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Research Article

Mechanism of Learning Implementing Metaphorical Thinking: An Understanding how it Works?

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Abstract

Understanding human learning a complex process that could not be explained by a single theory since ages, though several attempts were made as learning is associated with the conscious functioning of the brain which is a purely biological organ whose constituent elements are Oxygen, Carbon, Nitrogen, Calcium, Sodium, Potassium etc. This paper attempts to explain how human learning occurs pertaining to teaching/learning process in a classroom environment. The basic mechanism underlying any teaching/learning process is that the teacher stimulates the sense organs of the learner providing information mainly through visual, auditory, kinaesthetic (VAK) approach. During VAK approach if a teacher consciously implements metaphorical thinking statements in the content of the information proposed as learning objectives would enhance the learning as it chemically initiates a series of complex processes resulting in what is perceived as learning. The main objective is to understand how metaphorical thinking initiates active thinking in the brain regions responsible for learning enhancing beta and gamma wave activation in the pre-frontal cortex by recording scalp EEG before and after implementing metaphorical thinking.

Keywords: *Metaphorical Thinking; Visual; Auditory; Kinaesthetic; Learning and Classroom*

Introduction

Learning was considered to be the most difficult word to understand the exact meaning since several years in field of Psychology, Philosophy until recently with the emergence Cognitive Science or Cognitive Psychology which integrates Psychology, Philosophy with Neuro Biology, Physics, Computer Science as well as Chemistry to provide meaningful insights to the theory of learning. There has been long term controversy between learning and thinking since time immoral as which result in which similar to the mystery that "hen hatches the egg or the egg hatches the hen". Therefore, the role of brain is very important to predict the mechanism of learning as it is considered to be the organ of thought as it hosts our mind, memories of the past, as well as the centre of information processing hub due to our dependency on it to learn new information perceived through our senses. Several research studies in the field of Cognitive Neuro science as well as Developmental Psychology resulted in understanding the mechanism of human learning is proposed as follows:

- Learning changes the physical structure of the brain similar to rearranging furniture in a house.
- These structural changes results in the functional organization of the brain that is learning results in organization as well as de-organization of the brain similar to rearranging the furniture might result in either organization or de-organization.
- Different parts of the brain are stimulated at different times.

Eisenberg [1] suggested that learning results due to continuous interactions between the mind and body of a child with that of external environment. If such interactions are more it would rise questions such as how much learning ability of a child dependent on the genes the progeny carries or based on the interaction with the environment? This question is similar in asking which contributes to the area of the rectangle Is it its height or its width? Practice of metaphorical thinking statements during teaching learning process in a conscious manner enables a teacher to promote a continuous interaction between body, mind and the external environment essential for a child to understand the content discussed in a particular class. According to the views of neuro scientists as well as Developmental Psychologists a metaphorical statements usage triggers activation in the prefrontal cortex of the brain facilitating a simple mechanism involving a series of processes as represented below.

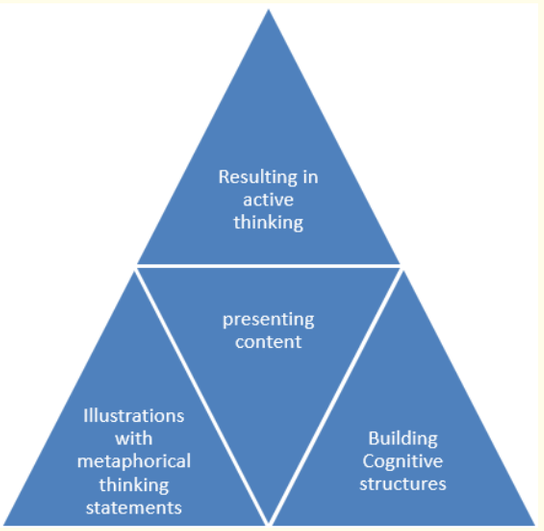


Figure 1

The above-mentioned model represents the idea that a teacher consciously delivering a content through VAK approach by integrating metaphorical thinking in explaining the content would certainly promote active thinking.

VAK approach and Metaphorical thinking

Brandt [2] mentioned a lot about the conceptual metaphors in language processing has been one of the intellectual gifts that humans are capable of using it commonly in a sub conscious level in everyday life due to its neuronal connections. In VAK approach the teacher kindles the sense organs by showing visual clips, playing audio tapes in a realistic manner that the learners consciously feel effect of the relevant content that they are exposed to. In the present research, the investigator explains how the inclusion of metaphorical thinking statements in the VAK approach helps the learner to engage actively throughout the process of teaching/learning. A lot research studies from Aristotle to Lakoff stated that individuals who could perceive similarity between two different concepts were intelligent and had a special gift. Howard Gardner, David Kolbe's model of experiential learning, as well as Daniel Goleman views on teaching/learning predicted in their research that human brain creation is highly individualistic in nature, therefore, it is truly impossible to design a particular learning style in teaching/learning process, however it is possible to engage the learners in their own thinking process by implementing metaphorical thinking statements. The content module explains how to implement metaphorical thinking statements as shown below.

Content Module: Electro Chemical cell

The concept of Electro Chemical Cell explained using VAK model for Visual learners showing the picture of Battery and Daniel cell, lightening simultaneously and introducing metaphorical thinking.

Figure 2: *Battery used to generate electricity.*

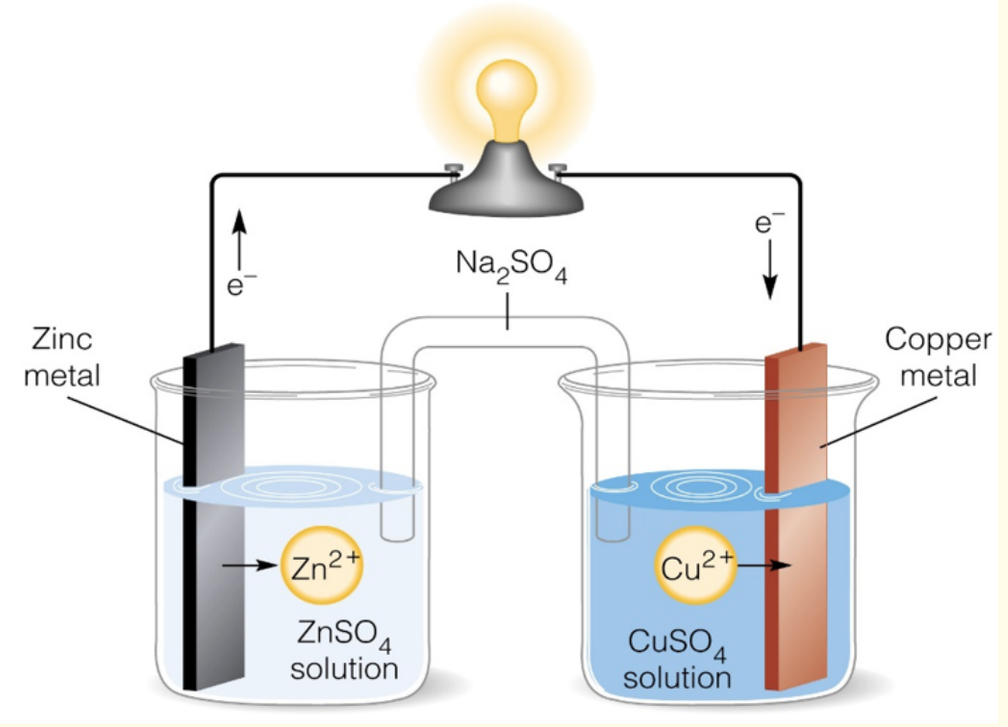


Figure 3: *Daniel cell designed in a chemical lab generating electricity.*

Figure 4: *Natural lightening process generating electricity.*

Figures 2, 3 and 4 shows the generation of electricity under different contexts, how do you relate the three in terms of the following: a) Intensity of production of electricity. b) Application c) Chemical changes involved d) Type of chemical change involved and e) Is it similar to the electrical signals produced in living organisms. The above module explains the integration of metaphorical thinking statements in VAK approach. Dr James McGaugh [3] research based on MRI scans revealed that emotional brain be engaged by making connections why the lesson learnt is useful and relevant to the content so that the learner's learning experience is memorable and long lasting. Similar research studies by Yob [4] who reviewed the work of Thayer-Bacon (2000) in which Thayer-Bacon compared two different metaphorical approaches to teaching and learning to develop on constructivism, critical thinking.

Objectives of the Study

- To find the variation of the spectral power density with the frequency of the waves.
- To interpret the variation in the power spectral density as the variation of frequency with respect to pre and post-test conditions.

Research Questions

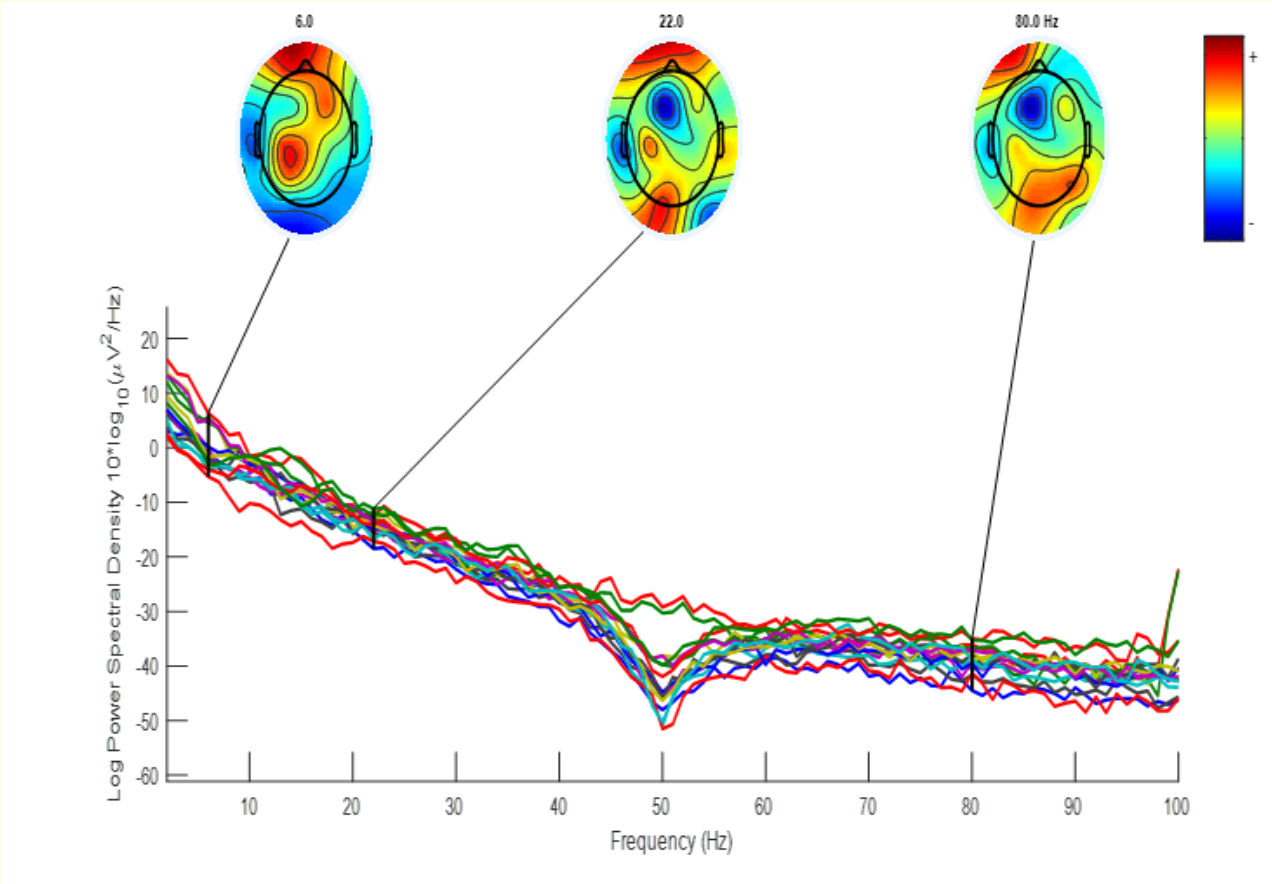
- Is there a significant difference in the power spectral density as the function of frequency between pre and post-test conditions?
- In which channel there is comparatively greater variation of power spectral density as the function of frequency in pre and post-test conditions?

Methodology

The present research work focused on to find out the variation of the power spectral densities vs frequency of the brain signals recorded using EEG. As the research topic titled as "Mechanism of learning implementing metaphorical thinking: an understanding how it works." The main focus was concentrated on understanding the brain dynamics in the prefrontal cortex which includes electrode channels FP1, FP2, F3, F1, F4, F8, T3, C3 and C4. International federation Electroencephalography and clinical Neuro Physiology adopted standardization of electrode placement called 10 to 20 electrode placement strategy. The experiment was conducted on teacher sample (both males and females) in the age group 30 to 55 years teaching Science subjects in schools. Research studies carried out over the past few decades established the fact that prefrontal cortex region of the brain processes higher cognitive functions and considered as the centre for active learning. The brain signals are classified in to five categories namely: alpha (frequency range 8 to 14 Hz), Beta (frequency range 12 to 40 Hz), gamma (frequency range 40 to 100 Hz), delta (frequency range 0 to 4Hz) and theta (frequency range 4 to 8 Hz). 10 - 20 electrodes are fitted on scalp of the brain manually using electrode gel as shown in the figure 5. Fz, Cz and Pz are reference electrodes. The rest of the electrodes measures the potential difference with respect to the reference electrodes. The continuous EEG data recorded before and after intervention given to a group of Science teachers were recorded with NIHAN CODON digital EEG machine used for diagnostic purpose in the Neurology Department of Sri Ramachandra Medical University and Research centre, Porur, Chennai, India. Each subject during pre-test condition was instructed to focus on letter "A" written on a white A4 sheet for fifteen minutes, their brain signals were recorded by placing 10:20 electrodes on the scalp in accordance to the international standards. At the end of fifteen minutes began the post-test condition in which each subject was given a sheet of paper consisting of Metaphorical thinking statements based on a lesson plan prepared relevant to a content in the subject "Chemistry" at the level of 9^{th} grade. The subjects were instructed to read each and every statement written on the sheet to relate it to metaphorical thinking, while performing the task scalp EEG was recorded. The total recording session lasted for 30 minutes (pre-test condition 15 minutes and post-test condition for 15 minutes).

Analysis of the data

The collected EEG raw data was saved in a text file subjected to power spectrum analysis using MATLAB 16b version which supports EEG LAB version 15 software developed by the SCCN (The Swartz Centre for Computational Neuroscience). The continuous brain signals after pre-processing using low pass basic FIR filters keeping the minimum frequency between 1 to 100 Hz as well as rejecting all the noisy data. The cleaned brain signals are subjected to Independent Component Analysis (ICA) to remove artefacts from the data. The brain signals recorded from 16 channels are expressed in terms of power spectral density being one of the statistical approach used to analyse continuous EEG data which describes how power of a signal or time series is distributed over a frequency range. The Fourier transformation decomposes the EEG time series into a voltage by frequency spectral graph commonly called the "power spectrum", with power being the square of the EEG magnitude, and magnitude being the integral average of the amplitude of the EEG signal, measured from (+)



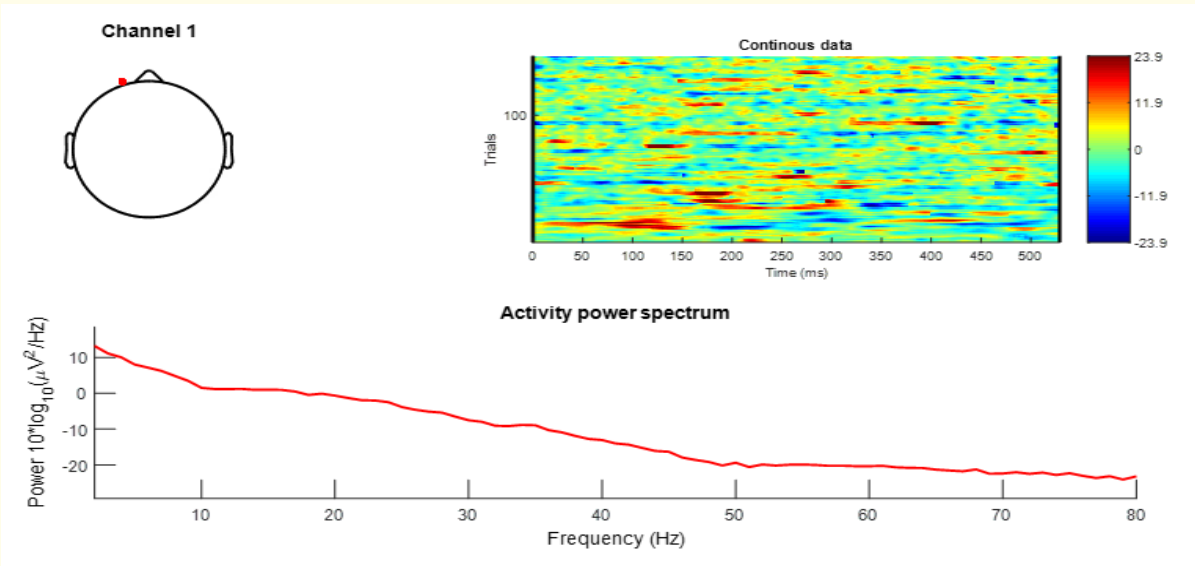


Figure 5: *Plot showing variation of power spectral density vs frequency in the pre-test.*

peak-to- (-) peak), across the time sampled, or epoch. Fourier coefficients represent the amplitude and phase relationship at each of the component sine wave frequencies. Squaring and summing the Fourier coefficients at each frequency provides the power at that frequency. A plot of power at each of the component frequencies is called the power spectrum. The power spectrum allows determination of relative amounts of given frequencies in the waveform over the time segment analysed. The total data sets used for analysis is from 20 subjects, 10 for pre-test and 10 for post-test. Using EEGLAB power spectrum analysis was carried out for all the channels, the output of the power spectral density vs frequency was graphically represented with two prominent frequencies of interest was at 22 Hz representing power of beta waves and 80 Hz representing the power of gamma waves. Analysis is limited to prefrontal cortex of the brain.

Though the brain is not involved in active thinking as in the case of a subject involved in a higher cognitive function where attention, focus, perception is simultaneously involved, there would be some thought process called as passive thought, hence brain signals seen in the figure shows activity represented by the red colour.

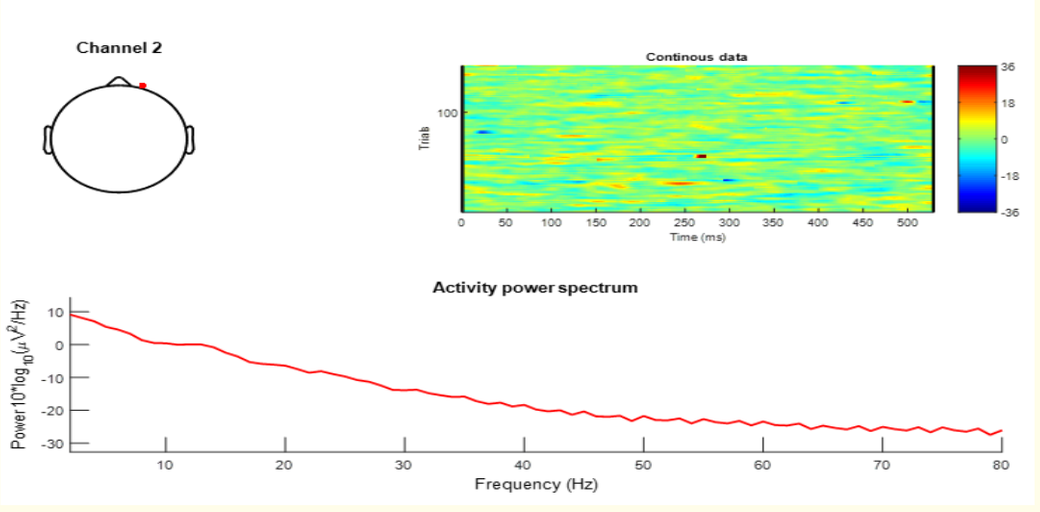


Figure 6: *Plot showing power spectral density vs frequency in channel 2 for pre-test.*

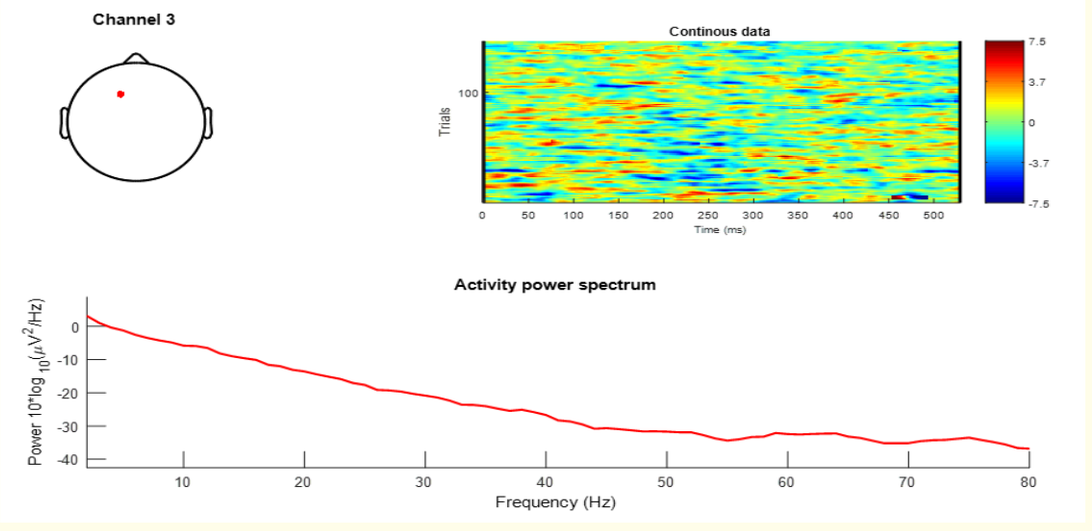


Figure 7: *Plot showing power spectral density vs frequency in channel 2 for pre-test.*

In this analysis only, prefrontal cortex alone is considered for the study, therefore power spectral density for the 8 channels alone is shown in the plot. The tabular column showing the variation of beta and gamma activity over the entire range of data is represented in the form of tabular for the 8 channels.

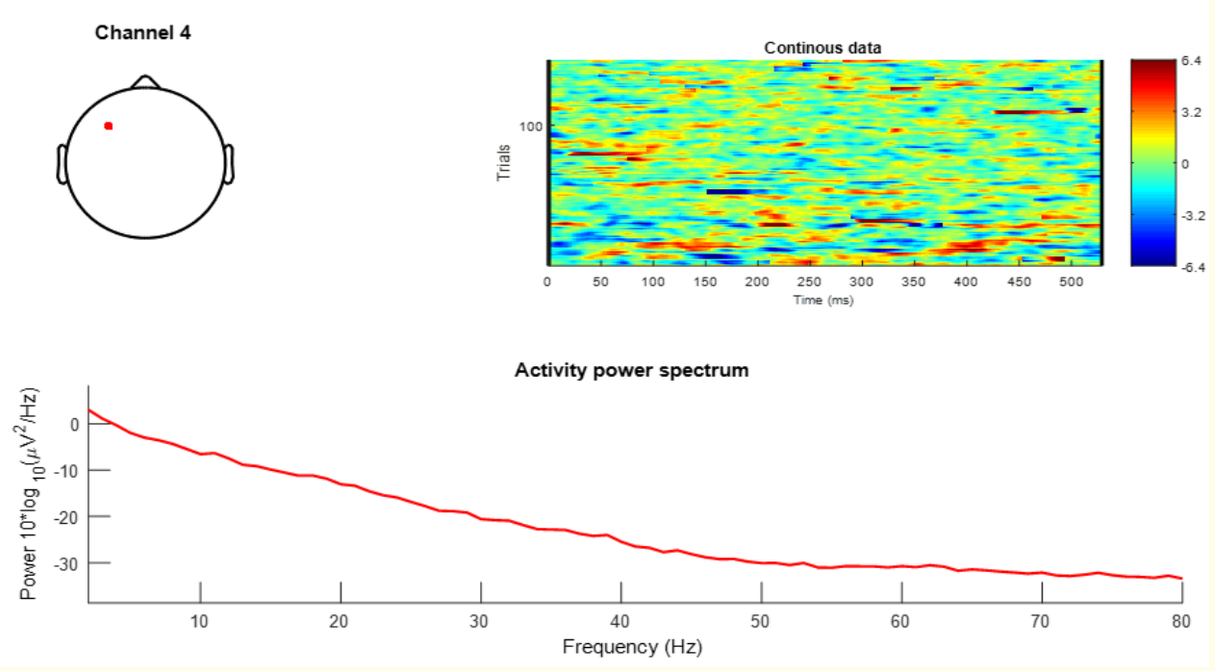


Figure 8: *Plot showing power spectral density vs frequency in channel 2 for pre-test.*

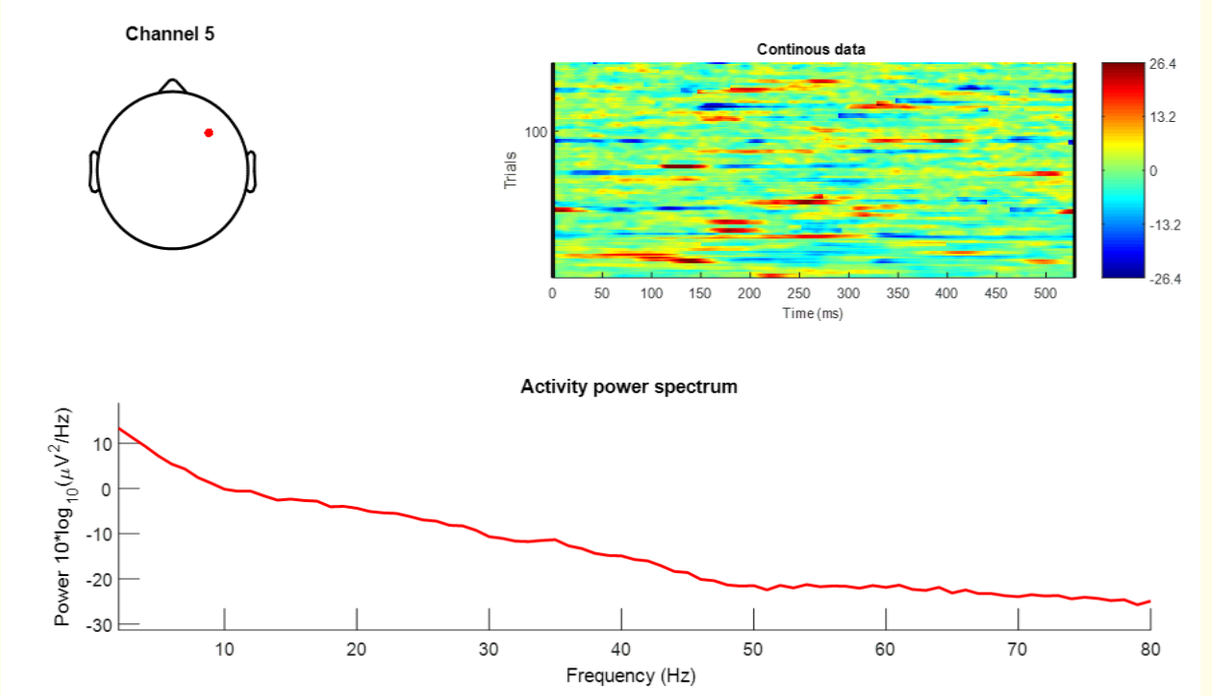


Figure 9: *Plot showing power spectral density vs frequency in channel 2 for pre-test.*

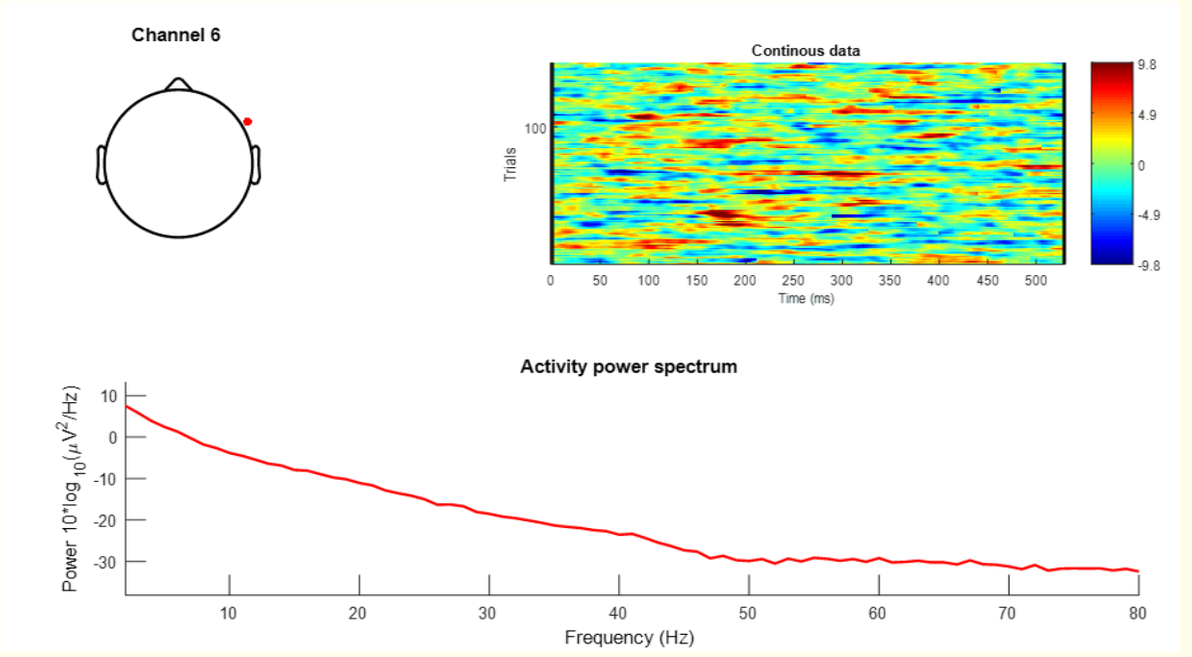


Figure 10: *Plot showing power spectral density vs frequency in channel 2 for pre-test.*

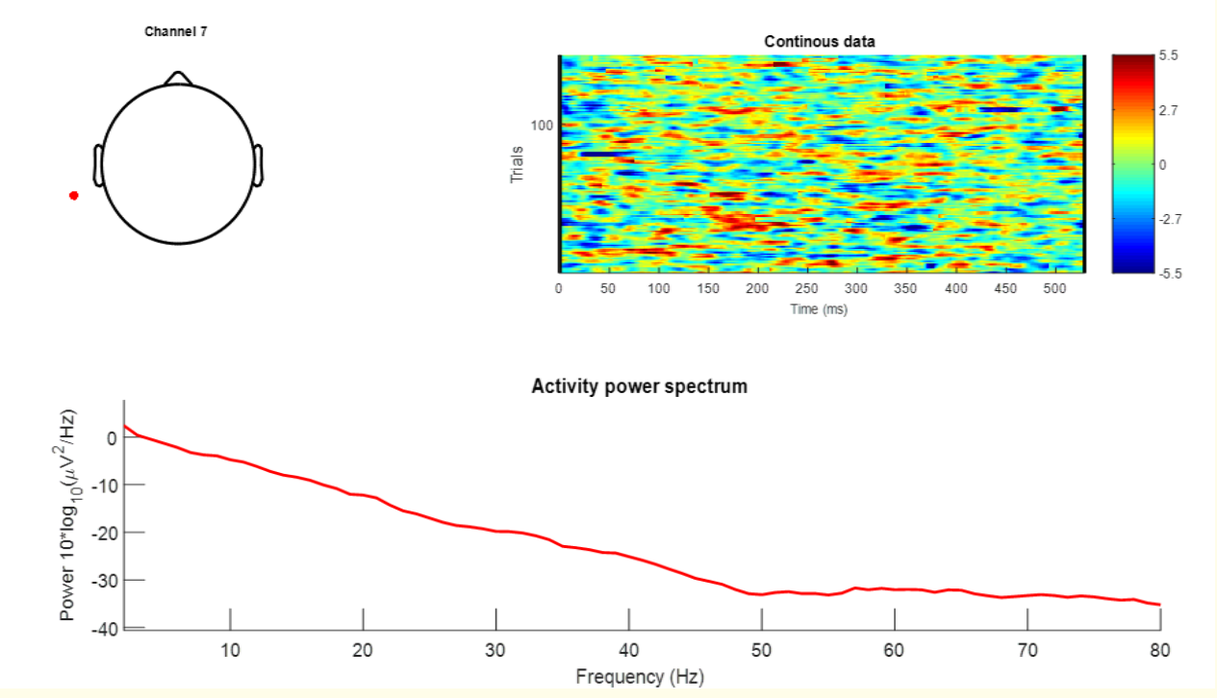


Figure 11: *Plot showing power spectral density vs frequency in channel 2 for pre-test.*

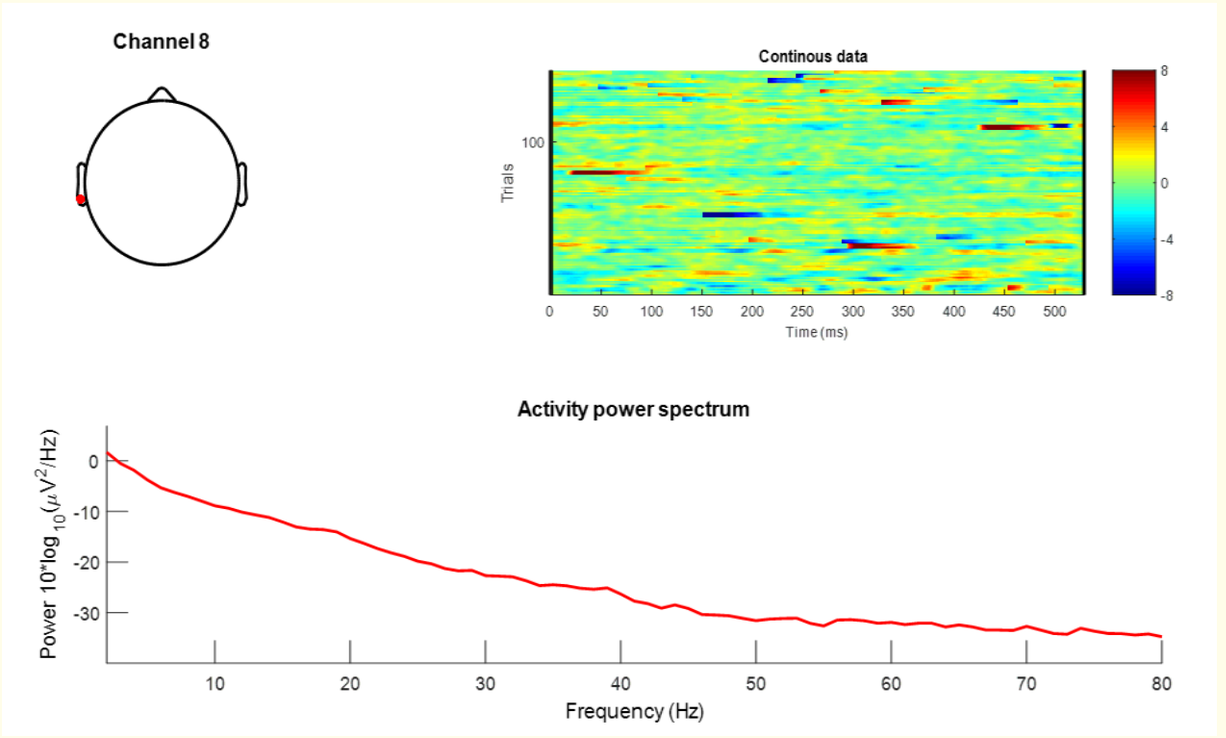


Figure 12: *Plot showing power spectral density vs frequency in channel 2 for pre-test.*

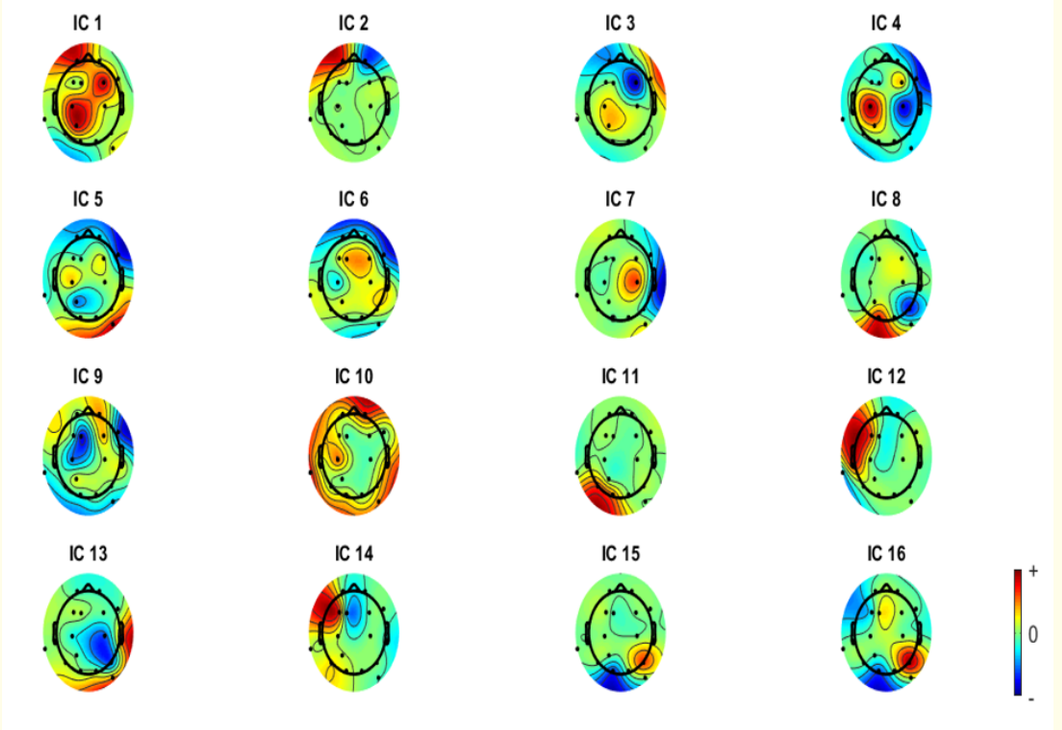


Figure 13: *Showing the ICA decomposition for all the components of the brain signals as shown in the scalp maps for the post-test.*

Channel name	Amplitude variation of Beta to Gamma range in pre-test	Amplitude variation of Beta to Gamma range in post-test
FP1	11.9 - 22.9	34.5 - 53
FP2	18 - 38	17.4 - 87
F7	13 - 17	17.4 - 57
F3	12 - 14	19 - 38
F4	13.2 - 25.4	12.7 - 28.4
F8	19 - 25	22 - 44
A1	2.7- 5.5	10.5 - 21
T3	4 - 8	15.5 - 28.9

Table 1: *Showing the variation of beta and gamma activity across the channels for pre and post-test.*

Independent Component analysis (ICA) is a statistical technique normally used for a complex data for example in the present situation is EEG signals obtained from independent electrodes placed on the scalp of the subjects. In order to understand the brain dynamics the brain signals obtained from independent electrodes were subjected ICA using EEGLAB tool box which has in built algorithm supported by MATLAB gave 16 ICA components for all the channels represented in the figure 13. On close observation of the figure reveals IC1, IC4, IC5 are strong components in the present experiment could be understood in terms strong activity in the brain regions mostly in the brain channels FP1, FP2, F3, F7 and F8. Hyvarinen A, Karhunen J, Oja E (2001) proposed that ICA from EEG signal is a higher order statistical technique and is able to separate independent sources which are linearly mixed in several sensors. From the present research data, it is shown that the Internal component1there is strong Beta and Gamma activity in the Pre-Frontal cortex of the brain.

The graph represents the variation of frequency with that power spectral density of the components obtained from ICA for all the channels at three different frequency ranges 6 Hz, 22 Hz and 80 Hz. Close examination of the graph reveals that there is variation of brain activity from prefrontal cortex to Hippocampus. In Hippocampus there is more of Gamma activity in active thinking whereas more of Beta activity in Pre-Frontal cortex.

The graph represents the components 1, 4, 5,6 and 7 obtained from the scalp brain activity map as a source showing Beta activity in prefrontal cortex. Michael Reddy in late 1970s pointed out that the use of metaphorical thoughts is a part of every life tasks of understanding till it becomes consciously aware to transform itself to the so called “Active thinking” to understand abstract concepts. Brown (2003) and Nersessian [5] expressed similar view that complex metaphorical thought such as gestures, imagery, videos etc.

Discussion

A number of research studies have supported the significant role of conceptual metaphors in language processing due its impact on long term memory and its ability to process the information quickly through mental images an individual is capable of constructing based on stimuli received through VAK sources [6]. Grady (1997, 2005) gave the name “primary metaphors for conceptual metaphors which an individual perceives in everyday subjective experience irrespective of geographical differences and cultures. Lehmann, Faber, Gianotti, Kochi and Pascual-Marqui [7], investigated EEG signals to understand coherence brain activity to know more about the human cognition. They suggested that frequency-dependent synchrony could represent a code of information processing that is responsible for functionally and transiently binding remote neuron assemblies involved in a common cognitive processing which could be supported by Knyazeva and Innocenti [8], Weiss and Mueller [9]. Whereas, asynchrony could indicate frequency dependent information exchanges between neuron assemblies involved in a common processing [9]. As the result these authors proposed EEG coherence could be used as a psychophysiological index of experimental condition-specific cognitive processes. Another study by Basar Gutekin [10] was conducted to investigate the role of beta oscillatory responses on cognitive ability in healthy subjects and in subjects suffering from mild cognitive impairment. They

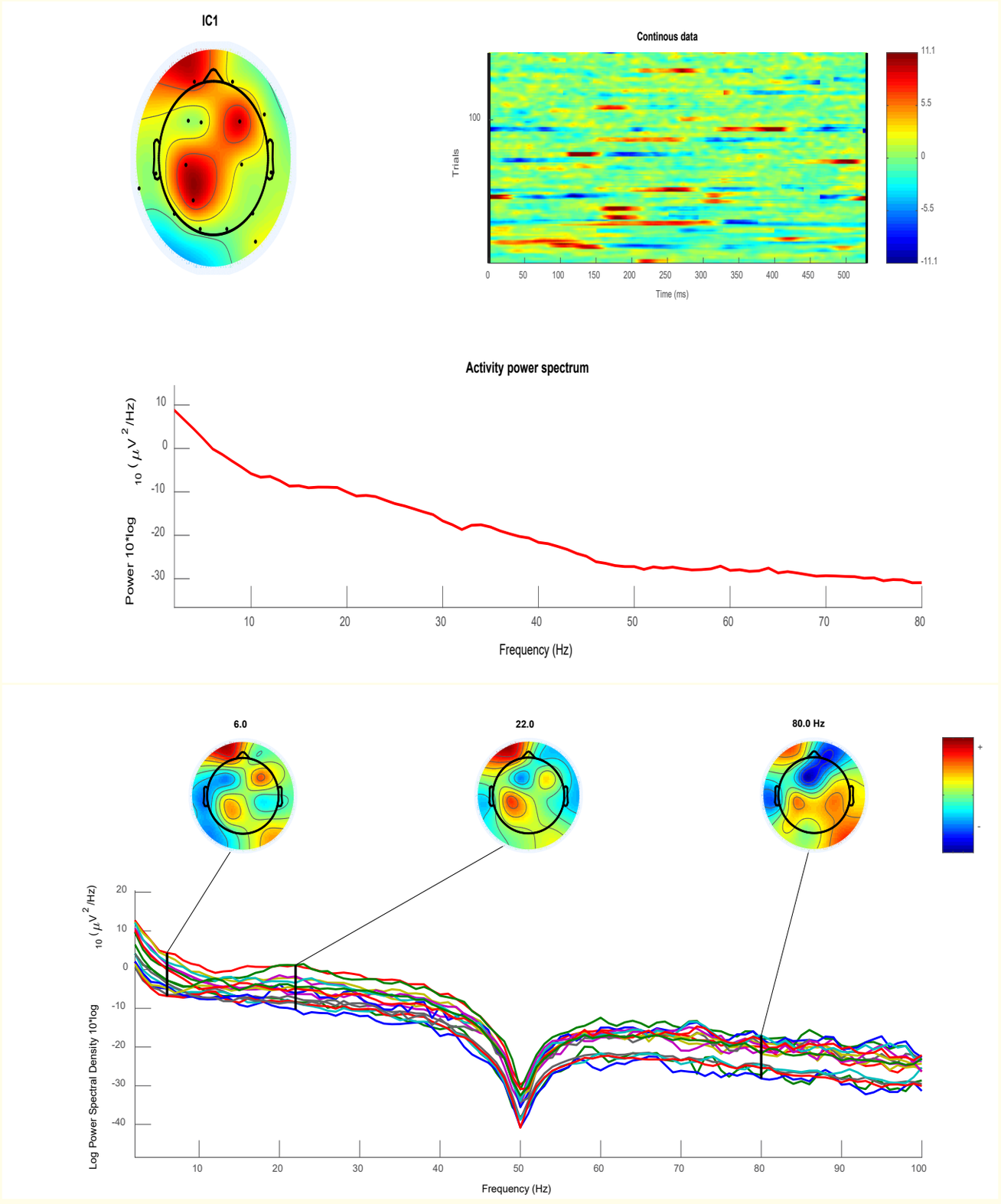
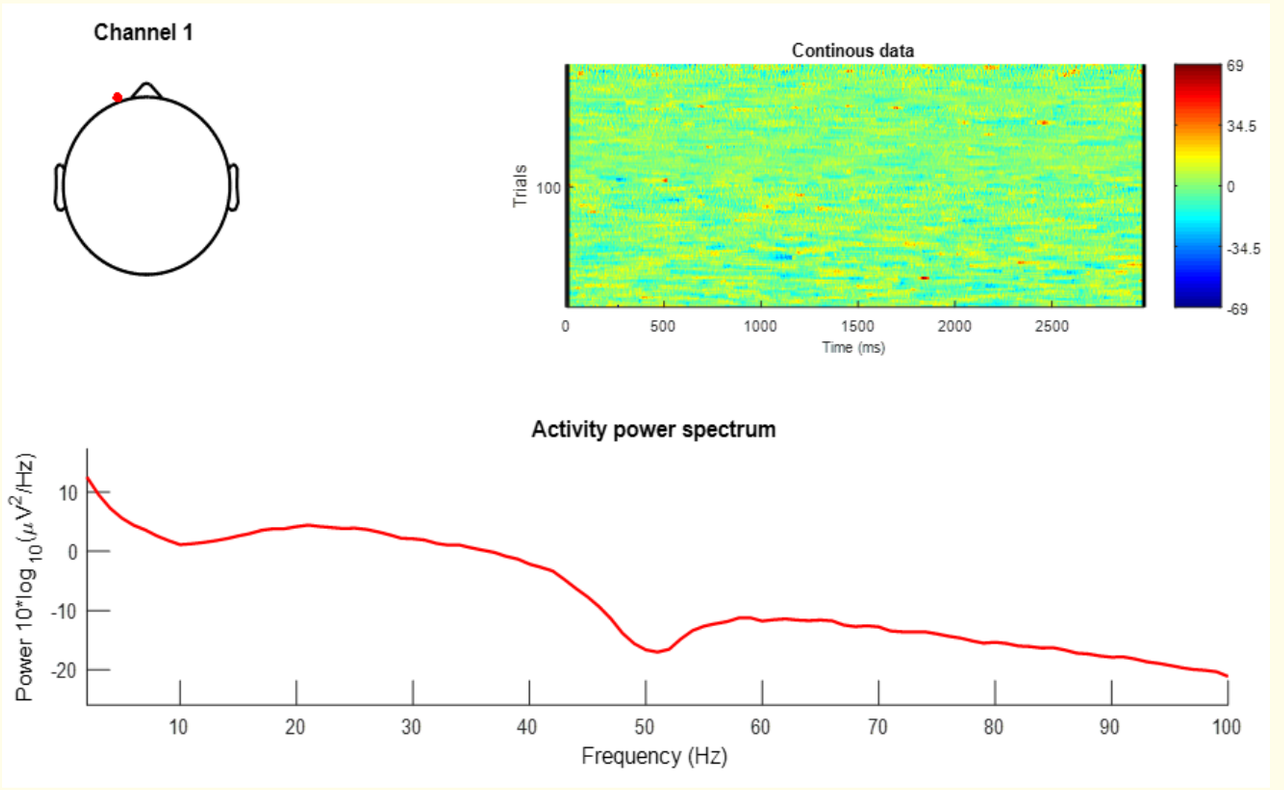
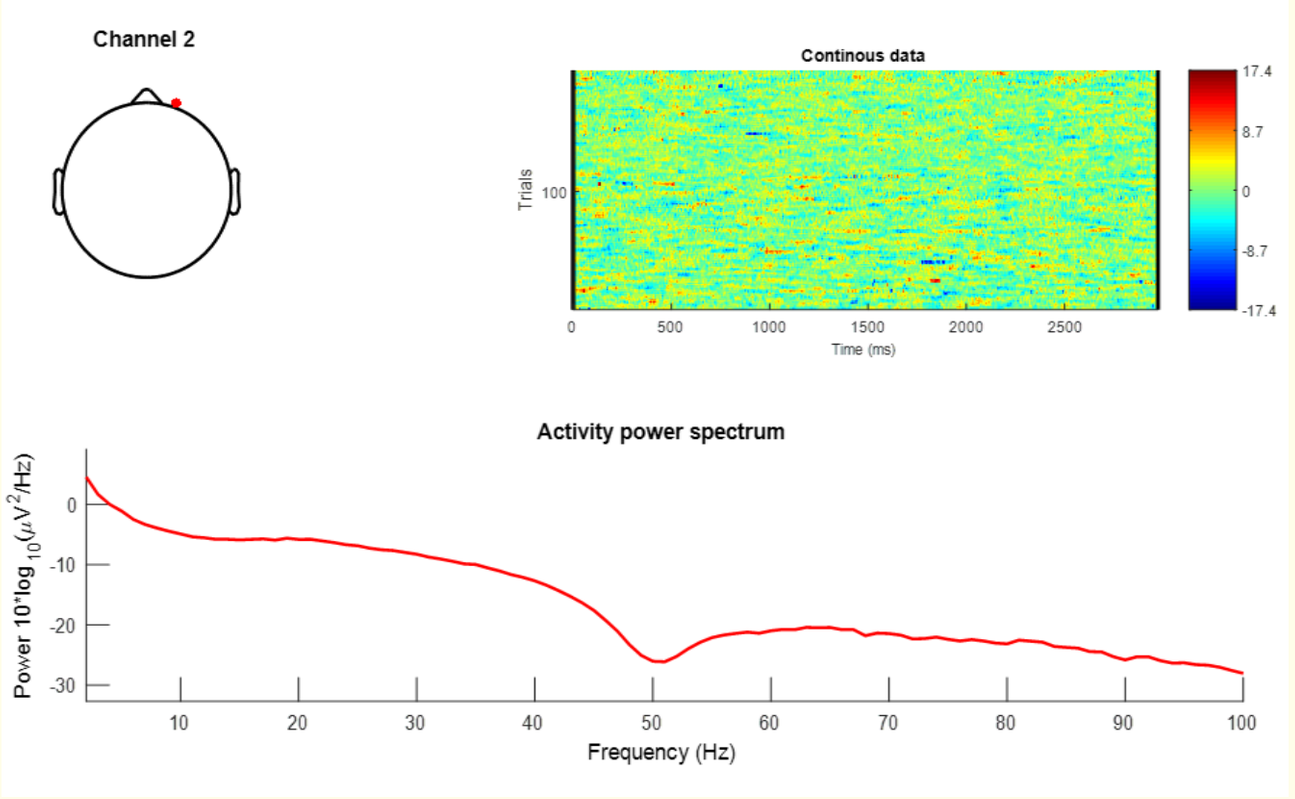
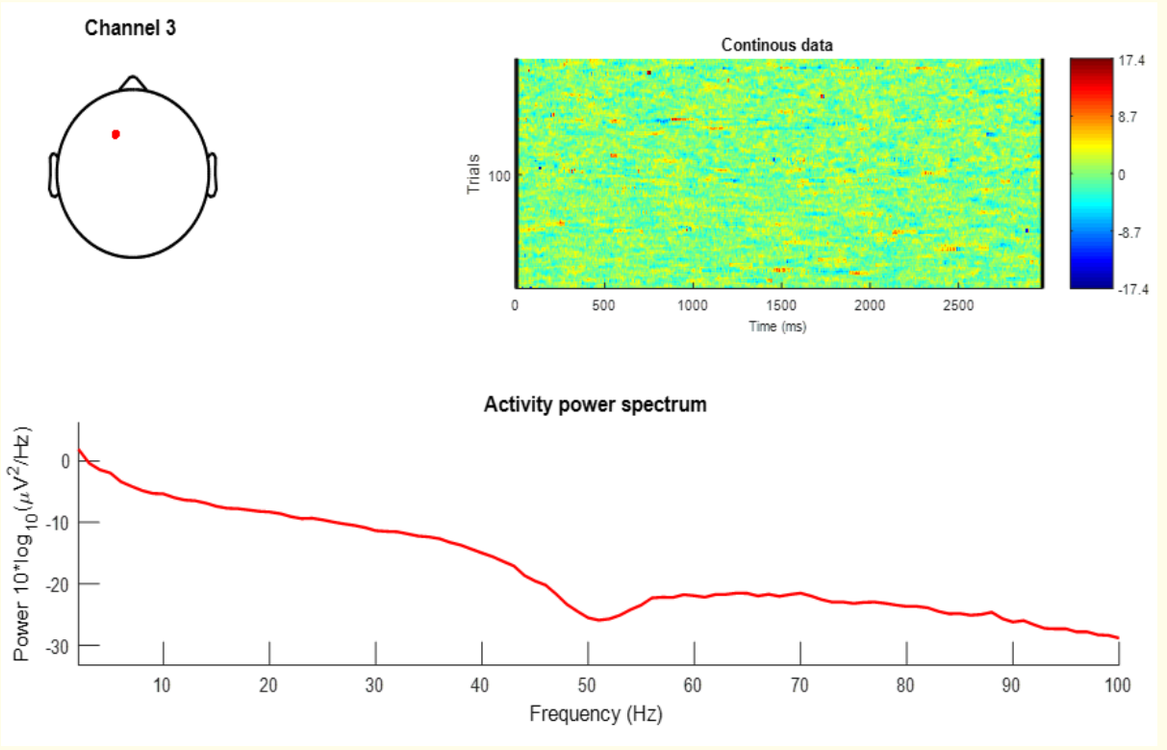
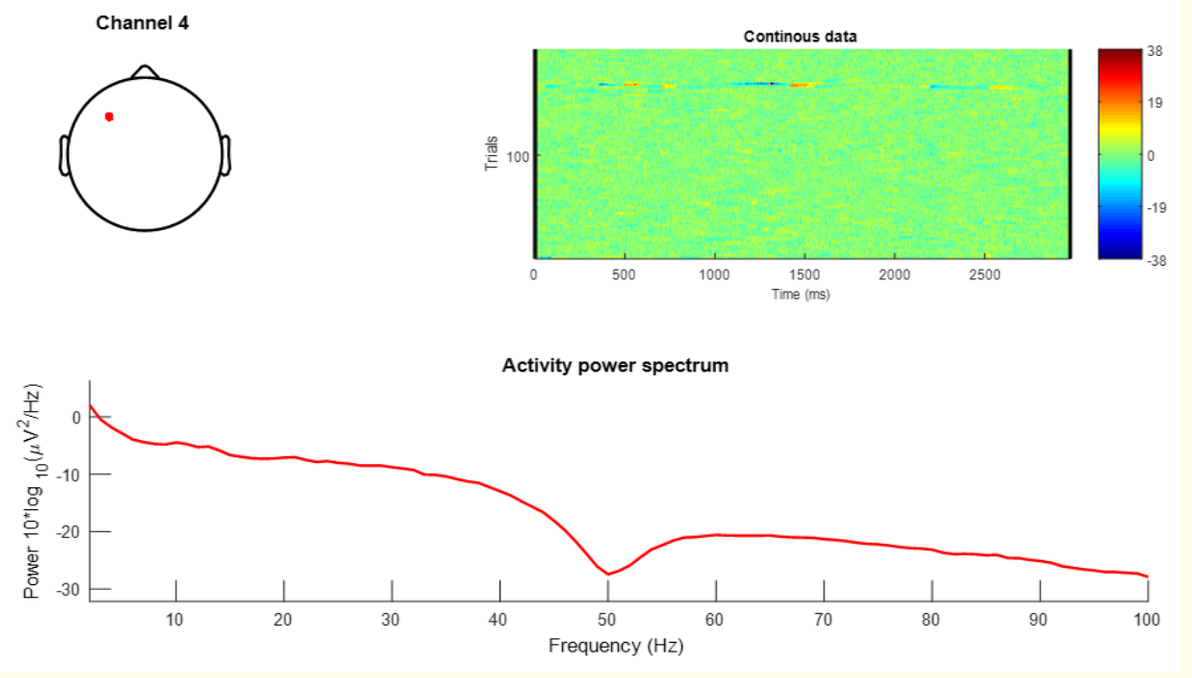


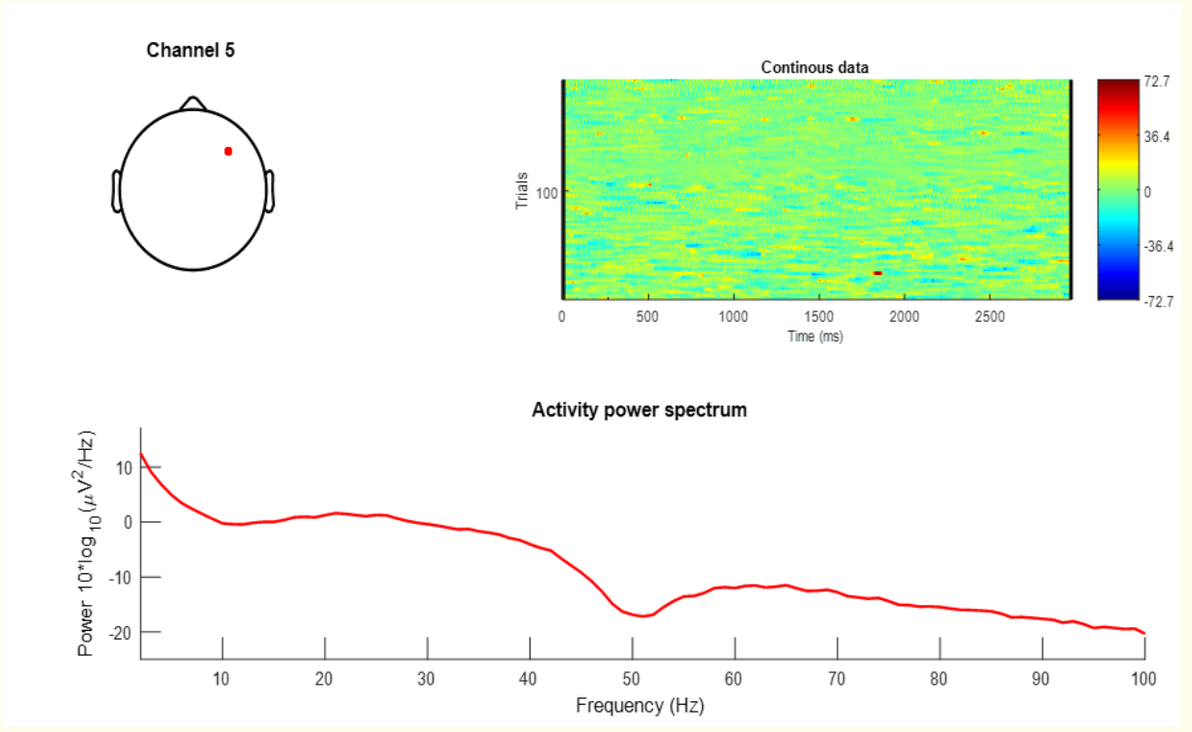
Figure 14: *Plot showing variation of power spectral density vs frequency in the pre-test.*

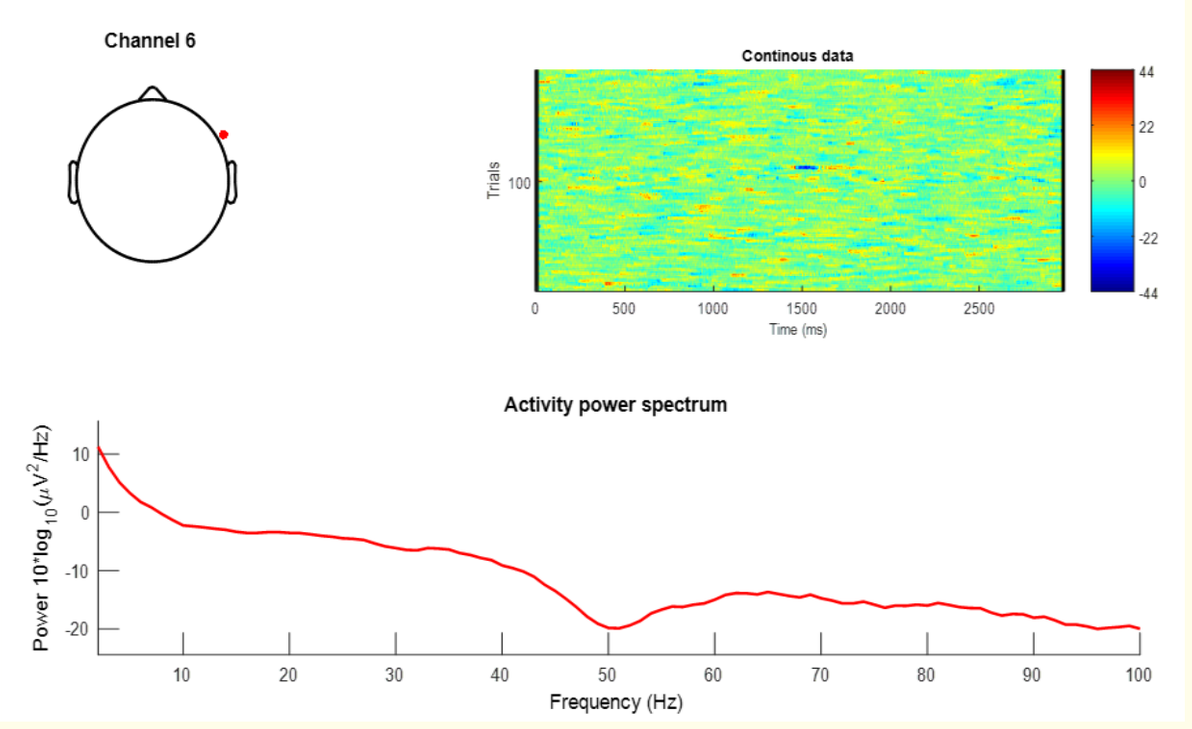

Channel 1
Continous data
Trials
100
0
500
1000
1500
2000
2500
Time (ms)
69
34.5
0
-34.5
-69
Activity power spectrum
Power 10*log 10(μV2/Hz)
10
0
-10
-20
10
20
30
40
50
60
70
80
90
100
Frequency (Hz)

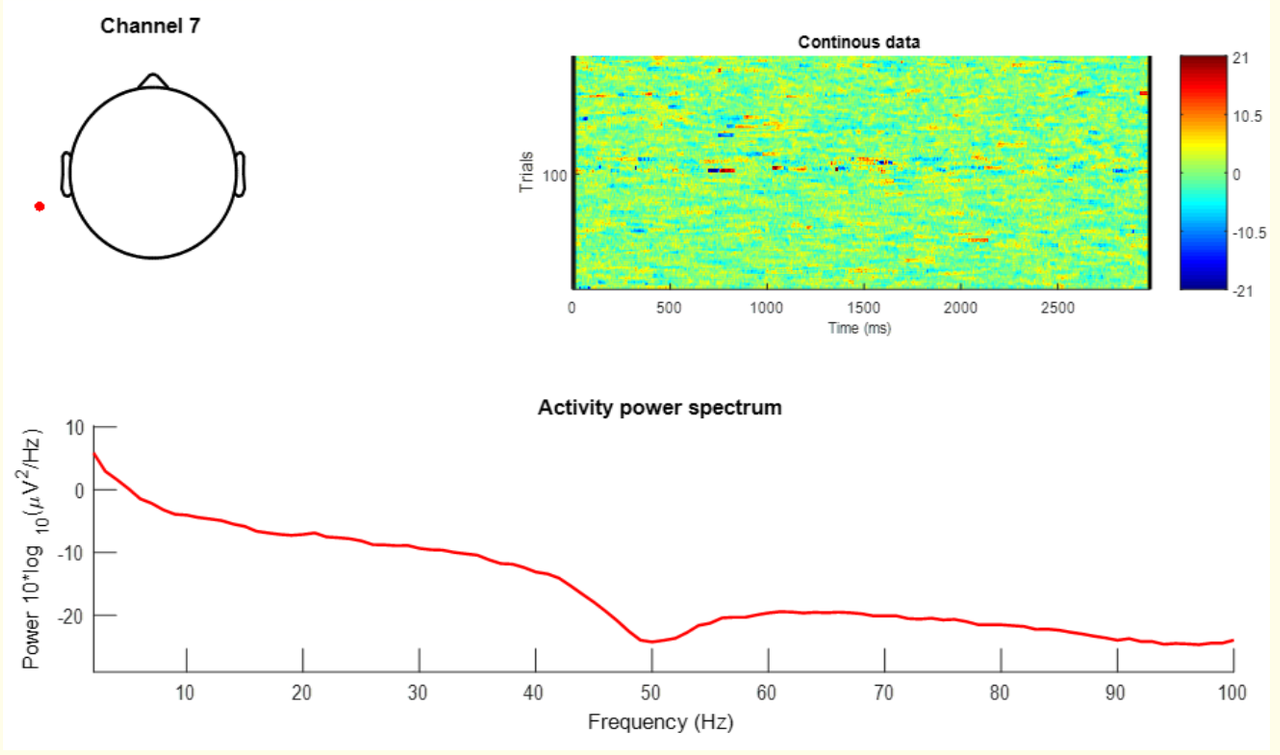

Channel 2
Continous data
Trials
100
0
500
1000
1500
2000
2500
Time (ms)
17.4
8.7
0
-8.7
-17.4
Activity power spectrum
Power 10*log 10(μV2/Hz)
0
-10
-20
-30
10
20
30
40
50
60
70
80
90
100
Frequency (Hz)

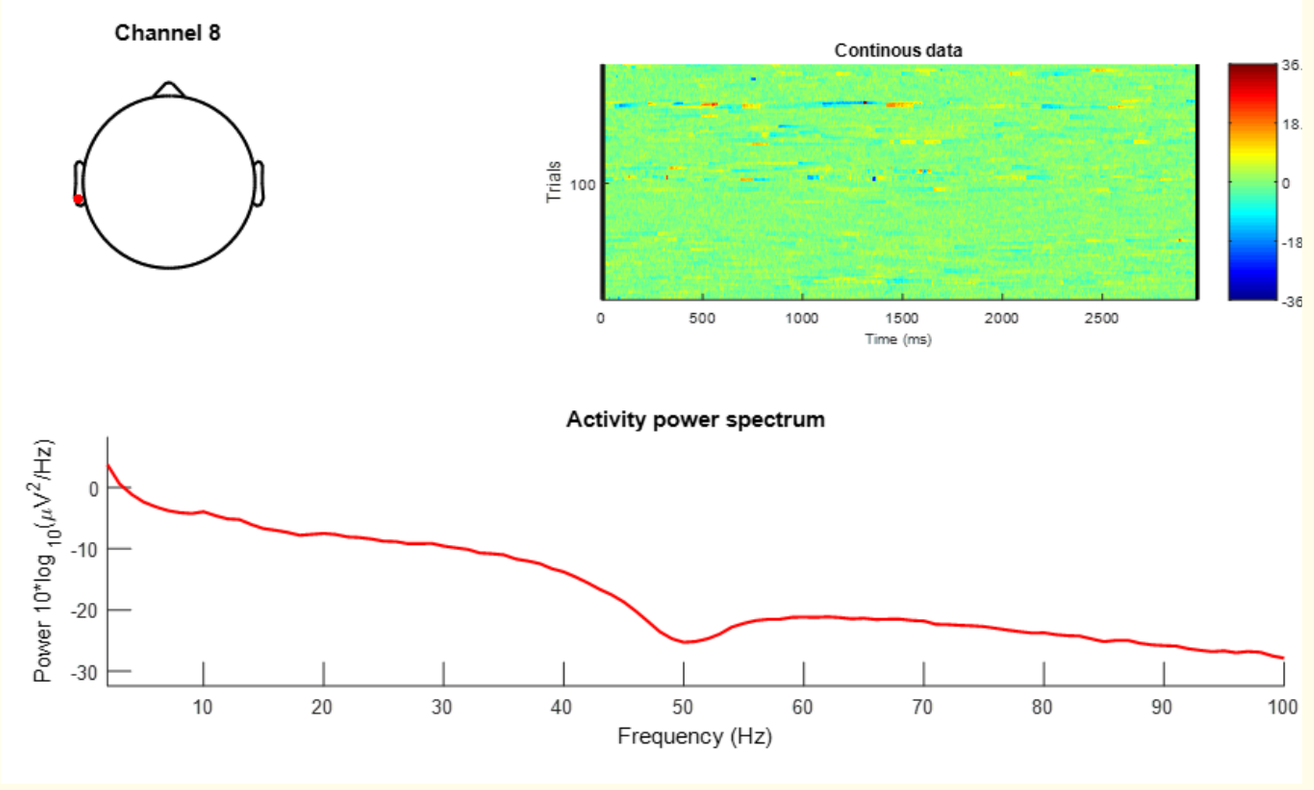

Channel 3
Continous data
Trials
100
0
500
1000
1500
2000
2500
Time (ms)
17.4
8.7
0
-8.7
-17.4
Activity power spectrum
Power 10*log10(μV2/Hz)
0
-10
-20
-30
10
20
30
40
50
60
70
80
90
100
Frequency (Hz)


Channel 4
Continous data
Trials
100
0
500
1000
1500
2000
2500
Time (ms)
38
19
0
-19
-38
Activity power spectrum
Power 10*log10(μV2/Hz)
0
-10
-20
-30
10
20
30
40
50
60
70
80
90
100
Frequency (Hz)


Channel 5
Continous data
Trials
100
0
500
1000
1500
2000
2500
Time (ms)
72.7
36.4
0
-36.4
-72.7
Activity power spectrum
Power 10*log10(μV2/Hz)
10
0
-10
-20
10
20
30
40
50
60
70
80
90
100
Frequency (Hz)


Channel 6
Continous data
Trials
100
0
500
1000
1500
2000
2500
Time (ms)
44
22
0
-22
-44
Activity power spectrum
Power 10*log10(μV2/Hz)
10
0
-10
-20
10
20
30
40
50
60
70
80
90
100
Frequency (Hz)


Channel 7
Continous data
Trials
100
0
500
1000
1500
2000
2500
Time (ms)
21
10.5
0
-10.5
-21
Activity power spectrum
Power 10*log 10(μV2/Hz)
10
0
-10
-20
10
20
30
40
50
60
70
80
90
100
Frequency (Hz)


Channel 8
Continous data
Trials
100
0
500
1000
1500
2000
2500
Time (ms)
36.
18.
0
-18
-36
Activity power spectrum
Power 10*log 10(μV2/Hz)
0
-10
-20
-30
10
20
30
40
50
60
70
80
90
100
Frequency (Hz)

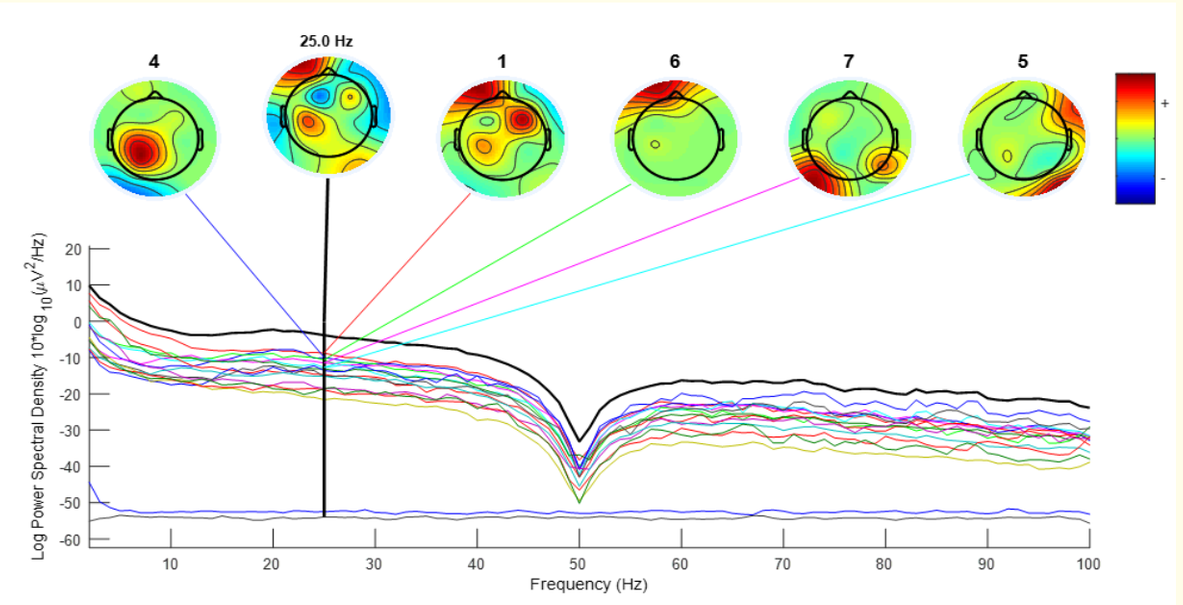


Figure 15

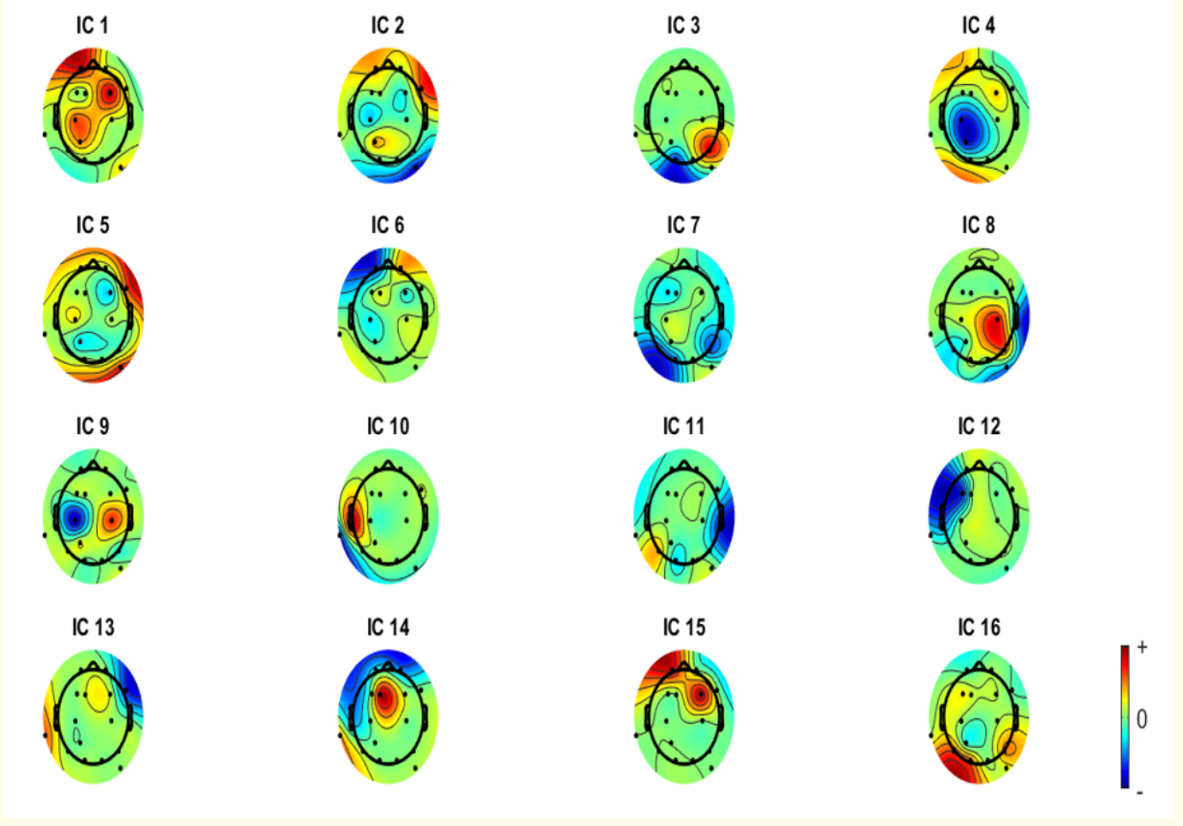


Figure 16

analysed event-related beta oscillations, in healthy subjects and MCI patients upon application of visual oddball paradigm by recording EEG. Event-related beta responses increased in power and in phase synchrony upon presentation of target stimulation in comparison to non-target stimulation. The study proved that beta activity increases with the engagement of cognitive task both in healthy individuals as well as in mild cognitive impaired subjects. S Gutierezz and M Corsi-Cabrera [11], studied EEG activity of 8 male volunteers was recorded at P3 and P4 electrodes during four resting periods and during the performance of three series of cognitive tasks: one verbal, one spatial and one demanding verbal and spatial processing or "mixed" task. Beta, alpha and theta relative power were compared between successful and unsuccessful trials during the beginning and end of performance interval as well as during resting and task periods. The analysis of the results showed increase in the beta power activity in the left parietal lobe. Several research studies on cognition showed increase in the beta power activity in the pre-frontal region of the brain.

Conclusions

The following conclusions could be drawn as the result of implementing metaphorical thinking based on VAK approach in the teaching/learning process.

- Learners generate new ideas analyse and evaluate to identify potential solutions to the given concept.
- By generating and refining ideas, the learners monitor their work and make adjustments as needed. This process would build self-regulation planning, monitoring, and evaluating their own thinking enable them to mould righteous attitude and acquisition of knowledge.
- Develops thinking beyond the given concept thus enable to synthesize and evaluate new knowledge.
- Lead to semantic understanding so that information is stored in long term memory.
- Engages learners in thinking process which in turn develops intrinsic motivation.

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