A Note on Methods Used for Deception Analysis and Influence of Thinking Stimulus in Deception Detection

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Abstract—Lie or deception analysis is a significant challenge for investigators especially in crime cases. Identifying liar from normal human behaviour has higher relevance with external behaviour and cognitive functionality of human brain. Methods such as polygraph, cognitive polygraph, facial electromyography, eye tracking, voice stress analysis and functional magnetic resonance imaging have been already developed for deception analysis. Even these methods has its own merits, all these methods faces a common issue of accuracy in deception detection ratio due to different kind of liars and learned criminals. Thinking is an internal stimulus having relationship with deception. Identifying thinking responses from brain is one of the measures used to detect deception. Electroencephalography is another modality to understand cognitive responses such as thinking from human brain and this method can be extended to detect liar from other people. Statistical features such as Power, Variance and Root Mean Square (RMS) have been calculated for normal and thinking patterns of EEG signal. Primary objective of this paper is to focus various methods used for lie/deception analysis. This paper also explains influence of statistical features to discriminate thinking patterns from normal signal.

Keyword-Lie detector, deception, EEG, thinking stimulus

I. INTRODUCTION

Lie or deception detection plays an important role especially in the field of criminology where investigating criminals becomes great challenge for the crime branch people. Lying may be a kind of character in human being where identifying truthness of the person is one of the critical applications in the crime domain. Internal and external responses of the person have very close dependency with their lying behavior. Fear, sweating, tension, stuttering speech, eye contact and facial expression are some responses with respect to persons lying behavior. Blood pressure, motor and sensory activities of human brain are internal responses which are used to identify lying behavior. Analyzing lie or deception property of human becomes critical challenge for researchers and crime department due to insufficient external responses by learned criminals. Development of an efficient lie or deception detection system will be the great help for researchers and investigators to discriminate human responses from lying behavior to normal behavior.

Electroencephalography (EEG) is an efficient modality to analyze internal responses of human brain in terms of brain signals. A brain consists of numerous neurons where there is an electrical potential from each neuron which will be recorded by using Electroencephalogram. Human brain has five lobes such as Frontal (F), Temporal (T), Occipital (O), Central (C) and Parietal (P). Internal and external behavior of the human primarily depends on these lobes. Deception has indirectly related with thinking portion of the brain when person trying to give false statement. Signal from portion of the brain which is responsible for thinking also helps to understand the lying behavior of human being. Brain functional responses and its corresponding psychological behavior can be easily measured through various intelligent mechanisms for lie detection.

Intelligent liars have lot of tactics to deceive investigators which encourage the researcher to develop lie detection [1]. Lying behavior has been measured by using the psychological activities like skin resistance, heart beat and breathing pattern through polygraph device [2]. Two standardized protocols such as Guilty Knowledge Test (GKT) and Comparison Question Test (CQT) are used for crime investigation which can be accompanied with polygraphy test [3]. Face projects internal activities of the human where facial responses have been measured using Facial Action Coding System (FACS) for developing deception analysis [4] [5]. Lee proposes a method using functional Magnetic Resonance Imaging for lie detection to discriminate between liars from normal human being [6]. An evoked potential stimulus has been widely applied for lie detection using EEG modality [7]. P300 is the positive wave lasts for 300-350ms which accurately induced by cognitive activity. Brian Fingerprint has been developed by Farewell which coupled ERP with Guilty Knowledge Test (GKT) for lie/deception detection [8].

II. METHODS USED FOR LIE DETECTION

Several methods have already reported in literature for deception analysis. Accuracy of discriminating lie from normal responses is primary issue in most of the detection system. Use of experimental methods like in-vivo studies are another constraint in lie detection system. This section gives widely used methods for deception analysis.

A. Polygraph

Polygraph is a well known technique for lie detection and commonly referred as lie detector. The main aim of polygraph method is to detect the changes in human body through signals which are difficult to monitor by manual inspection. The development of the polygraph machine has been started from mid-nineteenth century. Italian physiologist, Angelo Mosso, used a machine to measure the blood circulation and breathing activity is called Plethysmograph. Changes based on emotions and fears have been recorded using this method.

Cesare Lombroso, an Italian physician psychiatrist, who developed the first machine for criminology investigation in 1895. Existing machine has been enhanced with some modification to produce new device called Hydrosphygmograph which is used to measure the physiological changes through blood pressure and heart rate occurred during crime investigation. Sir James Mackenzie (1906) introduced clinical ink polygraph which is used to record the physiological emotions through ink. Hugo Munsterburg (1908) promoted the lie/deception detection machine in courts. Italian psychologist, Vittorio Benussi (1914) discovered a device called pneumograph during which helps to monitor the respiratory patterns. According to Vittorio, respiration activity has been changed when a person is lying. William Mouton Marston (1915), Harvard psychologist had done further investigation with systolic blood pressure and identified the physiological activity occurred during lying session.

John A Larson (1921), psychologist worked in Berkeley police department developed lie detector called polygraph based on blood pressure along with respiratory rate. Keeler Polygraph (1926) developed an improved version of Larson polygraph and brought into market. Leonarde Keeler (1938) also referred as father of polygraph has developed a new polygraph system for deception detection using another psychological measurement as skin resistance and the system is referred as psycho galvanometer. It helps to monitor the changes in heart rate, blood pressure, blood volume, breathing pattern and skin resistance due to involuntary responses occurred in our body. These methods will not directly determine the lie/truth instead it measure the physiological activities occurred during the enquiries about the incident by the examiners. A polygraph examination can be conducted to detect whether the person is lying or not. It can be performed using three phases such as pre-test, in-test and post- test [9]. In pre-test phase, subject will learn the investigation procedure and issues to be investigated can also be informed to the subject. Examiner connects all the necessary components to the subject. Continuous cardio activities such as blood pressure, blood volume and heart rate, blood pressure have been monitored in this phase. During in-test phase, questions will be raised based on the issues with minimum three separate sets and each will lasting for five minutes. The examiner investigates the person by asking questions and simultaneously monitoring the psychological information. Results will be projected in post-test phase.

B. Cognitive Polygraph

Cognitive behaviours have been measured through non-invasive and inexpensive technique called Functional Transcranial Doppler (fTCD). It measures the blood flow velocity in intracranial vessels. There is a correlation between blood flow and neural activation. Blood flow velocity will float during mental behavior [10] [11]. It can be recorded during rest or performing cognitive task. This method has been applied for crime investigation process. Blood flow can be monitored for deception detection while questions are raised by the examiner.

C. Electromyography

Face behaves like a mirror of internal responses such as happy, sad, anger, surprise and hate. Lying is also a kind of internal behavior which will reflect on human face with respect to the functional behavior of human brain. Eye contact and word flow are some important outcomes during person tells lie. Similarly facial muscles will also get influence on lie and truth cases. An involuntary muscle in the face produces emotional responses with respect to specific part of brain and also shows their expression in face. Darwin claimed that emotions and their expression are biologically combined together [12]. Facial muscle can stretch or shrink according to different mental activities. Chin muscles have higher activation in the human face when a person is in positive attitude. Similarly, forehead projects negative attitude and surprising situations [13]. Ekman was the first person who developed a device for measuring facial expression and movements called Facial Action Coding System (FACS) [14]. Electromyogram is a device contains electrodes which are attached on the forehead above the left and right eyebrow.

D. Eye Tracking

Eye-tracking based deception analysis is a promising technology alternative to other techniques. Infrared camera can be used to track eye movements and pupil dilation. In this system, liar will be interrogated with sequence of questions. Answers from liars have been monitored through glasses wear by liars. This glass will be directly connected to lie detector. The glass makes measurement of pupil dilation, blinks, reading time and responses. An eye tracking tool is under research for automated eye tracking using camera [15]. Cognitive behavior is connected with eye blink latency as time duration between blinks [16]. Pupil dilation plays vital role in lie detection [17]. Cook stated that ocular-motor responses which is pupil reaction and reading activity measures have been used to differentiate guilty and truth teller [18].

E. Voice Stress Analysis

Voice stress analysis is another method based on voice tension of the lair during investigation. Speech technology can also apply for lie detection using various parameters such as pitch, frequency, intensity and sampling rate. It helps to detect the small variation in the person's speech. Faye and Middleton have used voice stress for lie detection [19]. A set of questions for both truthful and untruthful situation and raised to the person who is liar are organized. Responses for these situations will be recorded based on this responses and correct rate can be identified for untruthful and truthfulness.

F. Functional Magnetic Resonance Imaging (FMRI)

Functional Magnetic Resonance Imaging (fMRI) is an expensive imaging technology, discovered by Daniel Langleben. fMRI can also be used to detect brain activities related to various responses which have been widely applied for lie detection [20]. Functional MRI is an advanced version of MRI where imaging technology helps to record time series of brain images with respect to internal and external stimuli such as hand activation, lip movement, leg activation and finger movement. It is used to measure the blood flow in specific region of the brain. It allows the radiologist to visualize activation of emotional responses in the brain [21].

The person will lie inside the MRI scanner machine which is surrounded by electro-magnetic field which cause the hydrogen molecules to resonate and radiofrequency will be emitted. The hemodynamic response or blood oxygen dependent level (BOLD) response from the brain will be recorded [22]. During investigation, the person will respond to the questions by tapping his hand or leg. Activated portion of the brain can be monitored and analysis can be performed to find whether the person is being true speaker or not. Langleben uses fMRI with Guilty Knowledge Test (GKT) for playing cards and asked the subject to lie about the card. Subject asked to watch cards either they may tell lie or truth. By his report, frontal gyrus, parietal lobe and frontal cortex are activated in brain during lying [23].

G. Lie Detection Assessment Protocols

Lie detection can be assessed based on two types of standardized protocols such as i) Comparison Question Test (CQT) and ii) Guilty Knowledge Test (GKT). Generally these protocols are defined based on three variables: Irrelevant variable, relevant variable and comparison variable. In Irrelevant variable, questions are not relevant to the investigation. Relevant variable is inverse of irrelevant case where questions are relevant to the investigation process. Comparison variable is the third type where comparison or control questions are framed indirectly relevant to the investigation process.

1) Comparison Question Test (CQT): CQT is one of the emerging fields in forensic polygraphy introduced by John E.Reid in 1940s. It is the type of conventional polygraph methods [24]. It works based on sequence of 'Yes' or 'No' type responses from the subject. This method helps to measure the psychological responses after crime investigation process is done and categorize whether the person is liar or not.

2) Guilty Knowledge Test (GKT): Guilty Knowledge Test (GKT) has been introduced by David Lykken [25]. The new lie detection protocol for investigation process has been proposed in this system. It is alternatively known as Concealed Information Test (CIT). This method identifies whether the person possess knowledge about crime incident and not identifying liar. This test focused on relevant information about the issues related to crime [26].

III. Influence Of Electroencephalography (EEG) On Thinking Behavior

Convention polygraph method can be easily fooled by learned liars. Honts et al [27] conducted stimulated test for detecting deceptive and non deceptive using polygraph method. Nearly 50% guilty subjects fooled the examiners by biting their tongue or press toe on floor and act themselves as innocent. Nowadays cognitive neuroscience becomes popular in lie detection which can be combined with psychology for detecting mental activities through brain responses. Brain activities depending on internal and external stimuli can be recorded and monitored through various imaging devices. It is not easy for liars to escape from the intelligent neuroscience techniques.

Electroencephalography (EEG) is a non-invasive and less expensive technique discovered by Hens Berger in 1929. It is used to record the rhythmic patterns of the brain which are emitted due to billions of electrons

interconnected with each other. These patterns are recorded using EEG device. It consists of varying range of electrodes placed on human scalp using conductive gel medium. EEG device is connected to the computer for visualizing the signals. Pair of electrodes will be used for recording called as channel. Recordings can be done using Monopolar and Bipolar methods. Monopolar recording will be based on relationship between single active electrode and reference electrode. Average value of two active electrodes will be recorded using bipolar recording [28].

Basically brain can be broadly classified into two hemispheres such as left and right hemisphere. Each hemisphere is further divided into five lobes as occipital, frontal, temporal central and parietal lobes. Occipital lobe is responsible for vision, recognition and perception. Frontal helps for voluntary movements, motor integration, concentration, emotional, creativity and planning. Temporal refers to hearing, smell, feelings and musical awareness. Parietal lobe is sensible for sensory activities. Each lobe is responsible for particular cognitive functions. EEG system electrodes are generally arranged according to 10-20 International Standards which elicit the exact cognitive behavior of the brain. Lobes play an important role in electrode arrangement. In Frontal polar lobe, FP1 and FP2 are placed to receive attention and judgment related activities. F3 and F4 are associated with motor activities, F7 and F8 are associated with expression corresponding to verbal and emotional behaviours and Fz is located in between F3and F4 which is associated with memories in frontal lobes. Cz is the central part of brain mapped for sensorimotor activities where C3 is responsible for left sensorimotor activity and right for C4. Temporal lobe contains T3, T4, T5 and T6. T3 and T5 are responsible for verbal memory and verbal understanding respectively. Emotional responses are associated with T4 and T6. Parietal lobes have P3 and P4 electrodes for cognitive processing. O1 and O2 electrodes are located in occipital lobes used for visual processing as shown in Fig.1.

EEG signals are generated from the lobes and characterized based on the cognitive function influenced by internal/external stimulus. Signals will be represented using frequency bands (number of oscillations per second) for various mental states. Based on frequency representation, EEG signal can be categorized as Delta (0.1- 4 Hz), Theta (4-8 Hz), Alpha (8-13 Hz), Beta (13-30 Hz) and Gamma (30-100 Hz) sub band. The architecture of the lie detection model is shown in Fig.2. Data acquisition is the process of gathering brain waves through the Electroencephalogram device which contains default device filter to cutoff higher frequencies. Recorded signal have chance of noise contamination which needs to be addressed properly. Filtered signal are decomposed into subbands for analysis such as gamma (γ), alpha (α), beta (β), theta (θ) and delta (δ). These subbands have specific cognitive behavior and are extracted using feature extraction. Classification is the last step to determine the lie and truth.

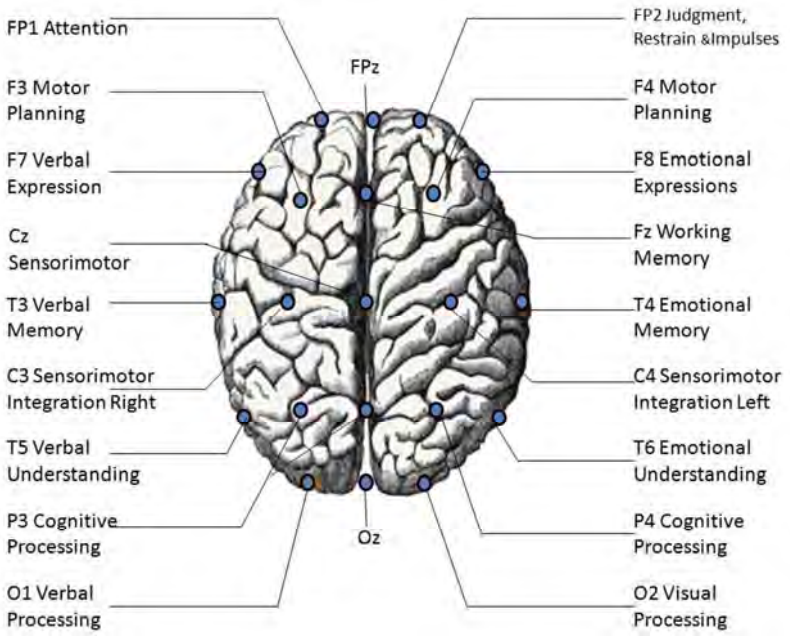

Fig. 1. Lobes and its behavioural activity

A. Event Related Potentials

EEG signal can be recorded based on neuronal activity of the brain. Particular activity of cognitive neuroscience will be separated as sensory, motor or cognitive activities using Event Related potentials (ERP). It was first recorded by Pauline and Hallowell Davis. After 1939, ERP became familiar for measuring the physiological activities and widely applied for lie detection. P300 is one of the evoked potential where 'p'

signifies 'positive' and '300' stands for 'burst of activity last for 300ms'. It can be recorded by attaching central electrodes such as Pz, Cz and Fz. It is widely used in neurological disorders and lie detection. Rosenfeld tested P300 using ten subjects. Each subject had stolen one item from the box and monitors the list of items displayed in the flash. P300 wave is evoked when the stolen item is displayed in the flash [29]. Lawrence Farwell developed a new technique called Brian Fingerprinting which is the combination of Guilty Knowledge Test (GKT) and P300 method. Holger Schultheis proved that P300 is more suitable for behavior indicators used for measuring the pupil size using cognitive load in applied context [30].

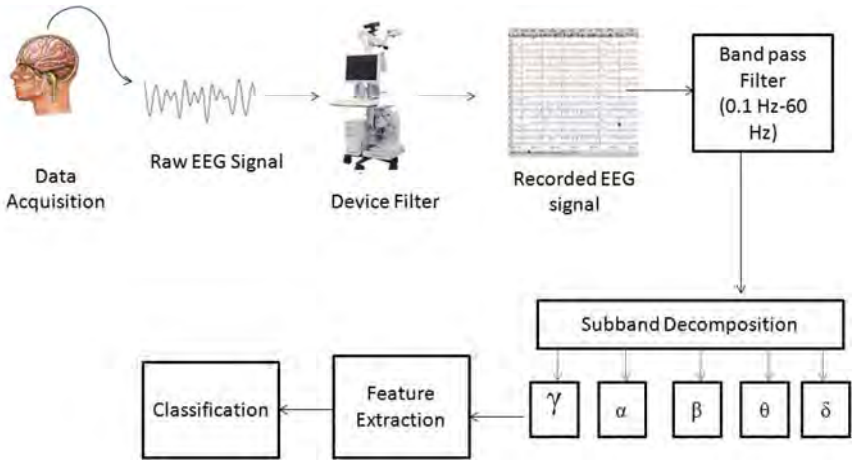

Fig. 2. Architecture of the Lie Detection Model

IV. Experimental Results and Discussion

Thinking is also associated with subject's lying behaviour at some extent which helps to analyze the deception level of a subject. As a pilot study, an EEG experiment has been designed based on Box-Car model with rest and active conditions and signals were recorded using BrainTech Traveller software. Electrodes were attached on the scalp which adopts 10-20 international standards. Referential montages were used for recording using frontal and temporal positions. Reference and ground electrodes were placed on different places of forehead. The subject will be informed to remember names of metals as first case and relaxed for static time interval. The same experiment is repeated for remembering activities on the specific day. The aim of this study is not to analyze deception/lie behaviour instead it helps to analyze thinking behaviour from normal behaviour. Signals from temporal, occipital and frontal lobes have been recorded in both rest and active stimuli for the period of 10 seconds each and the experiment ends up with 4 cycles.

Signal processing methods have been considered for nonlinear EEG signal analysis. Butterworth filter was set as (1-60 Hz) which helps to retain the specified range of signal. Discrete Wavelet Transform (DWT) was applied to decompose the filtered signal into five sub bands as shown in Fig.3 [31]. Root Mean Square, Variance and Power based statistical measures were used to measure the active memory portions from normal signal. Signals from temporal lobe alone were considered for identifying thinking patterns due to higher influence of statistical features in these signals.

A. Feature Extraction

Features are basic properties of a signal which helps to characterize raw signals. Features can be extracted in three different categories. Time domain extracts the temporal information from a recorded signal such as amplitude variation calculation and autoregressive method. Frequency domain makes use of spectral properties of a signal such as band power extraction and power spectral density. Combined Time –Frequency domain is a third case which is hybrid method to obtain useful information from both temporal and spatial properties of a signal. Entropy is a method related with information theory based on nonlinear type such as Shannon entropy, spectral entropy, approximation entropy and sample entropy. Discriminating mental task is difficult due to its reduced presence in EEG signal. Selection of appropriate features helps to segregate thinking patterns from normal patterns [32], [33], [34].

B. Statistical Features

In this study, three statistical features such as power (energy), variance and Root Mean Square (RMS) [35] were used to analyse thinking portion from normal signal.

1) Power: Power or energy of a signal can be measured through power spectral density. It reveals the energy distribution of each subband or frequency content of a signal. It can be defined as

$$Energy(n) = \sum_{i=1}^{n} | x(n) |^2 \quad (1)$$

where |x(n)| denotes the magnitude of the signal.

2) Variance: Variance is one of the statistical measures which can be calculated by taking the average of squared difference from mean of the signal.

$$Var = \frac{\sum (x-\mu)^2}{n} \tag{2}$$

where 'n' denotes the number of samples and 'x' denotes the actual signal.

3) Root Mean Square: Root Mean Square or quadratic mean can be calculated by taking the square root of mean of the signal.

$$RMS = \sqrt{\frac{x_1^2 + x_2^2 + ... + x_n^2}{n}} \tag{3}$$

where 'n' denotes the number of samples and 'x' denotes the actual signal.

Results of power, variance and RMS have been plotted in the fig. 4 to 6.

Temporal lobe is activated at the time of memory oriented task. During activation, Alpha wave is increased and Theta band is more active at the resting time. It is observed that, power values are very low in alpha sub band at the time of resting state. Alpha band shows significant influence in memory responses which reflects power values up to 11 in alpha sub band. Similarly variance and RMS values also shows higher domination in alpha band.

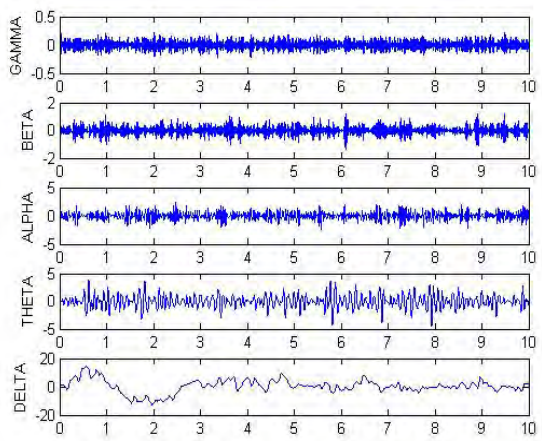

Fig. 3. Sub bands of raw EEG signal

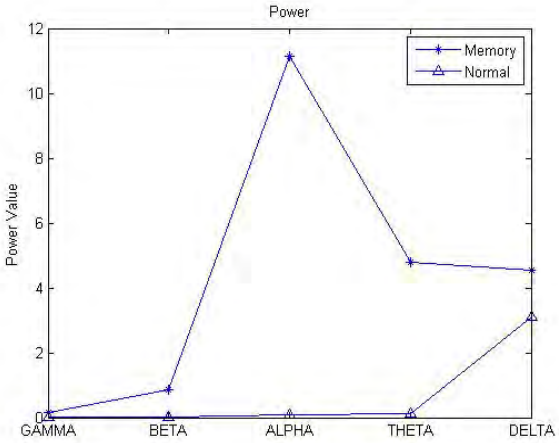

Fig. 4. Power variation for normal and thinking pattern

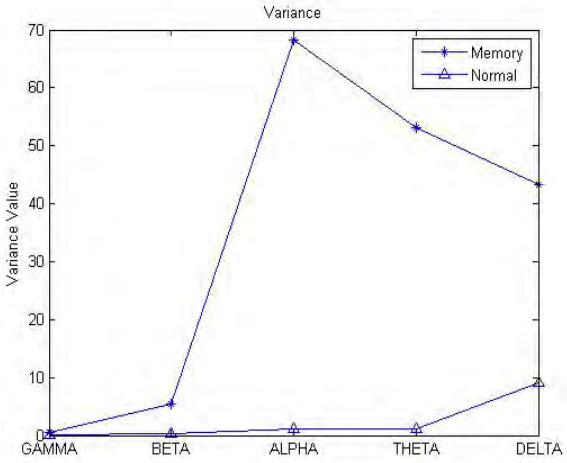

Fig. 5. Variance for normal and thinking pattern

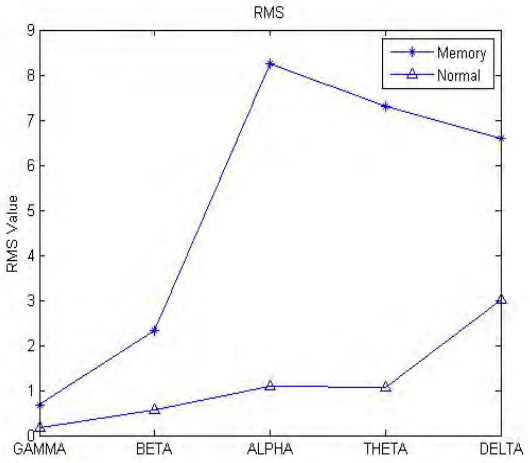

Fig. 6. RMS for normal and thinking pattern

V. CONCLUSION

Electroencephalography is an efficient method to understand brain signals with respect to stimulus. Lie detection is also a kind of internal stimulus which induce respective portion of the brain to be activated. Thinking stimulus is related with lie portion in the brain which helps to analyze deception status. This paper has detailed study about existing methods used for deception analysis and importance of EEG on analyzing thinking responses. Statistical features such as power, variance and RMS have been calculated for normal and thinking portion of EEG signal. Signals from temporal lobe have higher influence due to thinking behavior. Results show that there is a significant difference between normal and thinking part of EEG signal.

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