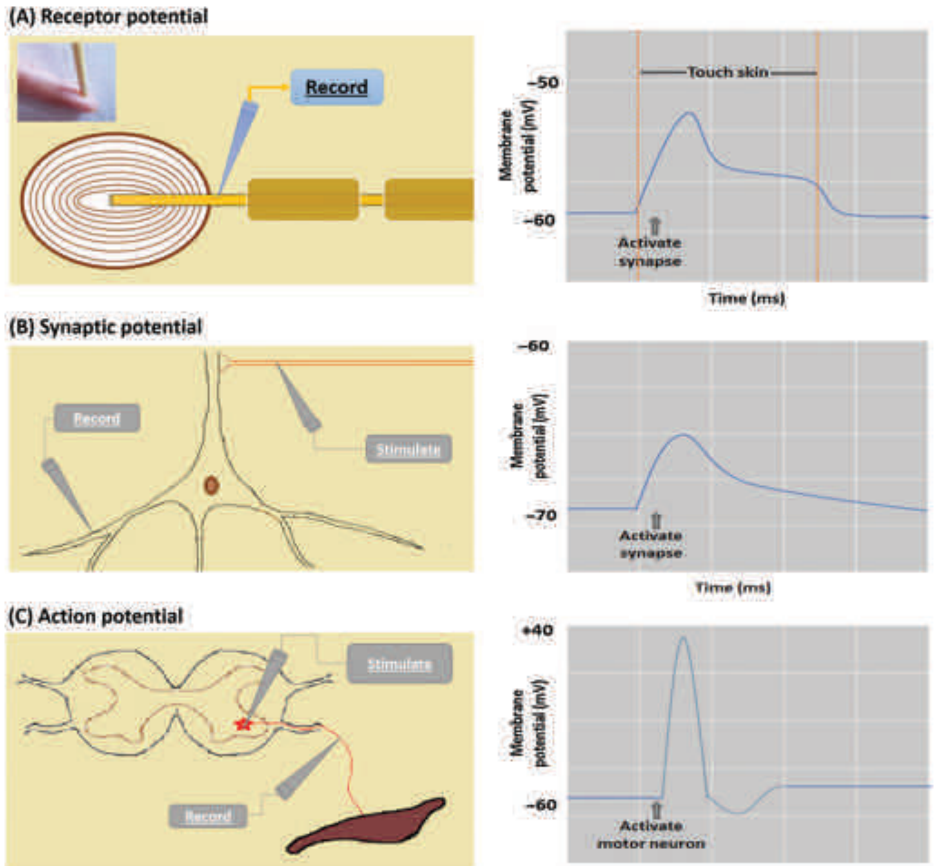

Figure 1. Three types of neuronal electrical signals.[5]

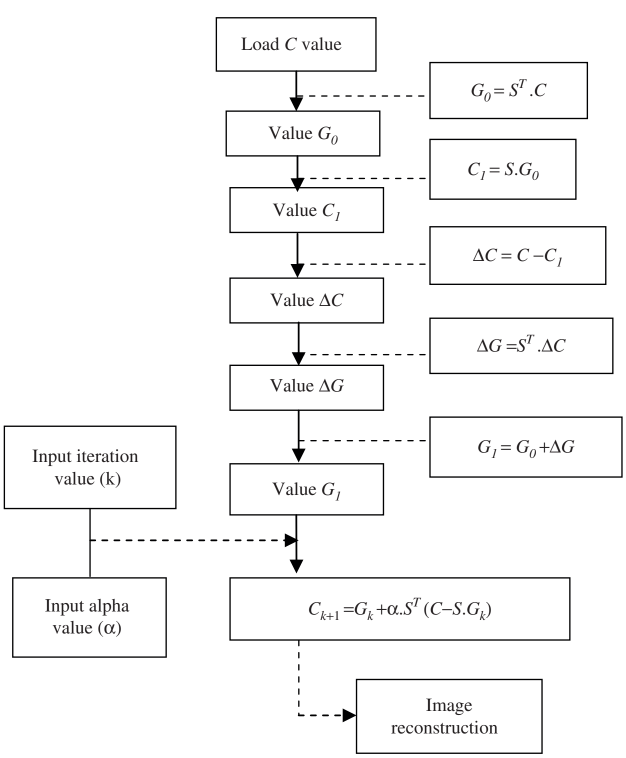

Figure 2. ILBP image reconstruction algorithm.

Neurons are organized into ensembles called neural circuits that process specific information and provide the foundation of sensation, perception, and behavior. The electrical signals produced by neurons are caused

Figure 3. ECVT brain scanner.

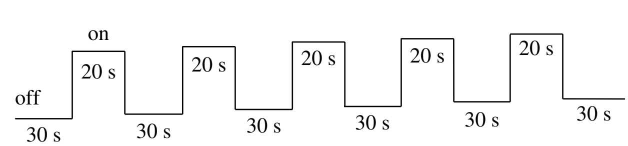

Figure 4. Schematic design of musical stimuli's time sequence.

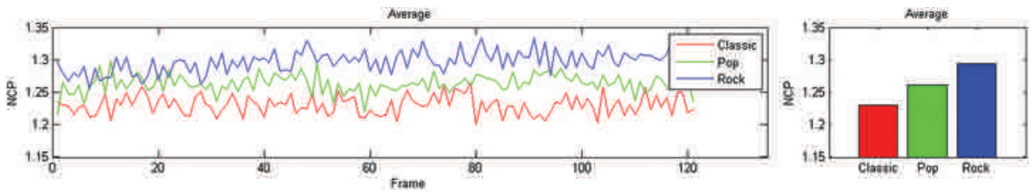

Figure 5. The differences in human brain activity signal (normalized capacitance) for the various musical stimuli.

by responses to stimuli. There are 3 types of neuronal electrical signal that is receptor potential, action potential, and synaptic potential as shown in the Figure 1.[5]

Receptor potentials are due to the activation of sensory neurons by external stimuli. The electrical signal produced by action potentials are generally very rapid (as brief as 1–4 milliseconds) and may repeat at frequencies of several hundred per second. They are large alterations in the membrane potential, they may change by as much as 100 mV.[6] Another type of electrical signal is synaptic potentials, associated with communication between neurons at synaptic contacts. The parts of the activated brain will have a lot of active neurons communicate. When the head is measured using the ECVT, electrical signals flowing in the neurons will provide electric field disturbances in certain areas. That's why with regard the brain as a dielectric material, ECVT able to monitor the activity that occurs in the brain.

This study will be assessed on experimental design using the ECVT to indicate changes in human brain activity when getting stimulus in the form of audio (music). The hearing ability, meaning information, and language in the form of music related to the function of cerebrum, especially in the temporal lobe. Furthermore, the analyzed data ECVT is compared to the results of analyzed data from EEG signals for the similar test condition.

2. METHODS

2.1. Subjects

The study involved 10 subjects consisted of five women and five men, with an age range between 20–35 years. The selected subjects had normal hearing ability and no history of disease associated with abnormalities in brain function.

2.2. Principle of ECVT

ECVT is a dynamic volume imaging method which is based on the principle of ECT. The ECVT process includes two stages, the first is the data acquisition process, measuring of data capacitance from the sensor electrode (forward problem). The second stage is the process of image reconstruction from the measured capacitance data (inverse problem). Measured capacitance between the source and the electrodes can be calculated by the equation:[3]

$$C_i = -\frac{1}{\Delta V_i} \oiint_{A_i} \varepsilon(x, y, z) \nabla \phi (x, y, z)\, dA \tag{1}$$

where ΔV_i is the voltage difference between the pair of electrodes, A_i is the surface area enclosing the detector electrode, $\varepsilon(x, y, z)$ is the permittivity distribution and $\phi(x, y, z)$ is the electric potential distribution. Equation (1) can be solved by linearization technique called model of sensitivity, which can be written in form of matrix:

$$C = SG \tag{2}$$

where $\boldsymbol{C}$ is the measured capacitance vector, $\boldsymbol{G}$ is the image vector (distribution of permittivity), and $\boldsymbol{S}$ is the sensitivity map.[3]

In image reconstruction, the inverse technique is implemented. This technique includes the estimation of the permittivity distribution of the data and the measured capacitance sensitivity matrix, which can be written:

$$G = S^T C \tag{3}$$

To reconstruct image, the method of Iterative Linear Back Projection (ILBP) is used. The flowchart of this method shows in Figure 2.

2.3. Experimental Design

The process of data collection is done by using a set of ECVT brain scanner consisting of shaped helmet sensors, data acquisition system and a computer for image reconstruction and display. The experiment used 32-channels DAS (DAQ 0312005, manufactured by CTech Labs) with data retrieval speed of 1.3 sec per frame. ECVT system is shown in Figure 3 below.

Data acquisition was performed on two conditions: relaxed condition (as a baseline) and given stimulus in the form of music with different genres include classical, pop and rock music. Scanning time for each kind of music takes 280 seconds with time squence shown in Figure 4.

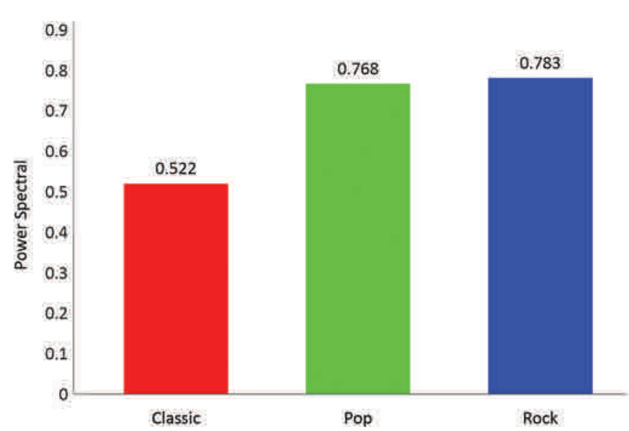

Figure 6. The histogram of alpha brain wave's average intensity for the various musical stimuli.

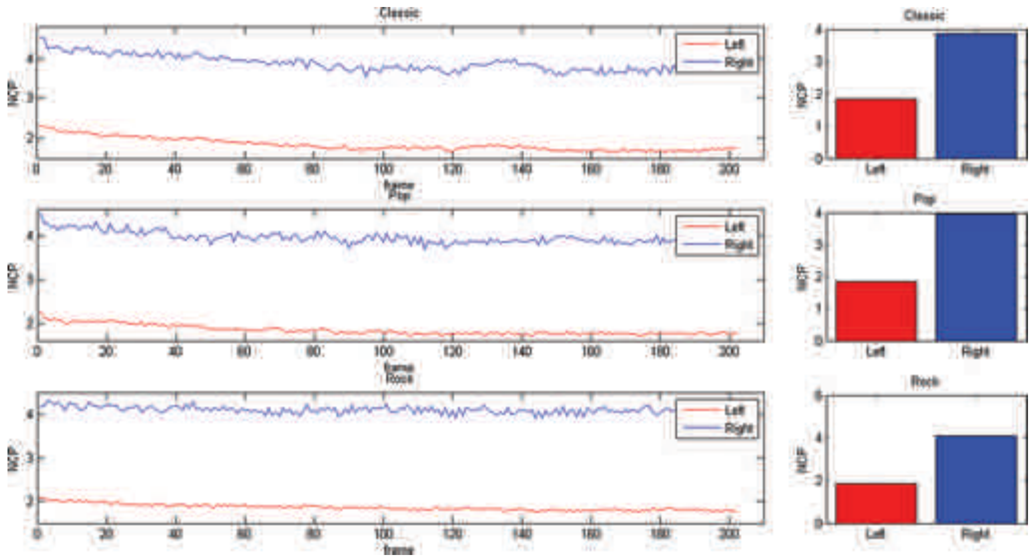

Figure 7. The normalized capacitance's signal ECVT of the left brain and the right brain for the various musical stimuli.

2.4. ECVT's Signals Analysis

The raw data from the measurement were normalized before being analyzed. The average capacitance from all electrode pairs for each condition was calculated. Using Iterative Linear Back Projection (ILBP) algorithms, measured capacitance data are reconstructed. The results presented in the form of image, in slices of axial, then they are able to be analyzed.[7]

2.5. EEG's Signals Analysis

The effect of music on the brain activity was analyzed with EEG as well. This analysis used as a comparison

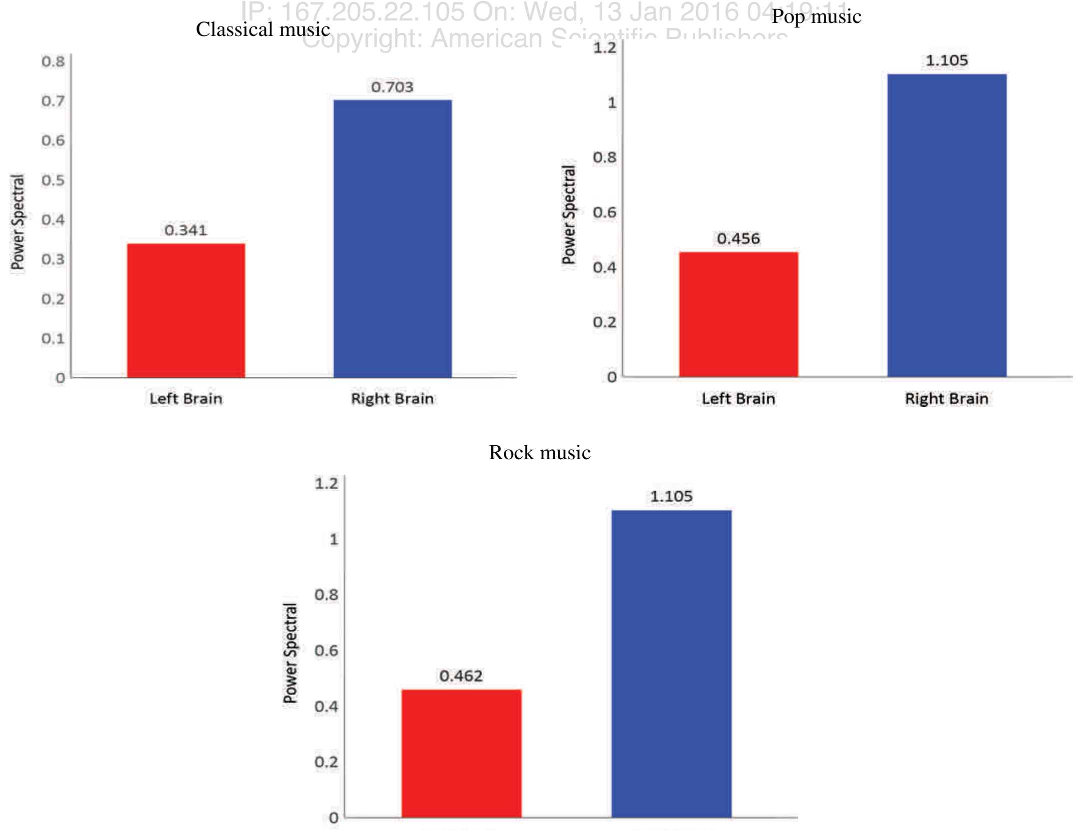

Figure 8. The differences in the EEG alpha brain wave of the left brain and the right brain when listening to music.

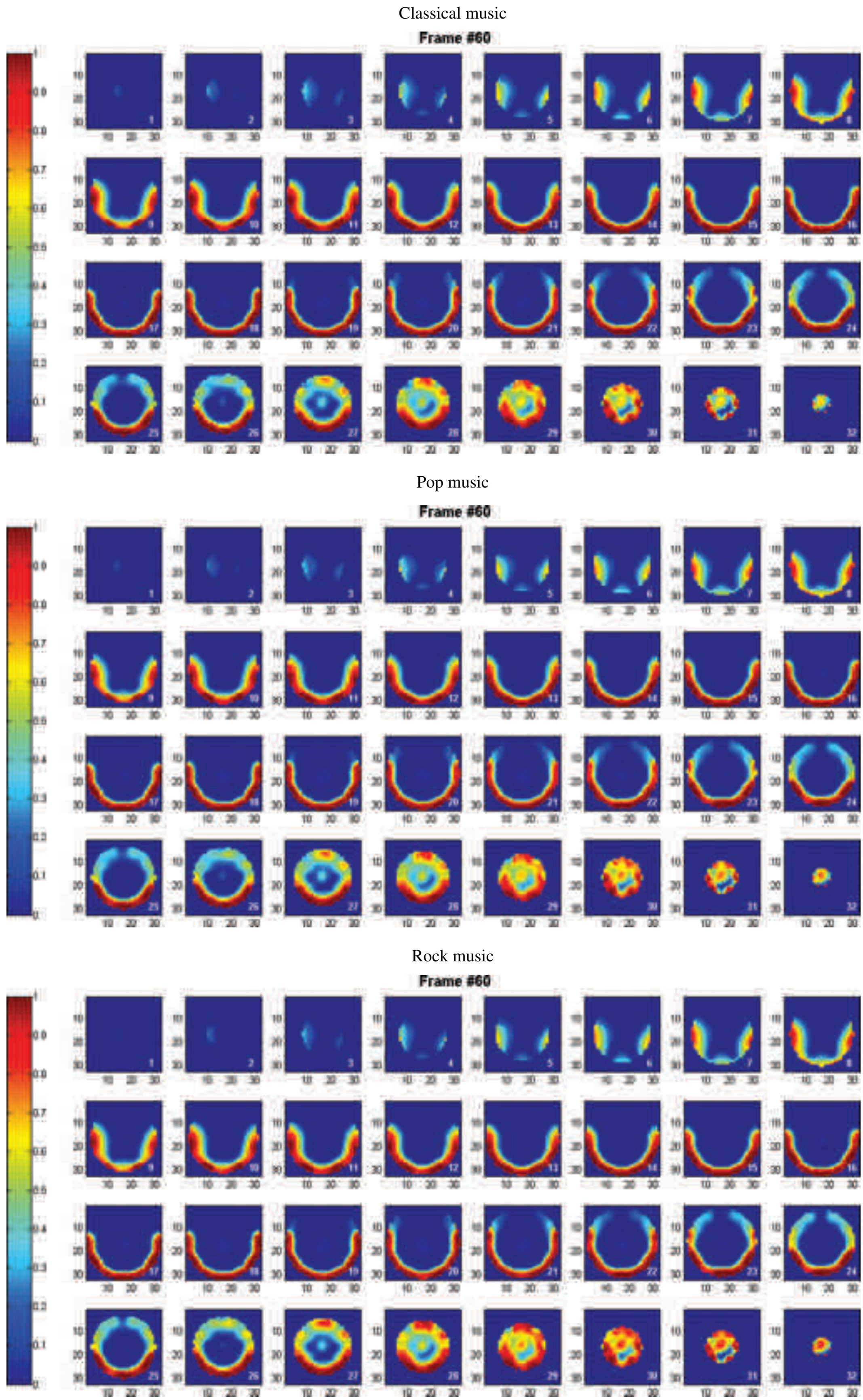

Figure 9. The 32-slices of reconstructed ECVT image for brain activity related to listening music.

because ECVT not have the golden standard. EEG is measured brain waves at different frequencies in the brain. The method used in the analysis of EEG data is a decomposition into different frequency ranges based on the Fourier transformation which includes Delta waves (0.5 to 4 Hz) associated with the deep sleep, Theta waves (4–8 Hz) associated with drowsiness, Alpha waves (8–12 Hz) associated with relaxed, alert state of consciousness, Beta waves (14–30 Hz) associated with active, busy or latexious thinking.[8] In this research, recording EEG signals carried on the subject with relaxed conditions when given the stimulus of music, so the data is analyzed only the alpha waves.[9]

3. RESULTS AND DISCUSSION

The results of this study showed differences in brain activity at the relax condition (no stimuli) and with auditory (musical) stimuli. The type of musical stimuli can be divided into three types: classical, pop and rock music. Based on the results of the ECVT data analysis (Fig. 5) showed that brain activity's signal is the highest when subjects listen to rock music and the lowest when subjects listen to classic music. The result of ECVT measurement expressed in ncp (normalized capacitance) while the result of EEG measurement expressed in the power spectral. The magnitude of the measured electrical signals in the brain when given classic, pop and rock musical stimulus, sequentially expressed in the histogram of red, green and blue.

In Figures 5 and 6 shows that the pattern of the signal measured by ECVT well-matched with EEG's signal. This means ECVT brain scanner which being developed has been able to measure changes in brain activity affected by musical stimuli.

Music is classified as a right-brain activity. It means that the act of processing music is centered on the right hemisphere of the brain.[10] From the analysis of the comparison between the activity of the left brain and right brain, which the right brain's signal was higher than the left brain's signal when listening to music. The results of this study also strengthen this phenomenon as shown in Figure 7 for ECVT's signals and Figure 8 for EEG's signals.

In this study, to see the differences in brain activity through a 3D image, the observation focused on the temporal lobe. ECVT scanning data extracted from the electrodes close to the temporal lobe of the left and right hemispheres only. From the Figure 9, the brain activity's signal shows pattern's change in the temporal lobe, especially when listening to different types of music.

For each data acquisition process (scanning) is obtained 186 frames. To facilitate the investigation, the analysis of the reconstructed image is displayed in axial slices as many as 32 slices from the bottom to the top of the head. Each slice contains 32×32 voxels in the x–y plane. Axial image data in Figure 7 was taken from the 60th frame. The red color on the image expressed high brain activity signals while the blue color expressed low brain activity signals. By visual inspection we can see in Figure 9 especially at slices 25–32 (near temporal lobe) that the brain activity signal more active when listening to rock music.

4. CONCLUSION

ECVT brain scanners can be used to observe the electrical activity of the brain that includes auditory activity. From the measured capacitance values of the brain, it is clearly found the differences on the brain activity's signal when listening to different types of music. The activated parts of the brain can be seen from the image of reconstruction process. From this study, it can be seen that the temporal lobes of both right and left hemisphere are activated during listening music.

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