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# BCI in classroom, system for assessing dynamic state of cognitive performance using EEG signals

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## Abstract

Brain Computer Interface is a technology where the real time brain activity is recorded and transmitted to an analyzer to interpret. BCI in Classroom will assist the facilitator and well as the learner. The facilitator can design the content in suitable to the learner learning style and provide Neuro-Feedback of the concentration applied and knowledge gained through computer based assessment. If the feedback is not considerate to the standard value, further motivation can be provided to enhance the learning process. This paper explains how to analyses BCI signals in the real life classroom environment ,method of study the Signals of an individual while performing a predefined task, procedure to procure, understand and evaluate the EEG signals. Analysis the EEG signals is done to interpret the brain signals based on frequency ranges depicting different waves Alpha, Beta, Gamma waves, an Algorithm was implemented in classifying the concentration levels as learning outcomes by taking Beta Waves into consideration for a set of students. This process helps to assess the learning outcome and academic performance of more than one learner by using BCI in the real life environment. The cognition levels of the learner are facilitated and motivation provided for better performance.



*Keywords:* EEG, Brain Computer Interface (BCI), Cognition, Beta Waves, Augmented Reality

## 1. Introduction

In this era of practical oriented teaching, Teacher design content in various format like models, Audio-Visuals etc. before going to class. Interactive teaching styles promote an atmosphere of attention and participation. If the teacher wants to check the Attention-grabbing component, different methods have been applicable till now. Is there a method where we can directly read the signals from the student brain and interpret the signal and measure the cognitive performance? The content designer can do the required changes before taking the actual lecture. Our brains process information and conduct the signals continuously on many kinds of levels, only some of which are consciously directed. But, conscious or not, the important thing to understand is that it is our brains that are doing the learning, and that this process is only indirectly related to the teacher and the teaching. This is a challenge to see what actually exists in the brains of students. This is the "summative" aspect. It is the easiest aspect to understand and it is well described in the literature. A classroom of students sitting and watching their teacher impart upon them the concepts and Theories. The little wonder what was going on inside their heads? Just how does the information they are taking in become actual knowledge?

Cognition is a process referred to mental abilities pertaining to knowledge, attention, working of memory, judgment, evaluation, reasoning, problem solving and decision making. Cognitive processes utilize existing knowledge and generate advance knowledge. The Memory ability is our capacity to register, store, and recover information over time more precisely the persistence of learning over time. Human memory can be affected by how well we focus on attention, motivation that we practice.

Memory is the cognitive process where brain holds some information or skills derived from the environment. It just doesn't memorize information but also understands concepts.

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This memory helps to develop the knowledge of an individual. To measure the amount of knowledge gained, spatial memory in the cognitive psychology can be measured. Some instruments have been developed to measure cognitive memory but had some limitations. Sensory, short-term and long term memory classifies the memory. When an item is perceived, it lasts in the memory for 200-500 milliseconds. Sensory memory is sensual to feeling, look and gaze and store. After a period of time of gaze an incidence is recollected then it is Short term memory. If the data is stored for longer duration then it is Long term memory. Spatial memory is the ability to generate, represent, transform and recall information. Both short term and long term memory have been traditionally assessed using animals. An application called ARSM task has been developed to measure spatial memory in children. Spatial short term memory has the ability to handle complex cognitive tasks such as problem solving using mathematical methods, number writing and magnitude judgment. The spatial memory is also predicts the learning outcome and the academic performance acquiring academic skills and other impact to academic performance. ARSM (Augmented Reality Spatial Memory)[1] is an application to assess and evaluate spatial short term memory in children involving movement unlike the BCI (brain computer Interface). Koening[1] developed VMT(Virtual memory Task) which gives the causes of brain cognitive defects in brain injury and the novelty of task concluded by comparing the virtual environment with the real environment but it lacked the attain focus on spatial short term memory load which had not been taken account in relation with real world environment.

### *1.1 Brain computer Interface*

The need arises if the measurement of spatial memory helps to assess the learner's capability, then how to measure the spatial memory for cognitive process. One of the procedures to measure the spatial memory is by using BCI (Brain Computer Interface) which is also referred as Brain Machine Interface (BMI) which is hardware and software communication system that facilitate humans to connect with their environment without the involvement of peripheral nerves and muscles inputs by using control signals generated from electroencephalographic activity (EEG). The BCI technology has been traditionally been unattractive for very serious scientific investigation. Earlier this investigation of reading signals from brain activity has been limited to explore neurological disorders[2]. The BCI activity was too complex because of limited resolution and reliability of information that is detectable in the brain and its high variability. The chances of using BCI as auxiliary technology that has helped severely disabled people proportionally increased social acceptance and need to accelerate the progress. Small specialized companies such as EMOTIV [3] and NEUROSKY[4] have developed applications oriented to the public domain. BCI uses brain signal to derive information on user intentions. It relay on measuring brain activity and translate information into traceable electrical signals.

The BCI system takes the bio-signal measured from a person and abstracts some status of cognitive state. The bio-signal are considered and passed through BCI interface and the prediction of different cognitive state is done. There are three types of BCI 1) Active BCI 2) Reactive BCI 3) Passive BCI. The passive BCI helps to measure the work load and attention levels and focus levels. This research is targeted towards non-passive BCI. The modern BCI has Jung et all [5] wireless headset and a portable interfacing and processing devices.

### *1.2 EEG (Electroencephalogram)*

EEG measures electric brain activity caused by flow of electric currents during synaptic excitations of the dendrites in the neurons. Electroencephalograms (EEGs) are one of the techniques which provide an electrical representation of bio signals that reflect changes in the activity of the human brain. The approach of BCI and their evolution within the last decades has provided a synopsis of the relevant methodologies and algorithms that are used to analyze EEG signals. When you are when actively engaged or paying attention, the brain emits a signal – an attention signature. The major challenge of the teacher is to analyze and evaluate the understanding aspect of the student, which will further motivate in the teaching effectively. The evaluation methods till now including the exam pattern of answering descriptive, subjective questions. This has some far fulfilled the needs of evaluation system.

Luis Fernando et al, Brain Computer Interfaces[3] has not be taken much potential proven outside the laboratory because of its robustness and We therefore identify the flaws in BCI training protocols according to instructional design principles at several levels in the instructions provided to the user in the tasks he/she has to perform and in the feedback provide. The poor performance is due to the signal processing algorithms for analysis of EEG [6] signals. Electroencephalography (EEG) is the neurophysiologic measurement of the electrical activity of the brain In 1875, the presence of electrical current in the brain was discovered by English physician [7] in a spontaneous and continuous manner derived from mammals. In 1912, A Russian physiologist named Vladimir [7] published a paper after the detection of the first brain signals and evoked potentials in mammals (dog).The German neurologist Hans Berger[8] recorded the first human brain signal in 1924,which was the beginning of knowing that electrical signals were present and can be recorded. The device was named EEG in accordance with the observation of Berger [9]. The readings of the amplified brain activity are recorded on graph paper[7].Technologically advanced EEG equipment and introduced concentric needle electrodes. In 1935,[10] described the characteristic form of spike waves, which started the field of clinical electroencephalography. After World War II, the researchers have tried to develop various methods of detection, purification, and classification of brain signals to diagnose abnormal signals. In the 1950s, [11] Developed an EEG topography, which enhanced the mapping of electrical activity taking place across the exterior of the brain. This topography was used in psychiatry until the 1980s[12]. From the year 1990 to 2000, many approaches were developed to process EEG signal such as Blind Source Separations (BSS) and Independent Component Analysis ICA.

The Application of AR are incorporated in diverse fields including human behavior [12]. AR is also used in education for the beneficiary visual alertness of students, by super imposing the virtual elements on the real space for immersive visualization. Mobile devices as equipped with all advanced features support AR applications at any point of time. Nevertheless, to our knowledge, one field lacking to assess AR is to evaluate cognitive processes. Mobile AR systems have already proven their potential in educational field. For example, [1] a digital game in developed using a gadget from the Nokia family in spreading awareness and importance of recycling and teaching participants how to achieve desired results. AR game in comparison of a video game, the following parameters

Like the level of participation, friendly use and perception involved during the execution of the game and the perceived learning about recycling had increased and created more awareness. A positive inclination is detected with respect to both the games [1] developed a game for learning the water cycle and compared the results using gadgets like an iPhone and a Tablet. The observation has derived that physical characteristics of the gadget like size and weight did not influence the learning curiosity and amount of participation in the experiment.[1] iPhone game is developed for learning multiculturalism, to achieve harmony and develop tolerance. Two different groups playing on mobile with the group playing traditional games have not shown significant difference [13] in comparison of a mobile AR system with a textbook material pertaining to forensic medicine, Only 10 third-year medical students participated in the study. Their results showed a statistically increase in knowledge acquired for the AR group. [14] presented mobile AR-based learning material in EFL English (English as a Foreign Language), Only 5 participants took part in the study. The results showed that the participants were engaged in the learning scenario, constructed linguistic and content knowledge, and produced meaningful essays. Use of AR has proved much desired results and the users were much benefited with high level of understanding. By integrating augmented reality into the lectures, it can capture the attention of your audience confirming undivided attention, motivating audiences participate**.** Students are able to access models on their own devices via Augment's app. By visualisation of these augmented models, the students gain a better understanding of the concepts they are studying. The fun way to engage students and reinforce concepts they've seen during class lectures.With Augment, you do not have to invest in physical materials. Students are given access to experiment on the models from any device at any time**.** Whether they are at home or in the classroom, students can study and interact with the course materials. In the digital era, students are constantly triggered with the use of augmented reality. The students are motivated by new ideas and can think critically about the world around them. Factors such as publication year, learner type (e.g., K-12, higher education, and adult), technologies in AR, and the advantages and challenges of using AR in educational settings are studied. The most reported advantage of AR is that it promotes enhanced learning achievement through live visualization.

The measuring of brain signals through an EEG headset, involving bio signal analysis is one of the most important topics that researchers have tried to develop during the last century to understand numerous human diseases. Electroencephalograms (EEGs) are one of the techniques which provide an electrical representation of bio signals that reflect changes in the activity of the human brain[15].

A challenge for the teacher is to help students in allowing them to concentrate more and to perform better. The learners can improve their attention problems, cognitive problems (mental skills that don't allow us to perform at our best) and behavioral problems but once if the learners or the teachers know how much level of concentration is made to understand a subject. It's a proven fact that Greater attention equals to greater learning. Attributes like Attention, concentration can be measured by measuring brain activity which is indicative of attention[16]. The research will help to collect signals from brain and later analyses them to an algorithm to find out the concentration levels in a learner.

Learner can activate great cognitive games by applying full attention to get started by using BCI devices. This technology can actually move game characters by mind/attention alone. If attention is lost, the game will exit until they fully apply themselves again. So, cognitive games + Play Attention's attention monitor = huge differences in success[17]. The Research works by tracking brain-wave activity as games are played or engage in virtual-reality simulations[18]. When synapses fire, they release electrical pulses that move through the body. The device uses three carbon contacts to tap the signal through the skin or the brain electrodes, while software filters out electrical interference from moving muscles, particularly the heart[10].A program paradigm is included for virtual training scenarios using games or virtual-reality[19], and it prevents you from engaging in any program until you're in the zone. To determine focus, the Research looks for brain-activity patterns indicative of attention, including beta-level waves from 12 to 30 hertz[20], which neurologists consent as a mark of attained concentration. Till the present time , the research was carried out from one learner to one monitor, if we include no of headset at one particular time , all the headsets will connected with a IOT protocol and all the signals connected via ARM processor with which it goes to the feedback computer. The teacher if can analysis the signals in real time, they can concentrate more on the students and change their way of delivery to meet the needs. Brain Computer Interface[9] is the fast working system with less errors as it does not contain human transfer at all. Cognitive computing[21] is also emerging area as few major companies like IBM started a machine called as "IBM Watson", Google

has started a App like "GOOGLE Now". The possibility of BCI will be used in future for "opportunistic applications''
The teacher explains the concept using Augmented Reality; the learners will wear an authentication band to and enter the class. The authentication is taken and learner is given access into the Augmented Reality LAB, the learners will be given a headband which has dry electrodes as they wear the headband as a cap, the electrodes gets fitted on the scalp and as the learner attends the class, the headband will obtain signals from the brain and are transferred into a computer for signal processing. The signals are interpreted to an algorithm depending upon the Delta, Alpha, Beta and Theta waves; we can determine the concentration depending upon the spatial memory of the cognitive skills.

### *1.2.1 Delta wave (1 to 3.9 Hz)*

Delta brainwaves are the low frequency waves but strong brainwaves. They are produced in time of meditation and dreamless sleep. Delta waves append the external awareness and are the source of empathy. This undisturbed sleep is needed to needed by the body for healing and regeneration.

### *1.2.2 Theta wave (4 to 7.9 Hz)*

Theta brainwaves occur most often in sleep when we are dreaming, intuition and sixth sense information is imparted and are connected to the past troubled history. In theta, senses are isolated from the external world and focused on signals originating from inner conscious.

### *1.2.3 Alpha Wave (8 to 13.9 Hz)*

Alpha brainwaves are prevalent with the present environment during thought process , and in some meditative states, detected better than Beta brain waves when a person is in creative zone, recreation, stress free. Alpha is 'the power of now', being here, in the present[22]. While the brain activity includes the mental coordination, calmness, alertness, mind/body integration Alpha is the inactive state.

### *1.2.4 Beta waves (12 to 38 Hz)*

"Beta waves are generated ranging from 13 to 60 pulses per second in the Hertz scale associated with focus, alert, agitated and dominate our normal waking state of consciousness and alpha waves are generated in relaxed, calm or quiet the mind," says Garten[23]. Human brain is usually in beta mode while performing routine task, but as the complexity and reasoning increase, the alpha rhythm is detected. To reduce the activity in the brain techniques like meditation and mindfulness is practiced releasing increased levels of beta-endorphins and dopamine. Beta brainwaves are further divided into three frequencies; Low Beta (Beta1, 12-15Hz) can be thought of as a 'fast idle, or musing. Beta (Beta2, 15-22Hz) is high engagement or actively figuring something out. Hi-Beta (Beta3, 22-38Hz) is highly complex thought, integrating new experiences, high anxiety, or excitement. Continual high frequency processing is not a very efficient way to run the brain, as it takes a tremendous amount of energy. Our main concentration is on Beta waves because these waves represent the cognition process like thinking, reasoning, concentration and attention levels.

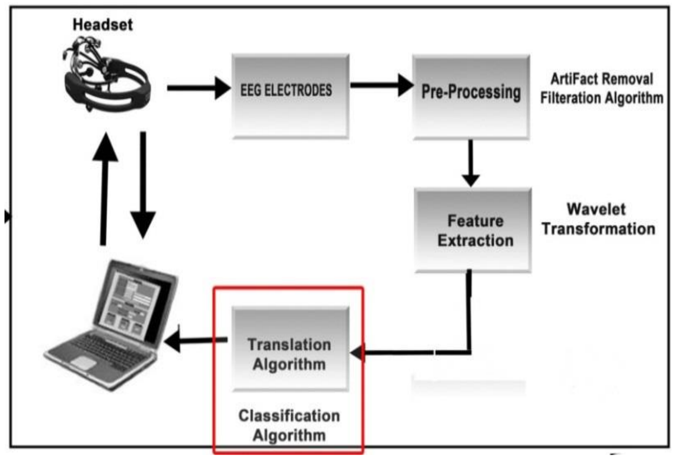


*Figure 1 : The Algorithms used in reading Brain Signals*

## 2. Feature Extraction

When the data which is to analyze from the device is sent to an algorithm as mentioned in Figure1. Data if bulky and redundant is subjected and transformed to a set of specific features [24].

### *2.1 Discrete Cosine Transform (DCT)*

It is a method to convert time series signals into frequency components. It is used to calculate Max, Min, and Mean Value of EEG signals

### *2.2 Discrete Wavelet Transform (DWT)*

This process feature extraction EEG feature extraction is done by using wavelet transform. But there are multiple wavelets available in the wavelet family therefore a suitable wavelet has to be chosen for the efficient extraction of different feature of EEG. EEG features mainly contains the different frequency bands.

### *2.3* K-Nearest Neighbor (KNN)

K-nearest neighbor is an instance-based, lazy and supervised learning algorithm. KNN is a simple algorithm that stores all available cases and classifies new cases based on a similarity measure. KNN is a non-parametric method that classifies the data by comparing the training data and testing data based on estimating the feature values.

### *2.4 Linear Discriminant Analysis*

(LDA) is one of the most popular classification algorithms for Brain Computer Interface applications, and has been used successfully in a large number of systems. LDA linearly transforms data from high dimensional space to low dimensional space. Finally, the decision is made in the low dimensional space.

### *2.5 Naive Bayes Probability*

It can be interpreted from two views: Objective and Subjective. The Subjective probability is called as Bayesian Probability[14]. Bayesian Probability is the process for using the probability for predicting the likelihood of certain events occurring in the future. Naive Bayes is a conditional probability model where Bayes' theorem is used to infer the probability of hypothesis under the observed data or evidence.

### *2.6 Support Vector Machine (SVM)*

The following factors are classified for EEG signals. The factors are Stability, low variance, regularization term, maximum margin method, Gaussian Kernel, smoothing parameter, Matthews's correlation co-efficient. Once the preprocessing is done, next task is to classify the signal into appropriate stress level. When a single classifier is used, it is difficult to identify the misclassification error. The solution to this problem is to develop a more complex classifier with a little misclassification rate. This approach may seem promising but it will make the system complex. Combination of simple classifiers can be experimented rather than using one complex classifier. One more advantage of this approach is that even if one of the classifier misclassifies the data, the other classifiers can rectify this error.

## 3. Classification Algorithm

The above experimental setup shows the Mind Wave sensor which is made available to wear on any subject for acquiring the EEG data from the scalp of the subject, the environment is set up with the entire required prerequisite and headband is safe and friendly use, then extracted EEG signal is connected to a digital device via Bluetooth. This step includes data extraction from the scalp and the analog signals are converted to digital signals, the headband sensor collects the data through the Think Gear Sensor placed on the scalp. EEG signals are detected when there is a potential difference across the brain when a neural activity takes place. These signals are monitored through Neuro Sky brain-computer interface technology. The input signals are collected through think gear chip, for further interpretation. After further analysis this signals are mathematical analyzed and displayed as output digital messages to the system, permitting to understand the brainwaves on the screen. The analysis is classified as the signals pertaining to attention and meditation, which gives a magnitude of the brainwaves to envision the acquired signals, will be displayed on the computer.

### *3.1 Algorithm*

Step 1: The BCI data signals are collected from the instrument
Step 2: The Signals are converted into CSV format and further analysis
Step 3: If the value of x =1, retrieve the bands of EEG
Step 4: Statistical analysis is done while calculating the learning styles of the learner
Step 5: if x! = 1, end the loop
Step 6: Exit
After implementation of the algorithm, the EEG band are retrieved and saved into a CSV format for further analysis with respect to time and the frequency range of each band.

### *3.2 Flow Chart*

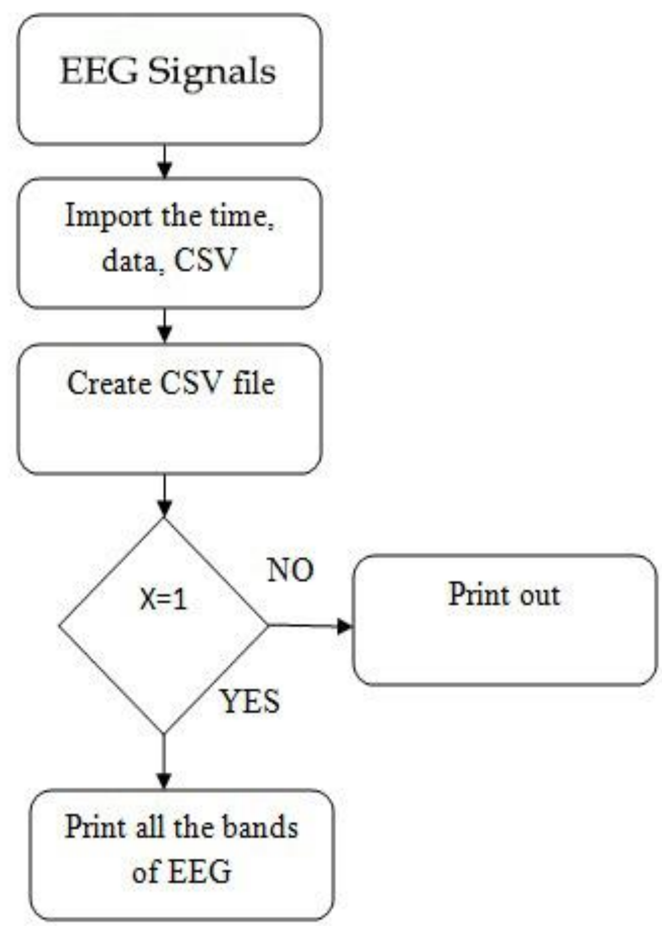


*Figure 2: Flow chart to read the Brain Signals*

NAME OF STUDENT : HIREN

| Time | Visual | Time | Audio | Time | Reading | Time | kinect |
|---|---|---|---|---|---|---|---|
| 16:11:14 | 1 | 16:12:23 | 3 | 16:09:02 | 26 | 16:13:58 | 61 |
| 16:11:15 | 1 | 16:12:24 | 13 | 16:09:03 | 8 | 16:13:59 | 54 |
| 16:11:16 | 11 | 16:12:25 | 16 | 16:09:04 | 3 | 16:14:00 | 53 |
| 16:11:17 | 21 | 16:12:26 | 17 | 16:09:05 | 26 | 16:14:01 | 51 |
| 16:11:18 | 23 | 16:12:27 | 11 | 16:09:06 | 16 | 16:14:02 | 54 |
| 16:11:19 | 38 | 16:12:28 | 11 | 16:09:07 | 27 | 16:14:03 | 44 |
| 16:11:20 | 48 | 16:12:29 | 1 | 16:09:08 | 29 | 16:14:04 | 44 |
| 16:11:21 | 61 | 16:12:30 | 10 | 16:09:09 | 21 | 16:14:05 | 29 |
| 16:11:22 | 70 | 16:12:31 | 13 | 16:09:10 | 38 | 16:14:06 | 50 |
| 16:11:23 | 70 | 16:12:32 | 24 | 16:09:11 | 30 | 16:14:07 | 60 |
| 16:11:24 | 56 | 16:12:33 | 24 | 16:09:12 | 30 | 16:14:08 | 44 |
| 16:11:25 | 38 | 16:12:34 | 10 | 16:09:13 | 30 | 16:14:09 | 56 |
| 16:11:26 | 43 | 16:12:35 | 10 | 16:09:14 | 30 | 16:14:10 | 47 |
| 16:11:27 | 47 | 16:12:36 | 1 | 16:09:15 | 38 | 16:14:11 | 35 |
| 16:11:28 | 56 | 16:12:37 | 11 | 16:09:16 | 38 | 16:14:12 | 40 |
| 16:11:29 | 61 | 16:12:38 | 21 | 16:09:17 | 53 | 16:14:13 | 44 |
| 16:11:30 | 54 | 16:12:39 | 21 | 16:09:18 | 56 | 16:14:14 | 43 |
| 16:11:31 | 48 | 16:12:40 | 26 | 16:09:19 | 56 | 16:14:15 | 41 |
| 16:11:32 | 40 | 16:12:41 | 17 | 16:09:20 | 69 | 16:14:16 | 57 |
| 16:11:33 | 29 | 16:12:42 | 11 | 16:09:21 | 70 | 16:14:17 | 48 |

*Figure 3: Implementation of Algorithm for EEG signals*

## 4. Conclusion

The Brain signals are analyzed and converted to measures of numbers, use of EEG signals of a student through wearable technology can be utilized for the purpose of tracing student attendance and authentication. To supplement the learner for higher level of understanding by immersive visualization with the use of Latest teaching methodology like Augmented Reality. BCI Data could be used as a metric for the design of learning resource because they allow establishing the extent to which students are engage in learning activities. The task is more challenging with the given variety of course components setting modest goals and using low-demanding technologies for practice of everyday session.

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