Analyze Learning, Attention, and InformationProcessing through EEG Signal Processing

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Abstract: Neurocognition is the mental process accountable for doing many tasks among these tasks learning, attention, and information processing are undertaken. This study shows the impact of listening to music on learning and analyzes the attention and information processing while pursuing learning in three different languages as Marathi (Regional), Hindi (National), and English (Foreign) Language. To achieve the target, 10 articles in three languages were given to the 5 subjects and EEG signals were captured for task completion. The device used for acquiring signal was Emotiv EPOC with 14 channels. EEGLAB open-source signal processing toolbox by MATLAB is used for processing the signal. Fast Fourier Transform (FFT) is used for feature extraction. Data analysis is done using statistical techniques, Mean and Standard Deviation. Results show more activity in the right lobe while listening to music whereas high activity in the left lobe is seen during language learning. Music helps to improve concentration levels during learning. From learning and information processing it is seen that the performance and understanding are excellent in the Regional (Marathi) Language, good in the National (Hindi) language, and low in the Foreign (English) Language. It is seen that understanding is excellent in the regional language and even the time required for processing information is less. Moderate time is needed for the National language and more time is needed for understanding the foreign language.

Keywords: Language, Learning, Attention, Information Processing, EEG Bands (Delta, Theta, Alpha, Beta, and Gamma), Music, Regional (Marathi) Language, National (Hindi) language, and Foreign (English) Language.

1. Introduction:

The Brain is an incredible three-pound organ in humans that controls various functions of the body. Broadly brain is composed of three components as Cerebrum, Cerebellum, and Brainstem. The Cerebrum is the largest part of the brain and is composed of two hemispheres as Left and Right hemispheres. Each hemisphere performs different activities like Left Hemisphere: Number skills, Math /Scientific skills, Analytical, Objectivity, Language, Logic, and Reasoning Right Hemisphere: 3-D Shapes, Music/Art Awareness, Synthesizing, Subjective, Imagination, Intuition, Creativity, Emotion, and Face recognition. These hemispheres have distinct clefts that divide the brain into four lobes Frontal, Temporal, Parietal, and Occipital as in figure 1. Each lobe is again

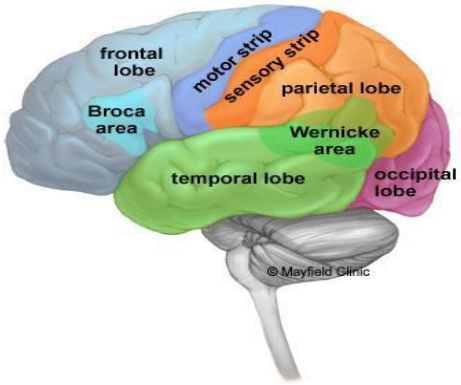


Figure 1: Brain and Lobes

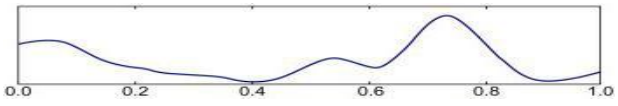
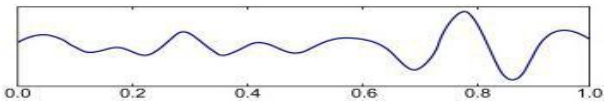
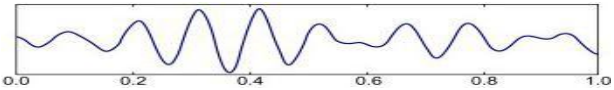
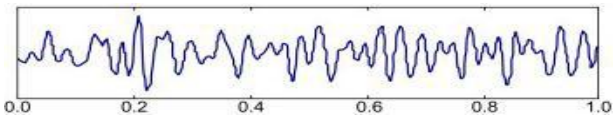
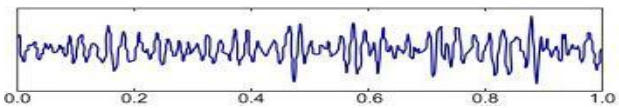
subdivided into subareas that serve special functions. The lobes of the brain do not work alone, they have a very complicated relationship with both the left and right hemispheres. Table 1 below shows the various responsibilities carried out by specific lobes [1, 2, 3].

Table 1: Brain Lobes and their Responsibilities

Sr. No.	***Lobe***	***Responsibilities***
1	*Frontal*	*Emotion, Forming Personality, influencing decisions, Judgment, planning, problem-solving, Motor Functions, Speech: Speaking and Writing (Broca's area), Intelligence, Concentration, Self-Awareness, Movement, Short-Term memory, etc.*
2	*Parietal*	*Speech, touch, pain, temperature, sensory, Spatial, visual perception, Information Processing, etc.*
3	*Temporal*	*Interpret sound and language with hearing (Wernicke's area), Long Term Memory Storage, Process new Information, formation of verbal and visual memories, etc.*
4	*Occipital*	*Visual and Spatial Processing, Movement, Color Perception, etc.*

The brain is composed of nerve cells called neurons. These cells are responsible for receiving sensory input from the peripheral world, sending motor commands to body muscles, and converting and transmitting electrical signals [4]. The recording of these electrical signals from the brain's scalp is Electroencephalogram (EEG). The waveforms recorded show the cortical electrical activity. Electrical or EEG activities are relatively small and are measured in microvolts (mV). The frequencies obtained from human EEG waves are categorized as Delta, Theta, Alpha, Beta, and Gamma. Each electrical band has its own characteristics as in table 2 below [1, 6, 7, and 27]:

Table 2: Band Frequencies and their states

Frequency Band	***Frequency***	***Brain States***	***Signals***
Delta (δ)	*0.5-4 Hz*	*Sleep*	
Theta (θ)	*4-8 Hz*	*Deeply Relaxed, inward-focused*	
Alpha (α)	*8-12 Hz*	*Very Relaxed, passive attention*	
Beta (β)	*12-35 Hz*	*Anxiety-dominant, active, external attention, relaxed*	
Gamma (γ)	*>35 Hz*	*Concentration, Problem-Solving, Consciousness, Cognitive Processing*	

2. Literature Review:

Brain cognitive skill/function is a mental process that allows us to gain knowledge and gives us the ability to think, receive, develop, transform, select, store, and recover information, etc. received from external incentives. These functions are the brain skills that help us to carry out various tasks from simple tasks to complex ones, and even understand and relate world effectively. Numerous cognitive functions are performed by the brain as Learning, language, math skills, Attention, Problem-Solving, Perception, Memory, Decision Making, Information Processing, Motor Speed/Cognition, Planning, Thinking, concentrating, Remembering things, Visual skills, Spatial skills, etc. Different Neurocognition functions are performed by specific brain parts [4,15]. This study focuses on three functions of Neurocognition: Learning, Attention, and Information Processing.

Learning is the process of adopting the change in the condition of the world all around us, behavior resulting from experience [8]. During the Cognitive Revolution in the 1950's a new question was upraised in relation to "language and cognition". Many appeals in these findings show different areas of the brain serve different functions such as Vision, Language Processing, Memory, etc. According to Chomsky's view, a child is born with a "Language Acquisition Device" with specific Linguistic Knowledge. With the birth of Computer Science, a new concept of Human Cognition arises. A new tradition in AI and Information Processing developments in Psychology gives special importance to "Learning" [9].

Language is an important phenomenon [10]. A huge study is carried out to analyze the cognitive process of "Language Learning" with the goal to serve efficiency in communication and understanding. The focus of the studies was for understanding the impact of the mother tongue on learning other languages that are familiar or unfamiliar [11,12]. Analysis can be conducted in two ways as pen paper and spectral band analysis. The questionnaire can be used for pen paper study [10,11], for spectral analysis activities like listening, reading, speaking, etc. can be used [12,13]. The coherence i.e., quantitatively measure dependency between the brain region by EEG activity is influenced by "Gender". Women have higher right hemisphere coherence with verbal stimuli [14].

Attention is a process when the mind focuses on an activity [16] that is an ability to maintain concentration on any object, task, thought, action, etc. [15] or a Psychological and Neurophysiological phenomenon associated with the difficulty of the task. The study of attention started in the 19th century and found people becoming progressively more aware of the significance of attention having a strong association between study and work [17]. Attention concentration is the essential basis for learning and EEG, or spectral signals hold considerable information for recognizing attention and gives objective and effective solutions to detect attention in the learning process [18].

Information Processing is the process that understands the level and pattern of intelligence and measures the behavior of various abilities [19]. Learning occurs through repetitive sequences of new occurrences or events and information goes along by reconstructing the knowledge frameworks [20]. When learning occurs it must be ensured that the new information should be processed in such a way that it must be retained in Long-Term Memory [19]. For Information Processing educational objectives were broadly classified as Knowledge, Comprehension, Application, Analysis, Synthesis, and Evolution. Knowledge is defined as recalling or recognizing information, ideas, and principles of approximation in the form it was learned whereas Application defines selection, transfer, data usage, and principles for computing a problem or task with minimum directions is done [20]. The approach of information processing largely grew in the research area of attention, perception, problem-solving, concept formation, Memory, Planning, etc. [22] The mechanism on which information processing works is encoding, transforming, processing, storing, retrieval, and information utilization [23].

3. Methodology:

The tentative flow adopted for performing this study is carried out as figure 2 below:

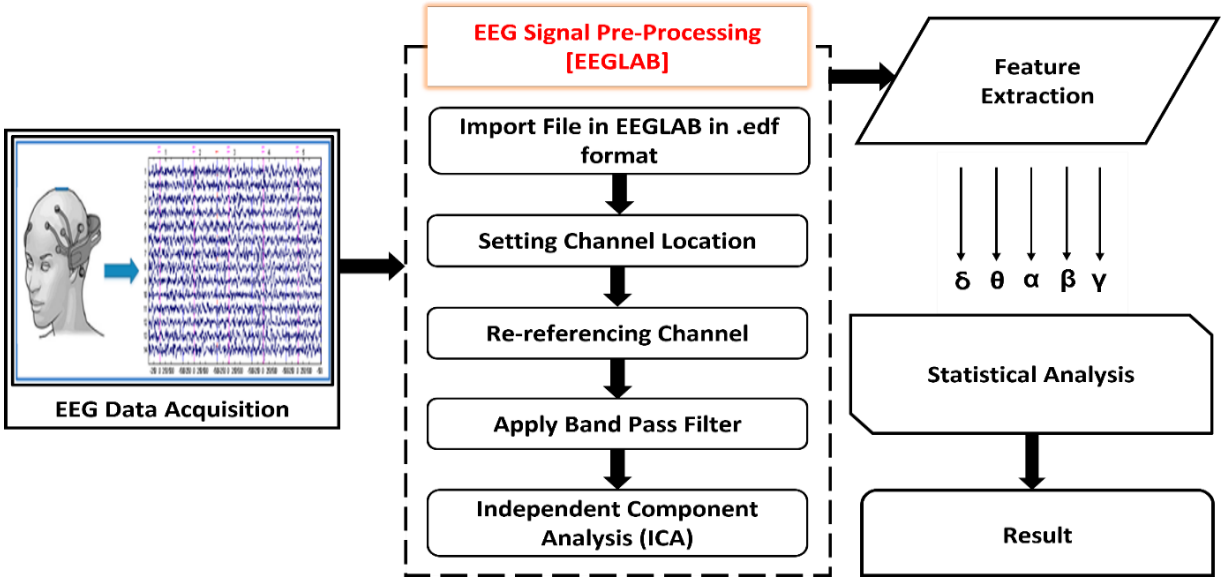


Figure 2: Workflow of Experiment

3.1. EEG Data Acquisition:

Figure 3 below presents the flowchart of the complete process adopted for acquiring the data of raw EEG signal. The experiment was conducted by explaining the process and a consent form was filled out and signed by participants involved in this study. Details of the participants are kept confidential. Overall, 5 participants (3 Male and 2 Female) were involved in the study. The 5 subjects involved were research scholars from the Department of Computer Science and Information Technology, Dr. Babasaheb Ambedkar Marathwada University aged in between 25 to 38. The subjects were informed to wash their hair, dry it properly, and not apply oil, gel, wax, or serum on hair before data collection. This was done to avoid interruptions during recording. Conduction of the experiment was done in a closed room at room temperature to avoid upheavals [24].

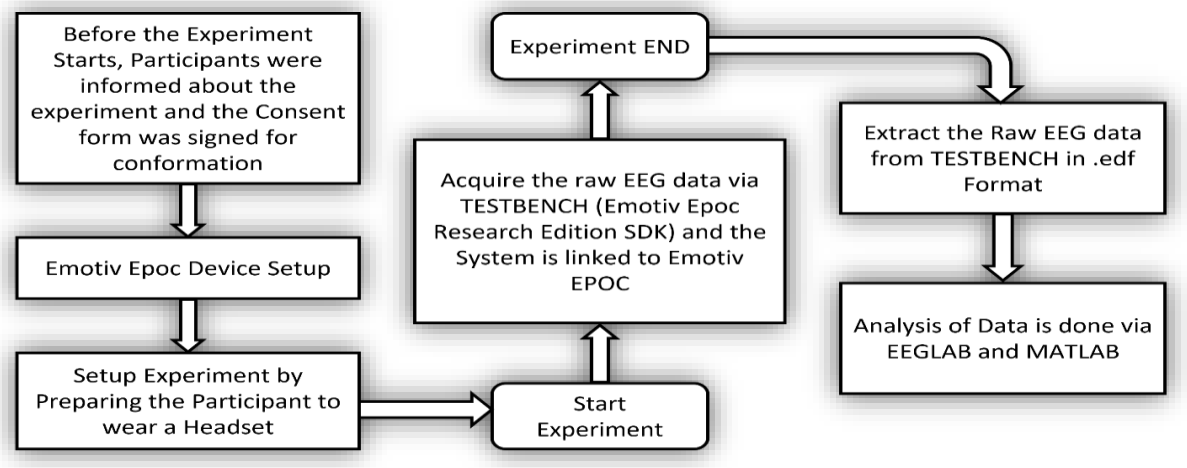


Figure 3: EEG Data Collection Process Flow Chart

The experiment starts with the preparation of wearing the headset by the participant. The device used for this experiment is Emotiv EPOC with 14 electrodes as shown in Figure 4. The 14 electrodes (channels) are placed according to the international 10-20 placement system named AF3, F3, F7, FC5, T7, P7, O1, O2, P8, T8, FC6, F8, F4, and AF4 [25,26,35]. Odd numbers represent electrodes on the left side whereas even numbers represent electrodes placed on the right side of the brain.

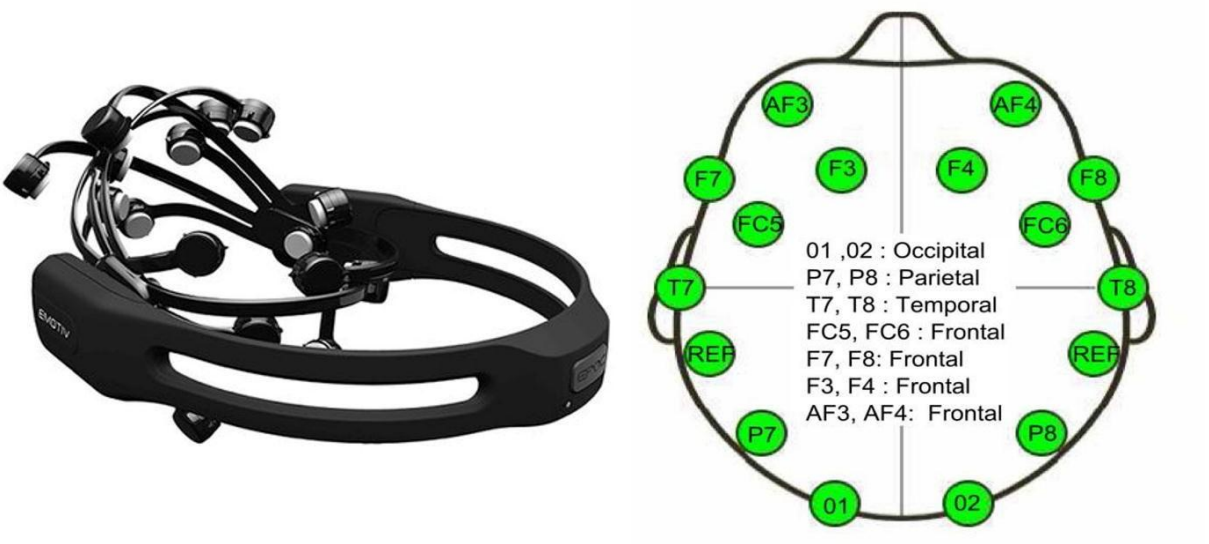


Figure 4: Emotiv EPOC and Electrode Placements

After the setup, the subject was asked to sit comfortably on a chair and relax before the experiment started. The study was conducted in 3 sections as shown in Figure 5. The music which was played is from Yellow Brick Cinema - Relaxing Music (Study Music, Concentration, Focus, Meditation, Memory, Work Music, Relaxing Music, Study, ✿161C) and was played loudly, subject was instructed to close their eyes and listen to the music for 3 minutes.

For the reading task, 10 Articles were selected from newspaper cutting and literature. Each article was converted into Marathi (Regional), Hindi (National), and English (Foreign) Language. The same article in the same language was read by the subject 3 times. The article was displayed on a computer screen via PPT and once the article was read, the subject was requested to press the bell. After the subject has read the article 3 times, the subject was expected to answer 5 multiple-choice questions based on the article read, the question was displayed on a screen and responses to the questions were collected via a Google form.

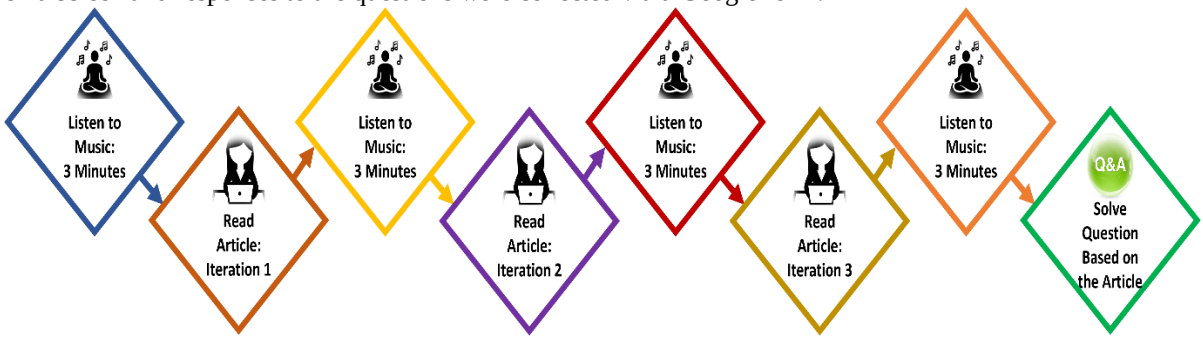


Figure 5: Experimental Flow

Emotiv EPOC was linked with software such as TESTBENCH Emotiv Research Edition SDK to obtain raw EEG data of the complete experiment. This software has helped to acquire raw EEG data from all 14 electrodes (Channels). The data acquired was obtained in European Data Format (EDF), which was further processed with EEGLAB, developed at SCCN/UCSD an open-source signal processing toolbox for electrophysiological signals to perform on MATLAB. Graphical User Interface (GUI) is provided by EEGLAB to process complex EEG data.

3.2. EEG Signal Preprocessing:

The major focus of preprocessing is to convert the raw EEG signals into the normal form, improve the signal-to-noise ratio and remove unwanted artifacts from the signal [29]. There are various methods through which EEG raw signals can be pre-processed but, in this study, we have used EEGLAB to pre-process the data. Figure 2 shows the steps followed for pre-processing.

The experimental data were acquired from TESTBENCH in .edf format is imported into EEGLAB. Once the file is imported channel locations were standardized with the external international 10-20 electrode placement system file as "emotiv.ced". [30,31]. As the data is acquired with TESTBENCH in EDF format the file contains 36 columns called labels (COUNTER INTERPOLATED AF3 F7 F3 FC5 T7 P7 O1 O2 P8 T8 FC6 F4 F8 AF4 RAW_CQ CQ_AF3 CQ_F7 CQ_F3 CQ_FC5 CQ_T7 CQ_P7 CQ_01 CQ_02 CQ_P8 CQ_T8 CQ_FC6 CQ_F4 CQ_F8 CQ_AF4 CQ_CMS CQ_DRL GYROX GYROY MARKER), which includes all data along with EEG data [32]. At last Independent Component Analysis (ICA) is applied to the signal to remove artifacts and recover the original features that were mixed in a linear combination fashion with the input dataset.

3.3. Feature Extraction:

Analysis of EEG can be done by using some methods such as Time Domain Analysis, Frequency Domain Analysis, and Time-Frequency Domain Analysis.

- *Time Domain Analysis* refers to the analysis of Mathematical functions, physical signals, or time series of economical or environmental data, with respect to time.
- *Frequency Domain Analysis* refers to the analysis of mathematical functions or signals with respect to frequency, rather than time.
- *Time-Frequency Domain Analysis* comprises those techniques that study a signal in both the Time Domain and Frequency Domain. Simultaneously, using various Time-Frequency representations.

Many researchers have used various analysis and Feature Extraction techniques as per their requirements, one among these methods is Fast Fourier Transform (FFT). J. W Cooley and J.W. Tukey discovered FFT in 1964 [34]. It is a Frequency Domain Analysis method from Spectral Methods [32,33]. In this study, FFT is used as a preferred method for feature extraction. It provides appropriate frequency domain interpretation of the signal; it is the fast and most widely used method [32] by converting it from Time Domain to Frequency Domain and obtaining frequency components [36].

3.4. Statistical Analysis:

The term "Statistics" carries a variety of meanings and is considered as one and the same ways of presenting and handling data, making logical inferences, and drawing related conclusions. It is a method of obtaining and analyzing data to make decisions. The methods through which statical data are analyzed are "Statistical Methods". The most important objective of the statical analysis is to obtain one single value that describes an entire mass of

unwieldy data, such values are called Central Value or Average or Mean. A set of observations cannot be adequately described with only mean it is necessary to describe the variability or dispersion of the observations. The Standard Deviation (SD) concept introduced by Karl Person in 1823 is the most important and widely used measure of dispersion. It measures absolute dispersion. A small SD measures a high degree of uniformity of data and homogeneity of series whereas a high SD is completely opposite [37].

Analysis of EEG data is a challenge to the high dimensionality of data. Even after initial dimensionality reduction, it involves spectral analysis in which the power spectrum is divided into frequency bands (Delta, Theta, Alpha, Beta, and Gamma), and a multitude of variables are there to analyze. The discrimination between unique components with respect to their action is not easy [38] so for this study, statistical analysis specifically Mean and Standard Deviation is used for making conclusions.

3.5. Results:

As in Figure 5 above the method adopted for conducting the experiment for acquiring data for a single recording, we examined the effect of music and reading by means of spectral bands. Figure 6 and 7 below shows the comparison of Spectral bands while performing the activity of Listening to Music and Learning. The subject was listening music for 4 times and was performing learning task for 3 times.

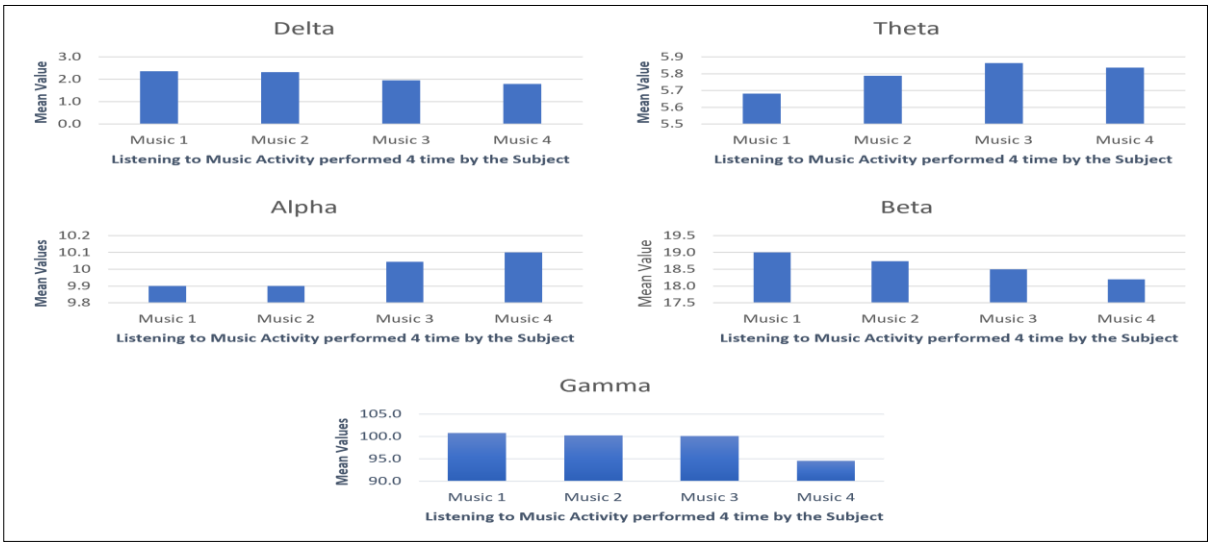


Figure 6: Effect on Spectral Bands during Listening Music

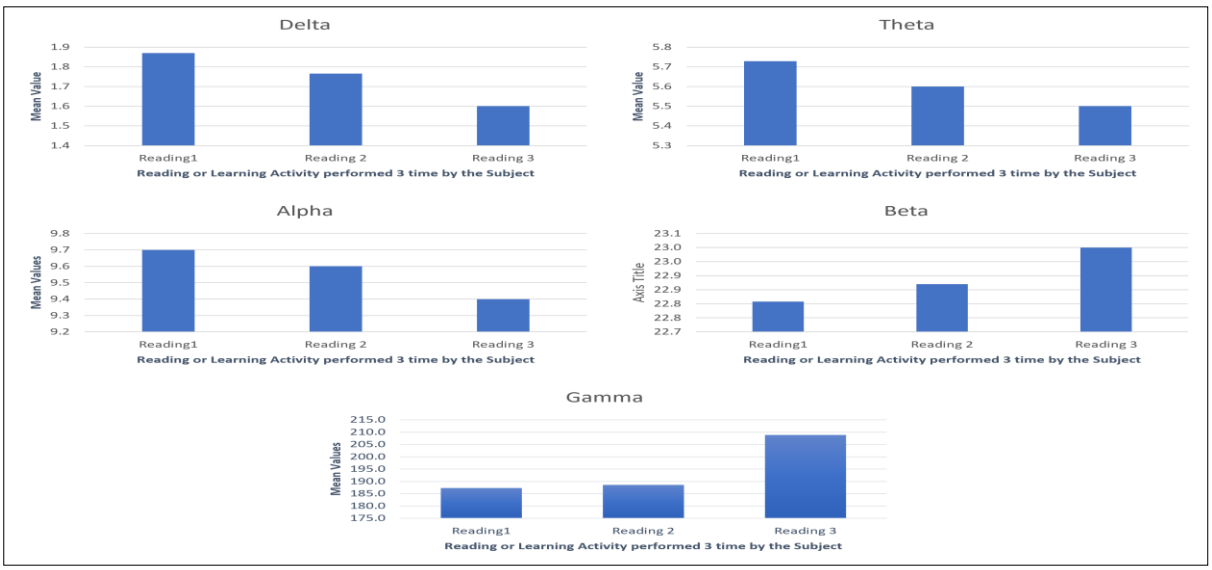


Figure 7:Effect on Spectral Bands during Learning

Delta band is responsible for sleep, it is high during listening to Music whereas low while learning. The Theta band represents Deep relaxation and inward-focused, listening to music increases the theta activity but during learning theta decreases. Alpha represents relaxation and passive attention, listening to music increases the Alpha

activity but while learning alpha decreases. The Beta band is responsible for the activity and external attention, listening to music decreases the beta activity whereas it increases while learning or reading. The Gamma band is responsible for attention or Concentration, listening to music leads the subject into relaxation hence decreases in the Gamma activity is observed whereas it increases during learning or reading. Overall, it is observed that while listening to music relaxation increases and concentration decreases, whereas while learning relaxation decreases and concentration increases.

Figure 8, 9, 10, 11, and 12 below shows the influence of music and learning on the left and right sides of the brain and the different patterns that can be seen in different spectral bands. It is observed from Figures 8, 9, and 10 that Delta, Theta, and Alpha bands are more active in the right hemisphere (AF4, F8, F4, FC6, T8, P8, and O2) and low in the left hemisphere (AF3, F7, F3, FC5, T7, P7, and O1). As compared to learning these bands show high performance while listening to music. High Performance of Beta and Gamma bands are found in the left hemisphere (AF3, F7, F3, FC5, T7, P7, and O1) while learning and in the right hemisphere (AF4, F8, F4, FC6, T8, P8, and O2) while listening to music. As compared to learning very low activation of the gamma band is seen while listening to music which means the subject is very calm or relaxed.

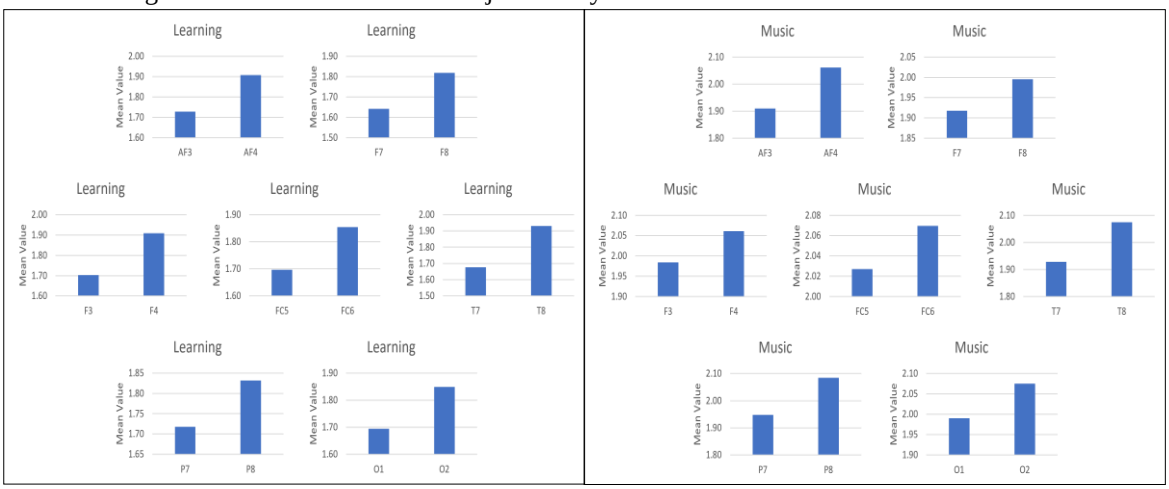


Figure 8: Comparison of the effect of Delta Activity for Learning and Music on the left and right hemispheres of the brain.

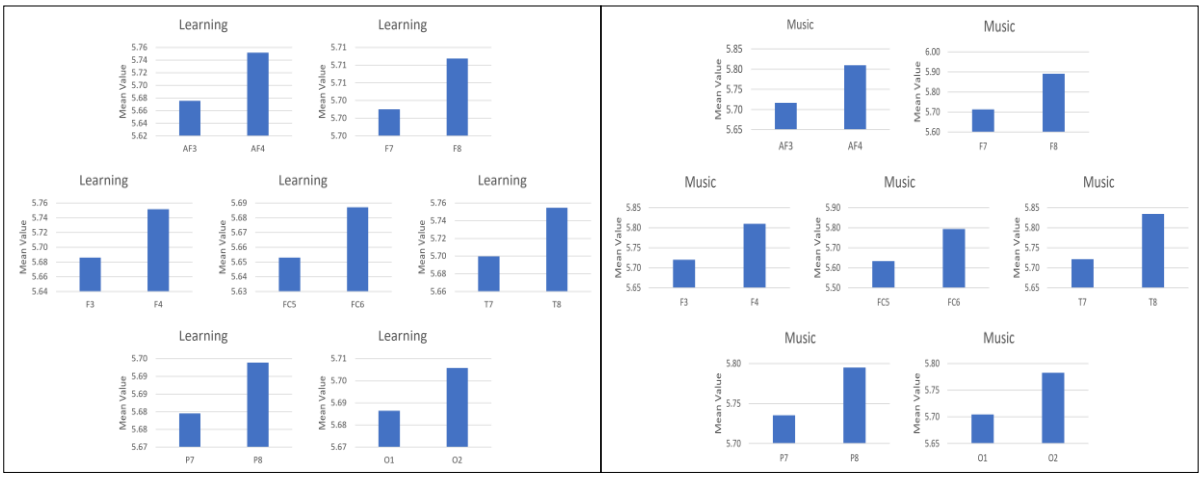


Figure 9:Comparison of the effect of Theta Activity for Learning and Music on the left and right hemispheres of the brain.

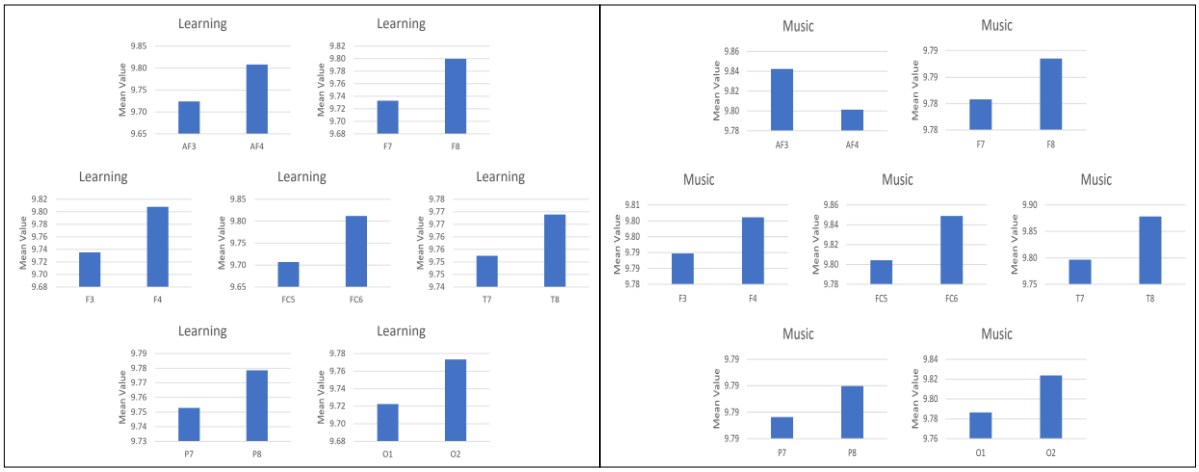


Figure 10: Comparison of the effect of Alpha Activity for Learning and Music on the left and right hemispheres of the brain.

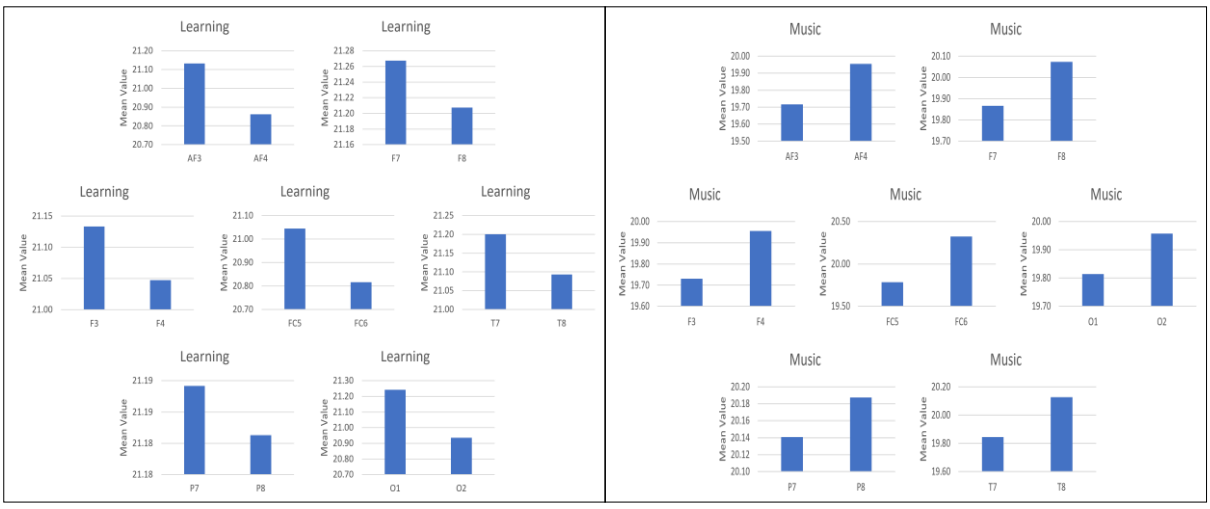


Figure 11: Comparison of the effect of Beta Activity for Learning and Music on the left and right hemispheres of the brain.

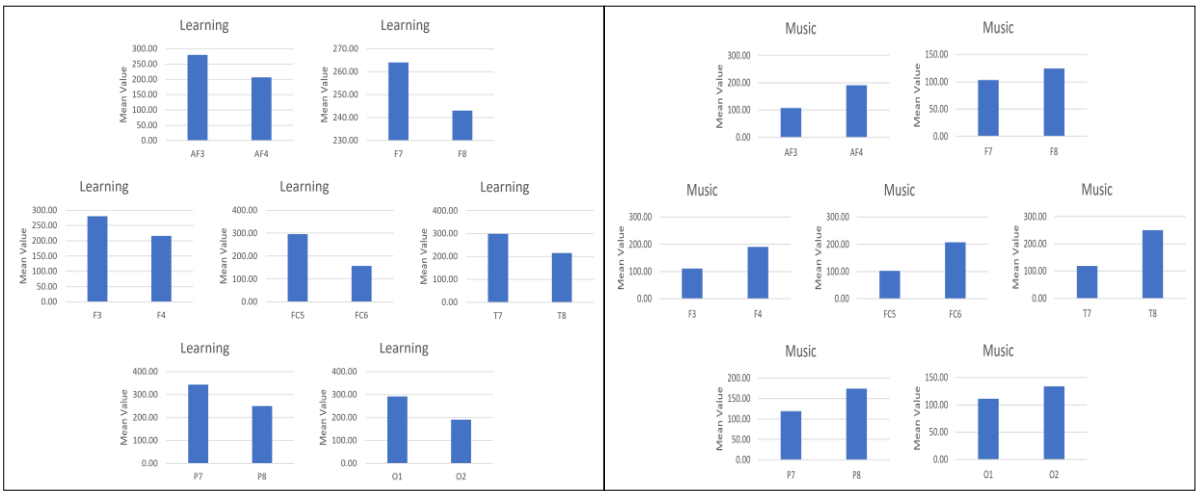


Figure 12: Comparison of the effect of Gamma Activity for Learning and Music on the left and right hemispheres of the brain.

The study is carried out on learning 3 different languages as English, Hindi, and Marathi. Speech (speaking and wiring) and understanding of language are done in Broca's area of the frontal lobe and Wernicke's area of the temporal lobe. Both Broca's and Wernicke's areas are on the left hemisphere of the brain. Electrodes coming under these areas are AF3, F7, F3, FC5, and T7. Among the 5 EEG signals, the Beta band is responsible for activeness so, the examination of activeness in which language the subject is more attentive is done using the Beta band.

Figure 13:Beta Band Performance During Language Learning or Reading

From the Figure 13 above it is observed that Subjects 1, 2, and 4 show more activity in Hindi, English, and then Marathi Reading whereas Subjects 3 and 5 were more active in English, Marathi, and then Hindi. More Activity can be seen in Node F7, F3, and T7.

Gamma Band is accountable for Concentration or Attention so for finding the attention level of the subject Gamma band is cast off. From Figure 12 observations for attention during learning and listening to music are as below:

- High attention can be observed during learning in AF3, F7, F3, FC5, T7, P7, and O1 electrode (electrodes in Left Hemisphere)
- Low attention can be observed during learning in AF4, F8, F4, FC6, T8, P8, and O2 electrode (electrodes in Right Hemisphere)
- Low attention can be observed while listening to Music in AF3, F7, F3, FC5, T7, P7, and O1 electrode (electrodes in Left Hemisphere)
- High attention can be observed while listening to Music in AF4, F8, F4, FC6, T8, P8, and O2 electrode (electrodes in Right Hemisphere)

As compared to learning activity attention level during listening to music is very low.

The study of language learning is conducted in three different languages as English, Hindi, and Marathi. The attention to the subject varies in learning languages. A comparative study is made to know in which language the attention of the subject is high. From Figures 14, 15, 16, 17, and 18 it is found that the performance of the subject's attention level during pursuing a language from high to low is as Subject 1: English, Hindi, Marathi, Subject 2: Marathi, English, Hindi, Subject 3 and 5: Marathi, Hindi, English and Subject 4: Marathi, English, Hindi. In general, high attention is found while learning Marathi, Moderate attention is seen while learning Hindi, and low attention is observed during learning the English language. From the observation of all 5 subjects for attention (Gamma Activation), it seems that while learning left hemisphere is more dominant.

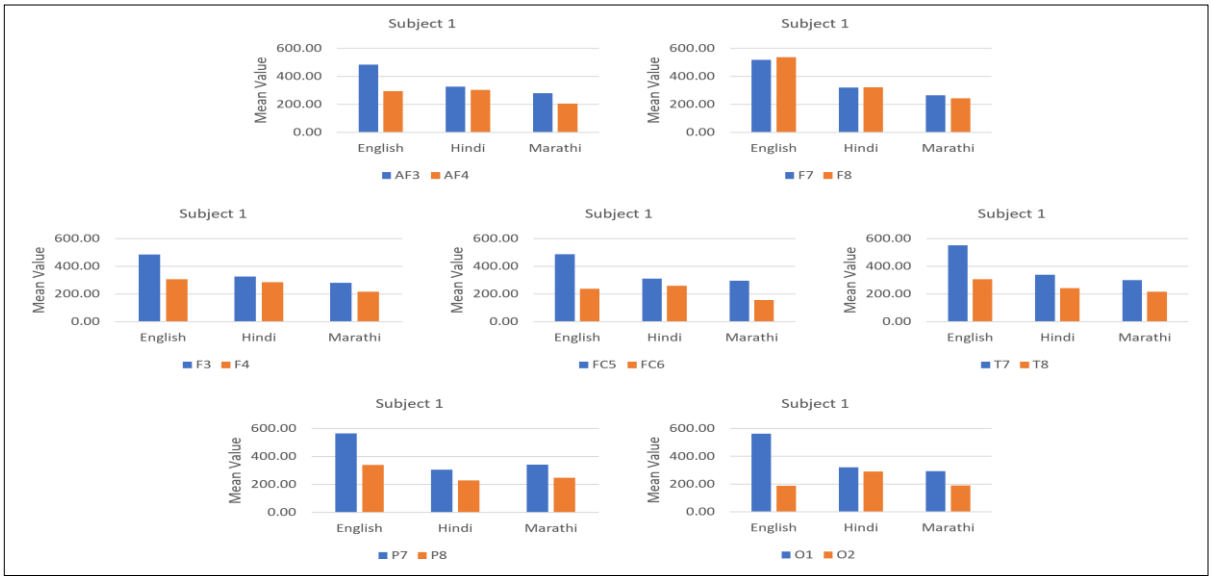


Figure 14: Comparison of Attention in Learning English, Hindi, and Marathi Language of Subject 1

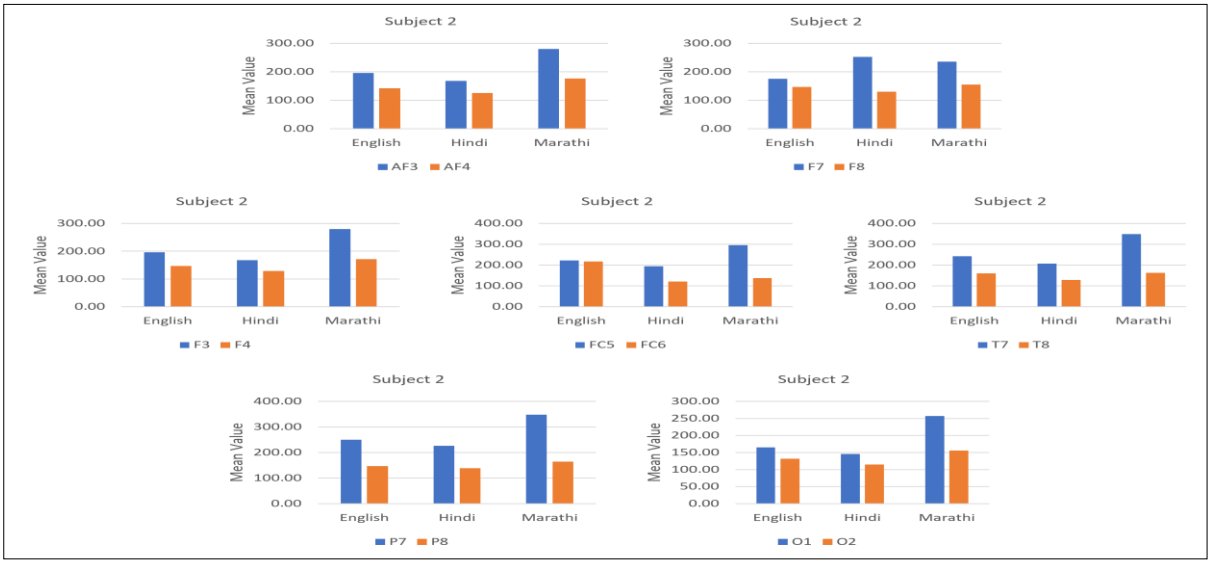


Figure 15: Comparison of Attention in Learning English, Hindi, and Marathi Language of Subject 2.

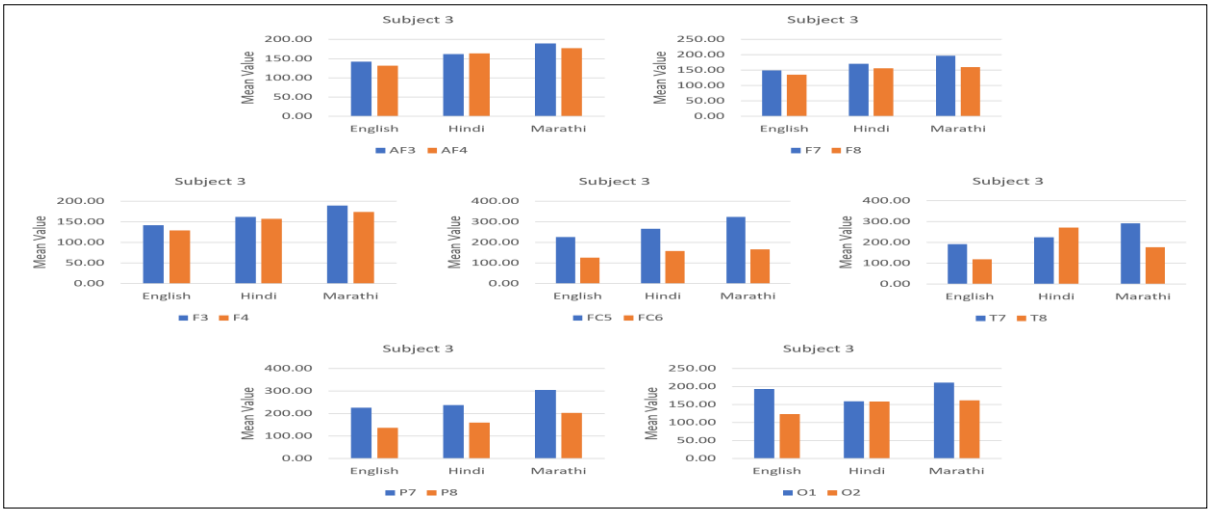


Figure 16: Comparison of Attention in Learning English, Hindi, and Marathi Language of Subject 3.

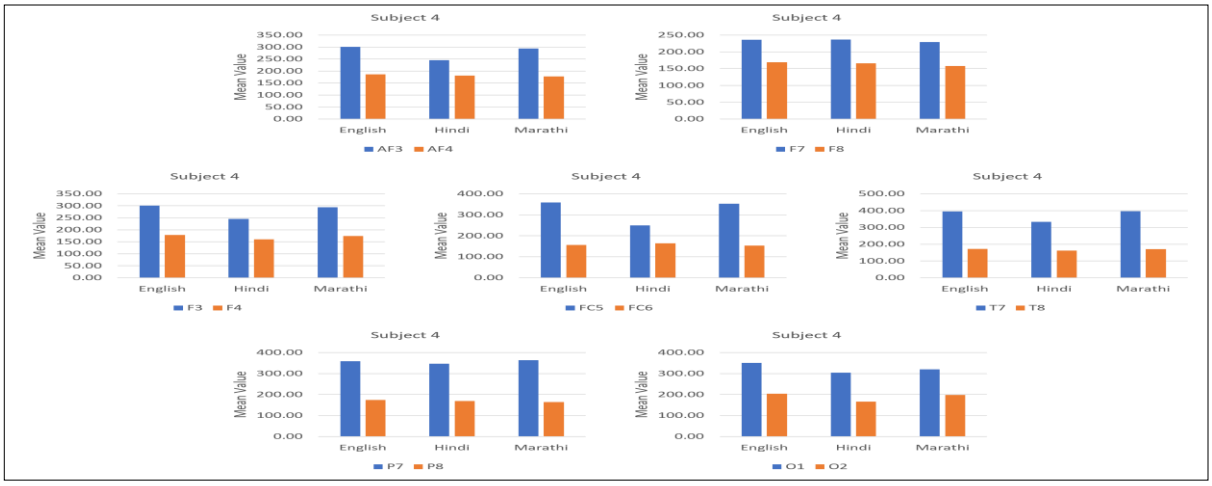


Figure 17:Comparison of Attention in Learning English, Hindi, and Marathi Language of Subject 4.

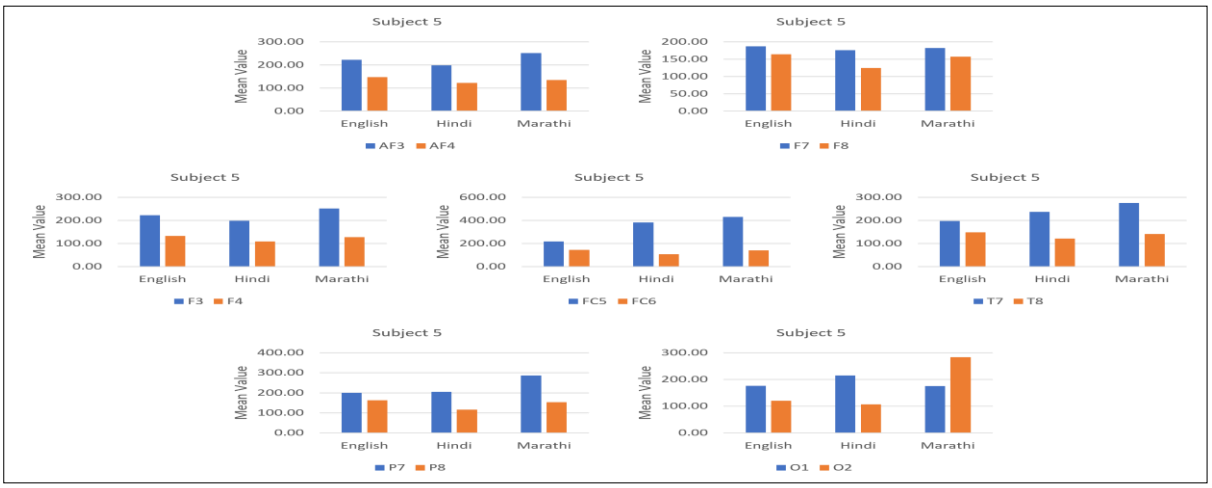


Figure 18: Comparison of Attention in Learning English, Hindi, and Marathi Language of Subject 5.

After reading article subject answered questions based on article that is subject was supposed to process the information and answer the questions. Gamma Band and Left side of the Brain are responsible for Processing Information and Problem Solving. Figure 19, 20, 21, 22, and 23 shows very high response of Gamma activity in Left Hemisphere and Low in Right Side. Overall high gamma oscillations that are more process of information needed to be required for English, Hindi, and then Marathi language. Observation says more recall is a need in the foreign language and less in the regional language.

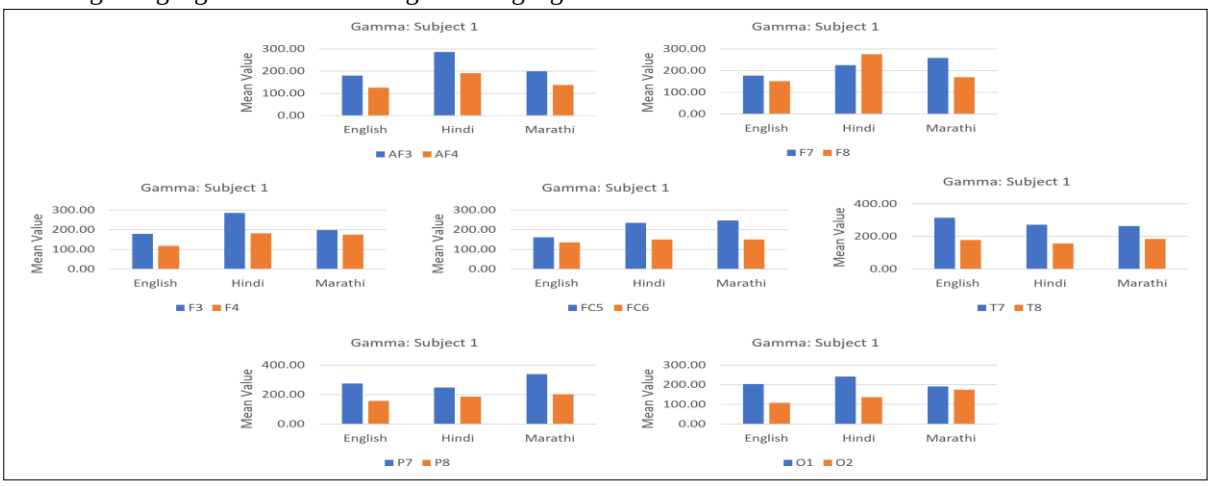


Figure 19: Comparison of Left and Right Hemisphere during Information Processing for Subject1.

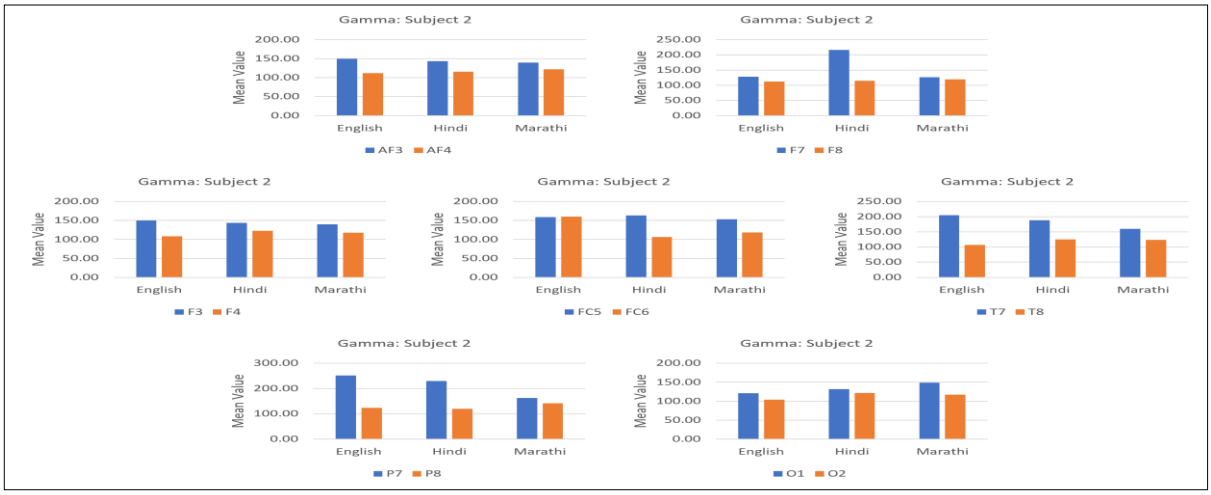


Figure 20: Comparison of Left and Right Hemisphere during Information Processing for Subject2.

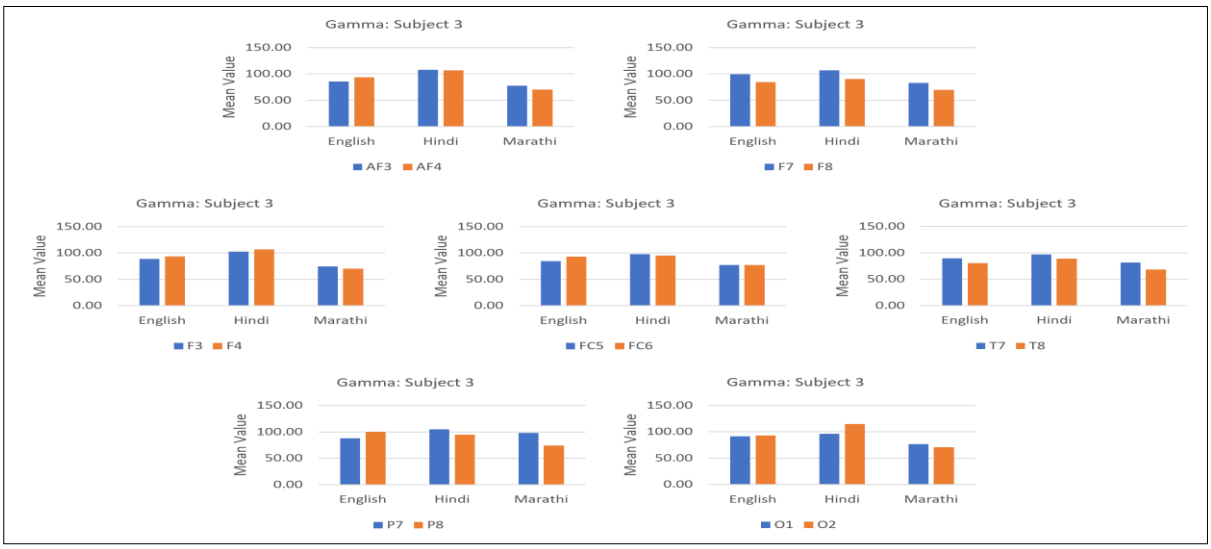


Figure 21: Comparison of Left and Right Hemisphere during Information Processing for Subject3.

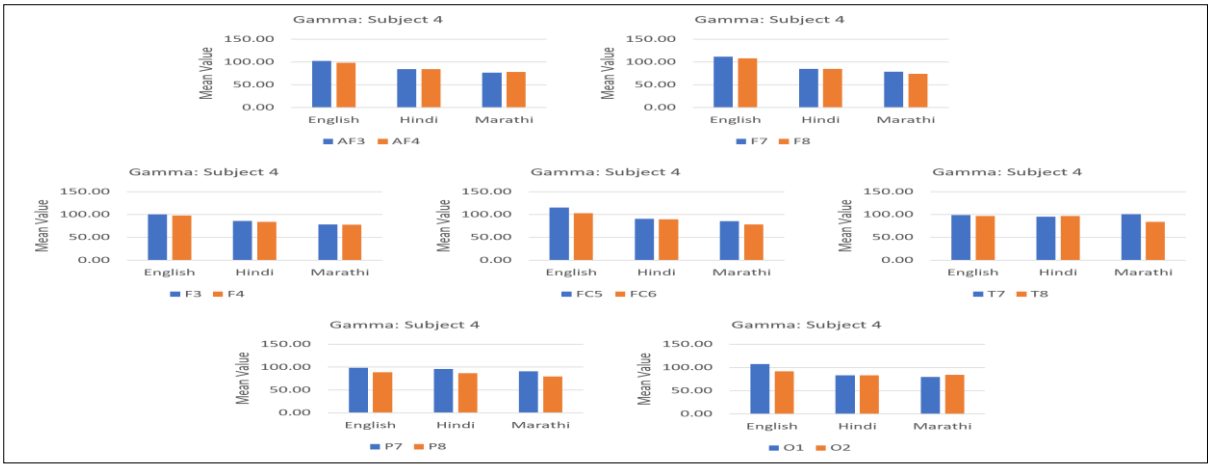


Figure 22: Comparison of Left and Right Hemisphere during Information Processing for Subject4.

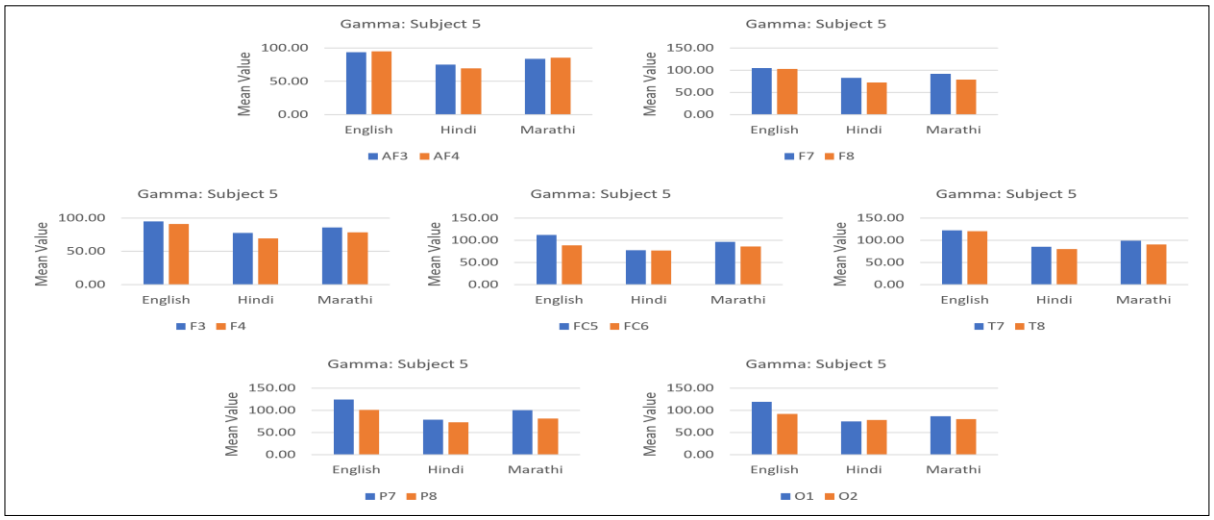


Figure 23: Comparison of Left and Right Hemisphere during Information Processing for Subject5.

The subjects read articles three different language, and they required some time for reading. Table 3 below illustrates the time required for reading an article. The time format for recording was HH:MM:SS. The sample of 5 subjects' time for reading article 1 from 10 articles in 3 different languages is shown in the table. Looking at the table of times it is observed that though it is any language English (Foreign), Hindi (National), or Marathi (Regional) less time is required for reading the same article for the second or third time compared to reading for the first time. When the same article in 3 different languages is read, from the observations we can also tell that less time is required to read articles in Marathi (Regional) Language. Moderate time is required for reading in Hindi (National) language and more time is needed for reading English (Foreign) language articles.

Table 3: Time Required for Reading Article

Subject	***English***			***Hindi***			***Marathi***		
	Read 1	***Read 2***	***Read 3***	***Read 1***	***Read 2***	***Read 3***	***Read 1***	***Read 2***	***Read 3***
Subject 1	*1.13*	*0.51*	*0.49*	*0.58*	*0.43*	*0.42*	*0.50*	*0.42*	*0.35*
Subject 2	*0.58*	*0.48*	*0.39*	*0.43*	*0.38*	*0.36*	*0.36*	*0.34*	*0.30*
Subject 3	*0.48*	*0.4*	*0.37*	*0.45*	*0.43*	*0.36*	*0.36*	*0.31*	*0.30*
Subject 4	*0.36*	*0.33*	*0.31*	*0.47*	*0.35*	*0.34*	*0.36*	*0.35*	*0.35*
Subject 5	*0.47*	*0.32*	*0.31*	*0.38*	*0.28*	*0.26*	*0.29*	*0.18*	*0.14*

After reading the articles subject answered the question based on articles and they required some time required to solve the questions. The Table 4 below show the time require for answering the questions based on the 10 articles read in 3 languages along with the time required by 5 Subjects for answering question for single article. From the observations we can say that majority subjects required less time for solving the question in Marathi, then Hindi and more time for English. Maximum correct responses are found for Marathi and Hindi as compared to English.

Table 4: Time and Responses to Questions

Subject	***Time***			***Responses of Questions***		
	English	***Hindi***	***Marathi***	***English***	***Hindi***	***Marathi***
Subject 1	*0.46*	*0.47*	*1.01*	*4*	*5*	*3*
Subject 2	*0.49*	*0.27*	*0.26*	*5*	*5*	*5*
Subject 3	*0.31*	*0.22*	*0.20*	*5*	*5*	*5*
Subject 4	*0.37*	*0.24*	*0.19*	*4*	*5*	*5*
Subject 5	*0.23*	*0.20*	*0.11*	*5*	*5*	*5*

4. Conclusion:

The Spectral signal emitted by brain from different lobes perform different activities. The study focuses to understand the impact of Learning, Attention, and Information Processing during listening to music and language learning. Results reveal the facts that reading any article in any language for the first time needs more time compared to the second and third attempts. Concentration and understanding increase after every next attempt at reading. A very good impact of music is seen on learning, as listening to music gives relaxation helps and increases concentration during learning. The study also reveals that while listening to music we get relaxed, and concentration or attention is low but high during learning activities. It is observed that while responding to music more activeness is seen in the right hemisphere and during learning language more activity is seen in the left hemisphere. From the learning, attention level, and the way information processing for solving the question base on learning is done, it is found that the understanding was good in the Regional (Marathi) Language, Moderate in the National (Hindi) Language, and low in Foreign (English) Language.

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