Investigate Brain Dominance with the help of EEG Signal Processing

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Abstract:

Brain Dominance is the more preference of one side of the brain while performing any activity. Knowing dominance helps an individual for improving his/her performance. Previously many studies have been conducted to identify one's dominance with questionnaires, but this study tends to identify the dominance of individuals with EEG Signal Processing. The study was conducted by performing two activities by the subjects, activity one Listening to Music which is the Right Brain activity, and the second task was Learning which is the Left-Brain activity. The results of EEG signals are compared with the designed questionnaires Brain Dominance Test. In this study, the Components maps, or topography are used for identifying the dominance and tracking the activity of the brain. The topography has represented the strength of the EEG signal with colors, red represents high EEG signal strength, Green with neutral strength, and Blue with Low strength.

While performing learning task the state of brain is more active and signal strength is high, whereas music decreases the activeness and increases relaxation due to which the strength of signals is low. Hence, learning activity is presented using red and music with blue color. The region of component maps is extracted respectively. The maximumly occurring patterns were used for identifying the dominance that is the electrodes maximumly occurring within the same or repetitive patterns in respective activity are considered for Brain Dominance identification. The results of brain dominance obtained from signals i.e., component maps are compared with the designed questionnaire (Brain Dominance Test) and from the results it is found that brain dominance of an individual can be identified with the help of EEG signal processing.

Keywords—Brain Dominance, Component Maps, Left Brain, Right Brain, Learning, and Music.

Introduction:

One of the most important organs in the human body is the Brain which controls numerous functions of the body. The brain is broadly composed of three main components: the cerebrum, the cerebellum, and the brainstem. The cerebrum is the largest part of the brain and is divided into two main sections termed hemispheres [1, 2]. These hemispheres possess complementary abilities called Left Brain (hemisphere) and Right Brain (hemisphere). The way these abilities of the hemisphere are used determines the personality and behaviour of the person. Both the hemispheres serve in different ways to sensory input and external stimuli as in Figure 1 below.

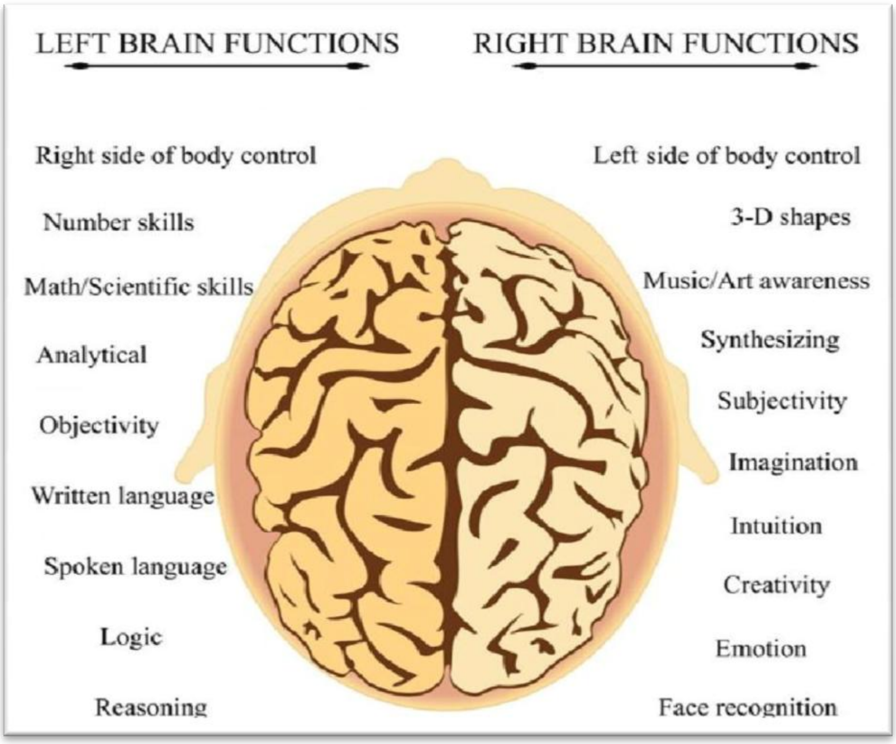


Figure 1: Function of Left and Right Hemisphere [1]

The primary determinant lies in the hemisphere you favour for processing is called to be "Dominance" or "Preference" [3]. Typically, individuals tend to exhibit dominance towards one side of the brain, leading to the classification of left or right brain dominance in most people. However, it is also possible for a person to maximize the utilization of both hemispheres. In this case, the individual is referred to as having a balanced left and right brain, and they are commonly known as a whole brain thinker. Multiple studies indicate that attaining brain balance has the potential to unlock the full capabilities of the brain. This aspect is considered a significant contributing factor to the successful accomplishments observed in an individual's life [8]. To assess an individual's brain dominance level, several tools and methods can be utilized to gather relevant information, such as Herrmann Brain Dominance Instrument (HBDI), Open Hemisphere Brain Dominance Scale, The Kolb Learning Style Inventory, Perceptual Learning-Style Preference, etc. [1]. Out of these methods, EEG stands out as the most suitable approach due to its non-invasive nature, portability, and high sampling frequency [8]. The captured waveforms depict the cortical electrical activity. These electrical activities, measured in microvolts (mV), are relatively small in magnitude [2,5,6,7]. Bioelectric signals reveal the complex dynamics of electrical activity in a population of neurons within the cerebral cortex, characterized by patterns of shots with nonlinear properties. As a result, the collective activities of neurons exhibit chaotic behavior, contrasting with the diverse activities observed in daily life.

Literature Review:

The preference for one hemisphere over the other, known as brain dominance, is a significant issue that should be considered when acknowledging individual differences. Due to distinct functions performed by the brain's hemispheres, research has sparked curiosity regarding the impact of dominance on various sectors and achievements. Numerous researchers worldwide have employed diverse tools and techniques to explore this phenomenon. Acquiring knowledge about our own thinking patterns, as well as those of others, empowers us to make better decisions, enhance empathy and relationships, improve communication, and problem-solving abilities, and facilitate enduring decision-making processes [1].

The theory of left and right brain dominance has been well-established for several decades. Additionally, the concept of balancing education and training between the left and right brain has been developed over many years. Presently, the primary method of determining an individual's left or right brain dominance is through questionnaire assessments. However, there is currently a lack of scientific data that directly correlate brain activity with the left and right brain theory, as well as the effectiveness of training for left and right brain development. A study was conducted to determine the brain dominance level and was benched marked with the Hermann Brain Dominance Instrument (HBDI) test. The HBDI test is a widely used assessment tool employed by numerous multinational companies to determine the brain dominance level of their employees. The EEG Topographical Power Spectral Density Percentage (EEGTPSDP) method was employed for analyzing the EEG signal. The findings obtained through the EEGTPSDP method provide compelling evidence of a robust correlation between brain dominance level and EEG power spectral density on a specific hemisphere. The application of the EEGTPSDP method allows for the classification of an individual's dominant brain hemisphere. Consequently, this research holds the potential to make valuable contributions to the field of education by accurately determining students' brain dominance levels and tracking their learning progress using a scientifically grounded approach based on EEG signals [8].

Advanced software tools like EEGLAB have revolutionized the processing and visualization of electroencephalography (EEG) signals, facilitating the analysis of signal traces and cortical topography. The visualization of cortical electrical activity is done through topography. The topographical maps or topoplots are also known as Component scalp maps. It is commonly used in studying EEG (electroencephalography) and ERP (event-related potential) [8, 14]. These topoplots are used to display the spatial patterns of neural activity that are associated with specific components or ERP waveforms. These components can represent various brain activities, such as sensory processing, attention, motor preparation, or cognitive functions. Topoplots are created by calculating the amplitude or activation levels of the component at each electrode location and then representing these values using color, shading, or contours on a scalp template. The use of this topography in EEG is often not used for investigation because of its representation through colors that make classification difficult. The distribution of color, among the ICs, represents the strength of the EEG signal as largest by red and small by blue [9]. The objective of this study is to Investigate Brain Dominance with the help of EEG Signal Processing via topography.

Methodology:

The steps used in this study for investigating brain dominance by means of EEG signals via topography are in Figure 2.

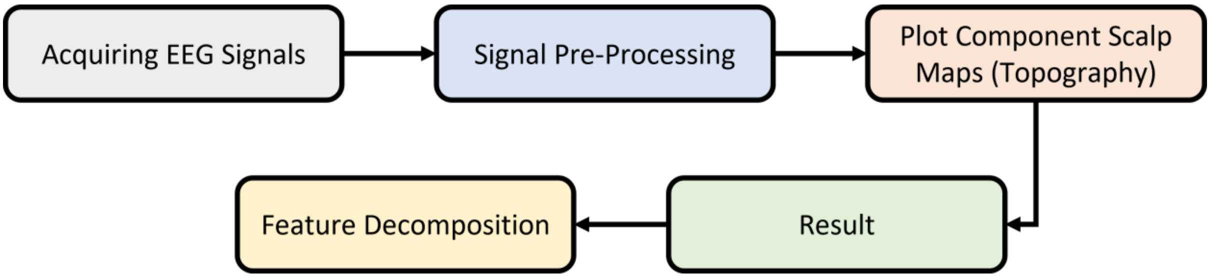


Figure 2: Methodology for Identifying Dominance

Acquiring EEG Signals:

The first step of gathering data was started by explaining the process of the experiment to the subjects and signing the consent form. For the experiment 5 (2 female and 3 male) research scholars from the Department of Computer Science and Information Technology, Dr. Babasaheb Ambedkar Marathwada University contributed, who were in the age bracket of 25 to 38 were selected, and their information was kept private. Two different types of data are gathered from subjects: Questionnaire (pen-paper Test) and EEG Test.

The device used for conducting the experiment is 14 electrode Emotiv EPOC. The device was placed on the scalp of the subject according to a 10-20 electrode placement system as in Figure 3 below. Electrodes with odd numbers are on the left side and even on the right side of the brain.

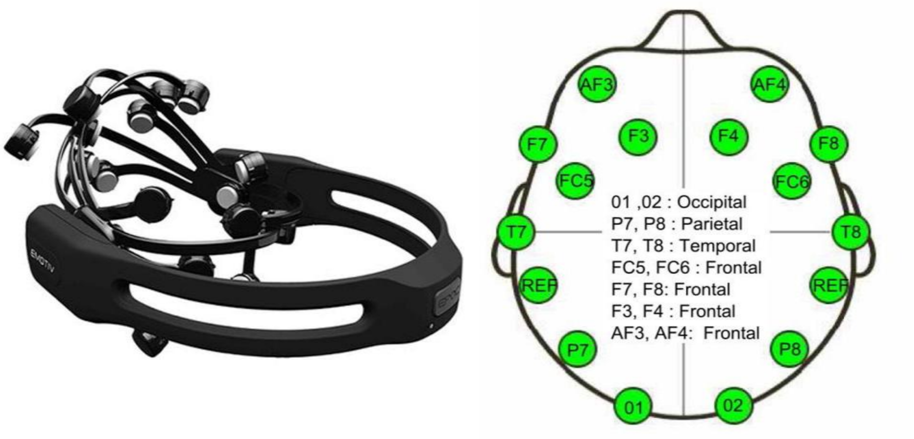


Figure 3: Emotiv EPOC and 10-20 Electrode Placement System [16]

After connecting the device to the scalp, the subject was asked to sit on a chair comfortably. The data collection process was completed by performing two tasks listening to music and learning. Relaxing Music from Yellow Brick Cinema was played loudly for 3 minutes, and subjects were asked to close their eyes, relax, and listen to music. Learning activity was performed by making subjects read 10 articles which were selected from newspaper cuttings and literature. All articles were converted to Regional (Marathi), National (Hindi), and Foreign (English) languages. Each article was read 3 times by the subject. The detail of the experiment is elaborated in Figure 4 below.

Figure 4: Data Acquisition Steps [16]

Raw EEG signals emitted by Emotiv EPOC were captured via TESTBENCH Emotiv Research Edition SDK. The raw signals obtained were in EDF format, which was processed through EEGLAB, an open-source signal processing toolbox for signals to be executed on MATLAB.

Once the EEG data acquisition was completed, subjects were asked to attempt a pen-paper test which is a set of designed questionnaires termed Brain Dominance Test. Before attempting the test, subjects were provided with the instruction that there is no time restriction for attempting the tests and no response to any question carries any marks neither the response is right nor wrong.

Signal Pre-processing:

One of the most important steps is pre-processing, as it helps to transform raw EEG signals to a standard format, enhance the signal-to-noise ratio, and eliminate unnecessary artifacts from the signal [10, 16]. In this study, we utilized EEGLAB as the tool for pre-processing the data. The steps followed for pre-processing the data can be seen in Figure 5 below.

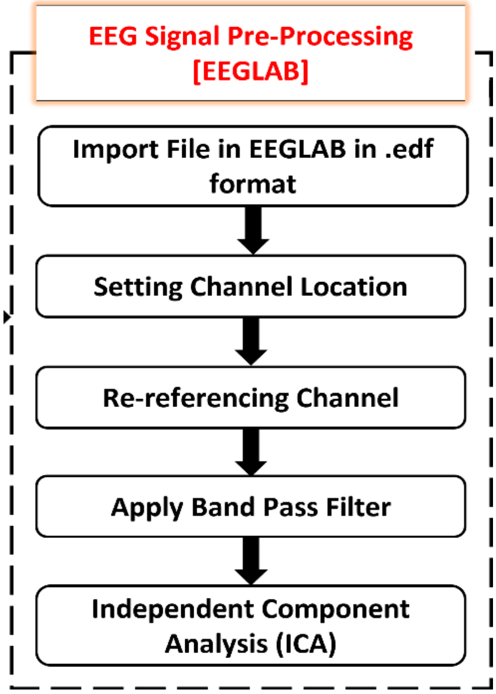


Figure 5: EEG Signal Pre-Processing Steps [16]

EEG signal data acquired from TESTBENCH is obtained in EDF format and is initially imported into EEGLAB for further processing. After importing the EDF file, the channel locations were standardized using the "emotiv.ced" file, which represents the external international 10-20 electrode placement system [11,12]. The obtained data contains information in 36 columns from which only 14 columns contain the EEG data (Columns 3 to 16), hence referencing is done to remove unwanted information [13]. After referencing the data, a bandpass filter is applied, and at last Independent Component Analysis (ICA) is employed on the signal to eliminate artifacts and restore the original features that were blended in a linear combination with the input dataset.

Plot Component Scalp Maps:

The pre-processed sheets after applying ICA 2D Component maps are plotted with the help of EEGLAB in MATLAB. These independent component maps in 2D can be seen in Figure 6 below.

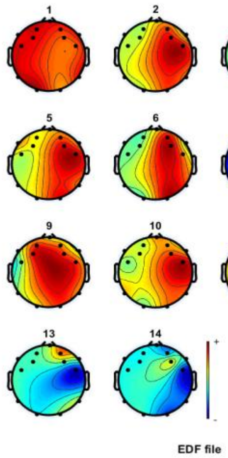


Figure 6: Representation of Component Scalp Map (Topography). Next to the last IC is the Color Spectrum representing the strength of the EEG Signal Red (Large), Green (Neutral), and Blue (Small).

Feature Decomposition:

The initial phase, known as feature decomposition, closely emulates the early processes of biological visual perception. The initial step in image processing involves decomposing the image into an intensity map and four-color channels with broad tuning. $I=(r+g+b)/3$, $R=\lfloor\tilde{r}-(\tilde{g}+\tilde{b})/2\rfloor+$, $G=\lfloor\tilde{g}-(\tilde{r}+\tilde{b})/2\rfloor+$, $B=\lfloor\tilde{b}-(\tilde{r}+\tilde{g})/2\rfloor+$, and $Y=\lfloor(\tilde{r}+\tilde{g})/2-|\tilde{r}-\tilde{g}|/2\rfloor+$, where $\tilde{r}=r/I$, $\tilde{g}=g/I$, $\tilde{b}=b/I$, and $\lfloor x\rfloor+=\max(x, 0)$. Next, the four-color channels are merged to create two color opponent channels: R - G for red/green opponency and B - Y for blue/yellow opponency. The feature space X is composed of these color channels, including the intensity map, the red-green opponency channel (R - G), and the blue-yellow opponency channel (B - Y) [15]. With this, the red and blue colors are separated from the component maps or topography. The figure below shows the extracted red and blue colors.

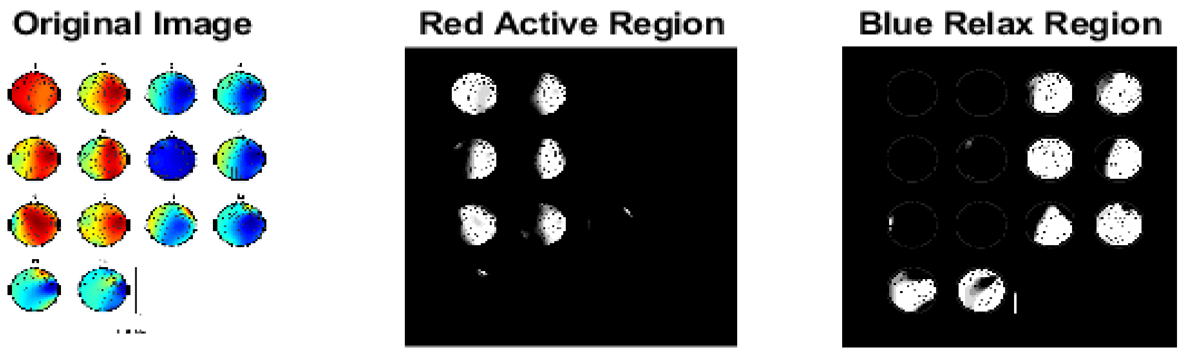


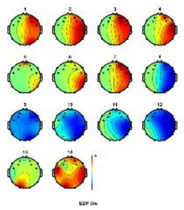
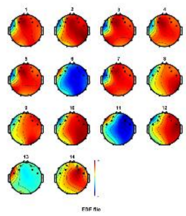
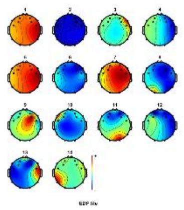
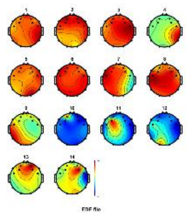
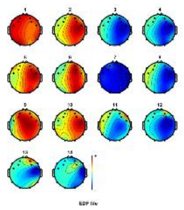
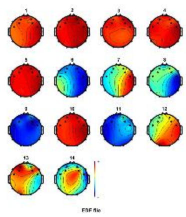
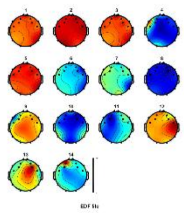
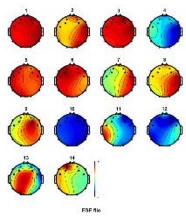
Figure 7: Separation of Red and Blue Color from the Component Map Image

Figure 3 shows that electrodes with odd numbers are on the left side of the brain and even on the right side of the brain. In the component scalp (figure 6), maps 1, 2, 3, 4, 5, 6, and 7 ICs represent the left side of the brain, and 8, 9, 10, 11, 12, 13, and 14 represent the right side of the brain. In this study, we have gathered data from two different activities listening to music and learning. Listening to music is the right-brain activity and learning is the left-brain activity. While learning the subject is more active and activity in the left part is represented with red color in the component map whereas while listening to music the subject is relaxed, and the right part of the brain becomes more relaxed and represented with blue color.

Result:

The EEG signals are represented here with 2D component maps (IC's). As in feature decomposition, red color in IC's is to represent learning activity and blue color for relax state of listening to music. Maximum number of electrodes active while performing this activity are obtained and summarized result of this with a sample spectrum are detailed in Table 1 below. The Table 1 also details the comparative results of EEG signals with the designed questionnaire the "Brain Dominance Test".

Table 1: Results of EEG and Questionnaire for Brain Dominance.

Subject	**Sampler Spectra for Music**	**Sampler Spectra for Learning**	**Max Active Electrode for Music**	**Max Active Electrode for Learning**	**Own Questionnaire "Brain Dominance Test"**
Subject1			7, 8, 9, 10, 11, 12, 13, 14	1, 2, 3, 4, 5, 6, 7, 10, 11, 14	Right Brain
Subject2			3, 4, 6, 8, 9, 10, 11, 12, 13, 14	1, 2, 3, 4, 5, 6, 10	Left Brain
Subject3			6, 7, 8, 9, 10, 11, 12, 13, 14	1, 2, 4, 5, 6, 7, 8, 10	Left Brain
Subject4			3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	1, 2, 3, 4, 5, 6, 7	Left Brain

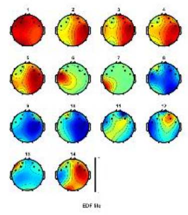
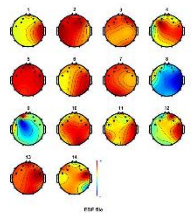
Subject5			7, 8, 9, 10, 11, 12, 13, 14	1, 2, 3, 4, 5, 6, 7, 8, 11, 13, 14	Right Brain

Table 1 above shows that while listening to music Right part of the brain is active and during learning left part is active. The EEG signals component maps observations display that while performing the non-dominant activity some part of the dominant side is active but very less active as compared to the other side. For example, in subjects 1 and 5 some part of the right brain is active while learning whereas in Subjects 2, 3, and 4's some part of the left brain is active while listening to music. The observations shows that subject 1 and 5 are Right Brain dominant person whereas subject 2, 3, and 4 are Left Brain dominant person. The test results of designed Questionnaire "Brain Dominance Test" completely correspond with the EEG results.

Conclusion:

Identification and knowledge of an individual's Brain dominance are important as it helps in improving performance. So far, the identification of brain dominance is done through the Pen-Paper method via Questionnaire, this study attempts to identify brain dominance through EEG signals. The component maps are obtained of the subjects while performing two tasks listening to music and learning and their results are compared with the designed questionnaires Brain Dominance Test. The results show that the Brain Dominance Test completely corresponds with EEG results and hence brain dominance can be identified with the help of EEG Signals.

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