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Review Article

Brain Electrical Oscillations Signature Profiling (BEOS) for Measuring the Process of Remembrance

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Abstract

The BEOS test was designed and developed as an alternative method to the use of polygraph based lie-detection test and test based on recognition measured by event related potential of P300. BEOS is a neurocognitive indicator of the presence of remembrance taking place in the brain, when the same is cued by probes referring to previous experiences. They are presented in a sequential manner to an individual, who sits silently with eyes closed, without having to give any response to the probes. There are several changes associated with remembrance that take place in the brain during retrieval and BEOS score of Experiential Knowledge (EK) is a reflection of several of them. Remembrance of a previously experienced activity may be automatically and mandatorily triggered by cues presented to a subject. It could occur only if one had either participated or witnessed an activity, which is different from knowing about the same activity from an external source. Remembrance may be blocked or lost because of debilitating states like repression or degenerative process of the brain, when the test cannot be administered. The procedure has gone through validation studies and has been since routinely and successfully used for facilitating forensic investigations. Several hundreds of cases have been successfully investigated using the procedure, which has helped to understand the specific roles played by participants in each episode. The system continuously records multi-channel electrophysiological activity (EEG) from the scalp of the subject and also presents the probes only when the subject is not engaged in any other mental-cognitive activity. The system carries out the analyses automatically and produces a final report of the findings. Details of multiple analyses used and issues of sensitivity and specificity of the technique are discussed in the article.

Keywords: *Remembrance; Autobiographic Episodes; Experiential Knowledge; Brain Electrical Oscillations; Frequency and Time Domain Analyses*

Introduction

Retrieval of stored information in the brain take place regularly and frequently from memory for different processing requirements. Three of the commonly used processing needs are related to recognition of entities using signals from the external sources, by comparing them with internal models or engrams in the brain. Engrams refer to retrieval of words referring to names of individuals, objects, animals, places etc. and their sensory imageries for recognition of words heard and orthographically received, and communication purposes. The third application relates to remembering past episodes with time and place references and with the details of the responses and actions that took place, and the recreation of the emotional effects produced during the original episode. Remembrance has been generally cited as the retrieval of autobiographical episodes or personal experiences of an individual. These are personal experiences acquired through participation in an activity, and each individual has his or her own experiences, which each may be able to remember. Experiences are always constituted by sensory-motor and emotional participation, and their remembrance may constitute recreation of the original sensory-motor components as imageries and re-experience of the emotional arousal and responses. Recreation of sensory-motor imageries

are carried out by the same neural activation which took place during the actual or online experiences. The accuracy of the remembered experience may obviously depend on the accuracy of the neural reactivation, which would be decided by the spectrum of knowledge one acquired of the experience when it really took place. The multiple sensory-motor components of every experience stored are recreated by neural activation of the same areas originally involved in the experience. Therefore, remembrance is not a processing for mere knowing or accessing the knowledge bank in the brain as in recognition, which one could verbally narrate or visually present, but a process of reactivation of the brain areas representing the original sensory-motor effects created during the real experience in a past episode.

Electrophysiological changes seen over the scalp represent important neurocognitive processes occurring in the individuals during wakefulness – sleep, recognition and retrieval. Hundreds of studies have recorded these changes using surface electrodes placed on the scalp. A few of our own early studies [1-6] helped us to understand the mechanisms and the effects of impairment of the cognitive processes in neuropsychiatric conditions. Attentional arousal and the detection and recognition of a stimulus presented to an individual is accompanied by the event related potentials culminating in the P300 potential [7-14]. However, the P300 response could be effectively produced for recording only by presentation of brief stimuli, not lasting more than 200 ms. The P300 response represents the detection or recognition of a new stimulus and the amplitude of the potential is controlled by the detection of a special meaning, novelty, changes in the flow of stimuli, unexpected familiarity or nonfamiliarity, etc. of a stimulus. The P300 potential can be produced by the infrequent stimulus in an oddball paradigm consisting of two stimuli one frequently and the other infrequently presented. Some of the later studies that helped us to explain our create our stimulus presentation designs for eliciting measures of recognition and remembrance are based on the or when the same stimulus is presented with varying inter-trial interval [15-21].

Reading from Memory

Larger areas of the brain take part in the process of remembrance of autobiographical episodes in comparison with that of recognition of familiar external entities. Recognition may take place within a few hundred milliseconds, as in P300 once the signals register in the brain. Recognition is known to require only minimal signals from a stimulus, using which the brain predicts the perception of a familiar object or entity [22,23]. On the other hand, remembrance of autobiographical episodes or experiences often constitutes a reexperiencing of the past episode, which may be pleasant or distressing and therefore, it may involve total or near total retrieval of all the aspects of sensory-motor information from the memory [24]. The experience remembered constitute recreated imageries of the sensory-motor components of the episode as they happened, which were shared by the individual. If one has already transcoded the episode, the transcoded details may often be recalled instead of retrieving the experience in its original modalities. Along with these components, remembrance is also accompanied by proprioceptive and emotional components originally experienced by the person [24-26]. All these affect the EEG recorded at the time of remembrance. Recreation of sensory and motor imageries are known to activate both primary sensory cortex and secondary association areas, and in the cortex which may be activated as per the contents of online experience [27-42]. Neurocognitively remembrance must involve a process of accessing long term memory accompanied by an inward shift in attention as the individual is attending to the retrieved internal processes and associated information. Recognition is often that of an external entity which requires attention to be directed outward to the source during recognition. On the other hand, attending to own thoughts and experiences need attention to be inward directed and one may become aware of its familiarity or unfamiliarity, when recognition takes place. One may also remember other associated experiences, which may be contextually or time wise related to the remembered episode. Remembrance may be the result of voluntary effort or provoked/triggered by external cues received. The cue has a personal value as only a given individual(s) would have had the associated experience and the neural reactivation of the experiential format is triggered by the cue value of a stimulus perceived. Others would recognize the same stimulus without the cue value and there would be no remembrance linked to it. Remembrance also involves recognition or encoding of the cueing stimulus.

Neuroimaging studies have demonstrated strong evidences of extensive activation of the brain during remembrance, especially in comparison with mere knowing or recognition [43-60]. Remembrance of past personal events also require activation of the source memory which includes the time and place of occurrence of the episode and its other contextual links [61-67]. Neural activation in remembrance

of autobiographical episodes has been reported in bilateral middle temporal lobes, including hippocampus and medial frontal regions [52,68-74]. Activation produced in pure semantic recall is seen in the left frontal and temporal areas, whereas person identification is found to be associated with the engagements of bilateral frontal and temporal cortical areas [43,71-74]. Giloba [48] obtained a left ventromedial prefrontal cortical activation during autobiographic recalls, whereas a right mid dorsolateral prefrontal activation was seen in the recall of familiar words, pictures, and faces, differentiating between routine episodic recall and recall of autobiographical events. Cabeza., *et al*. [47] found that autobiographical recall produced greater activation of medial prefrontal cortex, parahippocampal region, and hippocampus. Self-referential processing effects was associated of prefrontal areas, and visual and spatial memory effects, and recall effects yielded greater parahippocampal and hippocampal activation. Steinvorth., *et al.* [43] found that recent and remote autobiographical remembrance elicited activation of large bilateral networks. The activation during remembrance extended across the anterior and posterior parts of the middle temporal gyrus spreading into superior temporal sulcus, temperoparietal junction, middle and superior frontal gyri, anterior paracingulate and cingulate gyri, and left inferior orbital frontal gyrus pars orbitalis. On the other hand, semantic retrieval produced activation of bilateral supramarginal and inferior frontal cortices, left insular cortex, and inferior temporal gyrus. Neuroimaging studies have helped to identify the extensive localized involvement of the brain during remembrance. However, EEG recorded from the scalp is only a reflection of the distant electrical effects that take place deep within the brain. The frequency and the time domain changes seen in the EEG reflect only the significant summative effects reflecting at the brain surface, which are found to indicate gross and diffused changes associated with some of the major functional states of the brain. Significant electrophysiological changes have been reported during recall of autobiographic memory depending on the neurocognitive processes involved [1,2,37,53,68,75-98]. These studies have shown significant changes occurring in delta, theta, alpha, beta, and gamma ranges of EEG frequencies. Increased delta has been reported to be associated with internalization of attention, whereas theta is related to retrieval from memory, especially related to retrieval of source memory. Desynchronization of low and medium ranges of alpha has been reported to be associated with sensory registration within the cortex. Increase in high alpha and beta frequencies have been found to be associated with processing or encoding/decoding etc. Such processing as well as neural binding effects also bring about increase in gamma activity. Significantly increased coherence of gamma activity between frontal and medial or posterior electrodes is associated with such neural binding effect, when two distant cortical areas function in close association, which has been called neural binding effect.

One remembers for long durations only those experiences which have some emotional significance to the self, and those units of information which are routinely used in everyday life. Past personal events are remembered only when they still have emotional significance. The emotional effects may be pleasant or unpleasant and personally significant or not to the individual. Autobiographic episodes associated with emotional experiences are found to be eligible for such remembrance. On the other hand, one may never remember multitudes of actions and responses which one carries out in everyday life, when they have not caused any emotional effects in the individual. Emotional significance is therefore of crucial importance for one to be able to remember personal episodes for longer periods in life. Remembrance of a certain experiences naturally occurs when they are cued by external stimuli. Only that signal or unit of information which could attain a relationship with the original experience can trigger such remembrance. This effect of a signal or unit of information has been called cueing effect [99,100]. Thus, one remembers the fond memories of a many events which happened in life and the associated persons, every time one looks at a gift presented by a person or listens to the words referring spoken in the particular event. Such remembrance is found to be automatic and mandatory [99,100], unlike strategic retrieval, in which one must make an effortful attempt to logically retrieve different pieces of information in a sequential manner. On the other hand, one may also not remember the details of several experiences, which could have become traumatic to the individual, a feature often seen in several criminal offenses. They are considered as repressed information in psychoanalysis.

Electrophysiological Correlates of Remembrance

Studies have differentiated the electrophysiological profile of remembrance from that of knowing [90,95-97,99-102,107] compared remembrance and knowing using event related potentials in normal subjects and found that a distinct positivity in the 600 – 1000 ms

range associated with recognition of some words, as they were presented in an immediate earlier trial. Familiarity of recognition was detected in ERP studies by Curran., *et al*. [103] using recognition of words, some of which were presented in earlier session. The positivity was seen bilaterally predominantly in the frontal areas and lesser in the parietal areas, which was absent in the other conditions tested. The related studies have established that ERP associated with remembrance is indeed different from the P300 potential that is associated with mere recognition. Remembrance involves attending to cognitive processes taking place while retrieving the information and recreating sensory-motor imageries, and reexperiencing part of the original emotional components all over again. This results in a total or partial withdrawal of attention from the external world/stimuli, which may cause ignoring the inputs and perception of the external world transiently. Such inward direction of attention is required to become aware of the recreated mental imageries as well as transcoded thoughts and for selectively attending to them for further processing. Harmony., *et al*. [98] and Fernandez., *et al.* [104] found that delta band frequencies have such specific association with attending as well as becoming aware of internal processing. Robinson [105] reported that 4 Hz activity is related to behavioral arousal and it is negatively related to 10 Hz activity. The importance of frequencies in the theta and alpha ranges has been demonstrated in several studies. Klimesch., *et al*. [91] suggested that synchronization of theta and alpha frequencies across distant neural areas is for specific processing of internal mental contexts during cognitive processing. Klimesch., *et al*. [93,94] indicated that theta oscillations represent hippocampal engagement required for retrieval from long-term cell assemblies in episodic memory recalls. They [92,93] further reported that upper alpha band activity showed maximum sensitivity to encoding processes which could differentiate between bad and good semantic memory. They found significant correlations between upper alpha band measures and semantic memory when semantic processing was actually taking place. In a subsequent study, Rohm., *et al.* [106] found that processing of visually presented signals caused greater theta activity, whereas upper alpha increased only when there was semantic demand during the processing.

Excess beta oscillations have been always looked upon with clinical significance, and hence its neurocognitive importance has not been adequately understood. For example, excess beta oscillations have been suggested to show an excitation-inhibition imbalance in the cortex in alcohol dependent subjects [107], and it is commonly known condition in various barbiturate/hypnotic drug induced states. Desynchronization of alpha is always accompanied by an increase in beta activity and hence it has been considered associated with cognitive states when greater neural resources are utilized in the brain. Basar [82,83] and Basar., *et al*. [84,85] considered only delta, theta, alpha and gamma oscillations as of any cognitive significance. However, beta activity is induced in all conditions of cognitive processing demands and the activity subsides when the task is completed. Beta activity has association with mental motor imageries as found by McFarland., *et al*. [108] in their study that normal participants could control both mu and beta rhythm using real movement as well as motor imagery. Increase in beta activity was seen over the primary motor cortex even during action observation [77] indicating the possibility of presence of mirror neurons. In a comparative study using Pet and EEG, Nakamura., *et al*. [115] found that beta power was positively correlated with rCBF in the prefrontal cortex including the anterior cingulate while participants listened to music. Olufsen., *et al.* [79] found that gamma (30 - 80 Hz) and beta (12 - 30 Hz) rhythms occur successively and may have important role in the maintenance of cell assemblies requiring neural binding. Interdependency between gamma and beta activity is seen while listening to novel auditory stimuli [107]. Several studies [75,97,110-113] have demonstrated the role of gamma activity in the 35 - 85 Hz range during retrieval of information, especially recreation of visual mental imageries. Increase in the coherence of gamma activity across left frontoparietal areas is an indication of the frontal lobes recruiting neural structures from the parietal areas, during remembrance of visual mental imageries [14,27]. The frontal participation is associated with the use and recall of the verbally transcoded information from which visual mental imageries are reconstituted. Several of these findings are used for identification of remembrance taking place when the same is cued by probes auditorily presented.

Brain Electrical Oscillations Signature (BEOS) Recording and Analysis

The patented Neuro Signature System (NSS) for recording BEOS measures the electrical oscillations from the scalp and determines the presence of several specific statistically significant changes that indicate the presence of different processes related to remembrance tak-

ing place within the brain. The BEOS profiling program uses verbal probes to trigger remembrance of specific events investigated, which from the autobiographic episodes of a suspect or individual who was present when the related events took place. The aim of verbal statement used as probe is to cue an individual to remember a specific associated sensory and/or motor response and other component(s) of the event in which the person is suspected to have participated or witnessed. This occurs only if the person has had the referred experience or carried out the specific actions referred by the probe. Knowing about these actions or events is not enough to cue the remembrance of their experience. Unlike in the P300 or the lie-detection tests, the subject is not expected to make any behavioural or oral response to deny or accept what is referred by each probe. He has to only silently sit with eyes closed and listen to the probes. Electrical oscillations in 30 or 62 cephalic channels with linked earlobes as a common reference and 2 eye movement channels (vertical and horizontal) are acquired using a bandwidth of 0.016 - 85 Hz. Jell based electrodes have been so far used as recording may last for an hour or more, when the subject must not be disturbed for rearranging the electrode contacts. Continuous EEG is recorded which is marked with event markers for the beginning of preprobe baseline of 3 secs, beginning of a probe presentation and its end, and end of an epoch of 7 secs (total 10 secs). The interval between two adjacent probe epochs is kept at 10 secs. Analyses consist of single trial analysis of each epoch related to each probe, in which the integrated power values in different frequency ranges in each EEG channel is compared with its preprobe baseline values. Integrated power is determined in segments of 100 - 250 ms for each channel over 10 frequency ranges, comprising of delta, theta, alpha, beta, and gamma activities. The change detected in each segment of each channel is statistically compared with the preprobe baseline values to determine the statistical significance of the change, as and when it occurs anywhere in the 7 secs epoch. System makes extensive artifact markings in the beginning of analysis, for rejection of data segments with body, body parts and neck movements, and also those related to eye opening and their horizontal movements, if present. Power changes in the 0.01 - 1 Hz range, produced by body movements and eye movement artifacts are removed from each channel and not included for analysis. The system provides two online video pictures, one of the face and the other of the total person sitting on the recording chair. The audio and details of each probe presented to the subject is recorded in the system along with EEG. The mean power values and the related statistical values for the preprobe and probe epoch segments are computed and only those segments are accepted for analysis after rejection of epochs with artifacts. Single trial analyses of probes are carried out using a moving window program in the frequency and the time domains.

Probes for BEOS Profiling

A probe is a short sentence used in BEOS recording for referring to a specific component of an action or a proposed sensory-motor experience that is expected to have taken place in a person, involved in an episode. The probes are sequentially arranged to help them retrieve the memory of the details of an original experience in an orderly manner, as could have experienced by a person, suggested to be involved in an activity. The sequential presentation helps the individual remember the original participation with clarity and without reactions of reality contradictions. The examiner has to decide before presenting the probe as he has to enter a code referring to what exactly he expects to be retrieved from the subject tested. The examiner decides if it is a visual-sensory imagery or motor imagery that may be recreated during remembrance and other specific aspects of remembrance. The system will make a judgment of presence of EK only if these specific changes predecided are present in the EEG. The subject has to only listen to the probes with an instruction that he is expected to recall the probes and write down the details of the probes heard after the experiment. Each probe is nestled into the next, thereby unfolding a total episode. The examiner designs the probes after discussions with the investigating officers and interviewing the suspect regarding their versions, and to find details of his/her personal, familial, educational, and occupational background. They are arranged in scenarios depicting the different phases of the life episodes, that could have happened. Based on the considerations of the investigators and that of the examiner, more than one formulation of an action or episode being investigated may be proposed, if required. The probes relating to them are proposed in different scenarios and they are presented as different sets of probes in independent tests. They are designed in a manner to establish contextual references for each scenario and they may consist of probes referring to the experience/participation of the perpetrator or the guilty in terms of interaction with the victim and others, and details of utilization of objects and facilities for executing the act, and nature of movement to and out of the crime scene after an event. Probes are stated without any value

judgment and provocation of any emotional effects in the listener. In case one gets emotionally affected by a probe, such reaction will be identified by the BEOS program during analysis. The number of words used in a probe decides its length, with a minimum of 2 - 3 words, and the maximum length not exceeding 3 secs for their presentation. The list of probes are shown to the subject first when he could read them up and even discuss about their accuracy, etc. with the examiner. Probes are then automatically presented in the same sequence by a computer based Stimulus Presentation System. The probes are prerecorded in the SPS in a language and intonations familiar to the subject being tested. The system incorporates various event markers and presents the probe only when the BEOS recording system send signal regarding the acceptability of the online EEG recorded by it. Each probe is released for auditory presentation only when the online EEG is within preset limits of activity in terms of power distribution in the different frequency ranges. The examiner is warned when probe presentation is delayed because of countermeasures applied by a subject. This helps the examiner interact with the subject who sits in an adjacent sound treated room, with closed eyes. He could then interact with the subject and inform him that no recording will take place, if he indulges in any other mental or physical activity while probes are presented. Despite warnings some suspects may attempt to carry on with some mental activity while listening to the probes. This makes it necessary to repeat the recording with the same list of probes. Need to repeat the test two or three times in not uncommon. These procedures of interviewing, designing and recording the probes in the system may often take a day or two, whereas BEOS recording, its analysis and the report generation may take only about an hour.

Four types of probes are used for every suspect in a forensic investigation. The first set is called the Neutral Probes, which are mere semantic presentations not referring to any experiential event, and they are not expected to cue any remembrance. The next set called Control Probes referring to verified autobiographic episodes in the life of the suspect, which are unconnected with the episode being investigated. Positive findings using the Control probes are considered a process of self-validation of the test procedure as they represent verified and noncontroversial episodes in the life of the suspect. The examiner can share these findings with the suspect for generating confidence in the test protocol and use them during the post-test interview. The third sets of probes are called Target A probes. These probes are presented in different scenarios and they are designed to present various events starting with the happenings antecedent to the main episode(s) related to the crime. The scenarios then shift to unfolding the crime and the activities following the crime. The probes are formed as per the suggestions of the investigator and in terms of alternate formulations by the investigators and examiner. The probes contain items referring to the proposed experiences of the person who is suspected to have committed the act, as hypothesized by the investigators and the examiner. The last set of probes is called Target B probes and they refer to the activities of the suspect according to his own version, which he considers could give him immunity as they could demonstrate his innocence.

Identification of Neurocognitive Processes

After the statistical analyses comparing the several EEG-ERP variables in each epoch cued by a probe, the significant changes are identified as 'signature' indicating the presence of remembrance by the respective probe. Presence of EK is arrived only if all the variables required to fulfil the presence of EK are statistically significant in the NSS analyses. The NSS program identifies significant changes indicating sensory registration, inward shift in attention, encoding of the probe, source memory activation, occurrence of sensory-motor imageries, and presence of emotional responses. These changes reflecting cognitive processing are derived from both frequency and time domain analyses of the EEG acquired while listening to the probes. Presence of significant increases in different frequency ranges within 1 – 85 Hz are searched for and their presence are interpreted to indicate the presence of sensory registration of the probe, encoding, accessing source memory, internalization of attention, presence of sensory and motor imageries, presence of positive ERP of 2 - 4 sec width and negative peaks of width within 500 ms - 1 sec range.

Single trial analyses are carried for determining the significant changes in all the variables. Repeat ANOVA and other tests are used for comparison of the preprobe values with the epoch scores in each channel. Significant increases or decreases in the integrated power values of data segments in the probe epoch are identified at 0.01 level of significance, and the data segments are marked accordingly. The significant changes detected for the different variables are linked to one another, though their onsets change from probe to probe and

from person to person. Positivity is identified only if it occurs within the 7 secs range of the probe epoch. Based on the topographical features and the spread of the time domain data, the EK is labelled weak, moderate or strong. EK is marked only if all the above different responses are significantly present. The above analyses are repeated for each probe. The complete ranges of signal processing and statistical analyses are carried out automatically by the program and the stored results are entered in a pdf file for storage and printing. The program looks for the above changes only in data segments cleared of artifacts. The program further computes brain maps and histograms for the data segments for visual display, which could be examined by the user. Generally, probes may be presented in 1 to 3 sets, one after the other, with 60 - 100 probes in each set, based on the formulations made by the examiner. The number of probes is decided indeed by the number of issues decided for verification through presence of EK. After completion of the analysis, the program prints out a PDF report of the analyzed results. The result of the analysis of each probe is reported as one of the following: - Primary Processing Present, presence of Inattention, Encoding or Encoding ++ Present, and finally EK Present. If the above results are not present, there may be presence of Emotional Responses or Activity Suppression. The probes which produce EK scores are marked and studied. They may be presented to the suspect during post-test interview for explanations. The investigators are informed about the results of the test, so that they continue investigations in other directions, which is one of the essential uses of the BEOS test.

Accuracy of BEOS Profiling

The accuracy of BEOS profiling was determined by a normative study supported and supervised by Technology Information Forecasting and Assessment Council (TIFAC) of India, New Delhi and Directorate of Forensic Science, Gandhinagar [14,16,27,115-118] on 56 experimental and 54 control volunteers selected from the city population after examination on General Health Questionnaire. They participated in a simulation experiment in which each experimental participant performed several acts using the materials provided in a testing room, whereas the control participants had only knowledge of these acts. Both had the opportunity to read the list of probes prior to BEOS profiling. The main task for the experimental group was to enter a dark room, switch on the light, observe the articles inside and detect a piggy bank, open an almirah, take out an iron rod from it, break the clay piggy bank kept on a table, collect the coins from it, and clean up the place before leaving. ROC analysis of the EK scores of the two groups showed that the BEOS test has a sensitivity of 95% and specificity of 94%. With a cut of score using 3-SD of the control group, the specificity reached 100%. A major and serious demand from the investigators has always been that the test must have maximum specificity so that the test would not elicit any serious EKs which may be used to identify an innocent person as guilty. No single isolated EK is interpreted as indicating involvement, unless there are a few more sequential probes with EK scores. However, later investigations showed that isolated EK may occur, when the action is not correctly formed by the probes. Presently even an isolated EK is taken seriously, as it shows the need to reformulate the probes and test the subject all over again. The probes used may not have referred to what really happened or what the person really carried out. It has now become an inevitable practice that the examiner would consider alternate possibilities and alternate probes for testing a new hypothesis, which reflect a different mode actions. There have been more than 1000 forensic cases investigated by BEOS over the past 9 - 10 years, and BEOS findings have helped investigators in dozens of cases, who could later elicit convincing primary evidences and the cases have been successfully solved in courts. BEOS findings have been accepted as corroborative findings. Several suspects were freed by the court as both BEOS findings and investigative findings could support their innocence. The test has also helped to determine the specific roles played by individuals involved in criminal cases, when more than one person has taken part in a criminal act. Time has come when we are in a position to decide the usefulness and reliability of the BEOS technology based on the actual case results seen in hundreds of cases. The test has successfully differentiated a witness from a perpetrator of a crime. Most of these cases have been presented by the forensic psychologists of forensic laboratories where they conducted the BEOS tests in their professional conferences, though they are not published.

Counter measures known in lie-detection tests or brain fingerprinting tests are not present in BEOS profiling as the subject does not have to respond to questions or cognitive tests presented. However, it is seen that the subject may try to willfully ignore listening to or semantically process the probes. It is observed that subjects may get into meditative state of mind or mentally praying, chanting or counting, etc. during probe presentation, which interfere shift attention away from listening to the probes. Online evaluation of the EEG, which the

NSS employs for determining presence of altered mental processes, greatly help to identify such alternate processing, as the NSS system delays or stops probe presentation. The examiner has to then discuss the issues with the suspect, and inform him that the test cannot continued if he or she engages in such mental activities. The electrophysiological changes derived by the test only indicate the presence of a neurocognitive process of remembrance taking place and its relative strength, as obtained by the measures used. It does not indicate the content of the thought or remembrance, which is inferred from the reference made by the contextually relevant probes. It is an inference that the probe, which elicited an EK has cued the remembrance of a past action one carried out or witnessed, and hence cannot be used as primary evidence. But the findings have always helped the investigators to examine their cases in different formats, and obtain evidences they could present in court of law. The test must also not be used with individuals who are diagnosed to have neuropsychiatric conditions of dementia, brain lesions, alcohol and drug dependency, mental retardation, head injury etc. as they can easily affect the process of remembrance of autobiographical episodes. If the probes are not adequately designed to suit the individual's experiential styles, educational and cultural backgrounds and preferences, probes may not effectively trigger remembrance. The absence of EK responses may not automatically indicate that the suspect is innocent, as such absence may be because the probes presented are not truly relevant and have not effectively cued remembrance of a past event. Presence of many EK responses triggered by interconnected or related probes in each scenario does strongly imply that the suspect has had experiential participation in the activity investigated. On the other hand, absence of EK responses to Target - A probes and their presence to Target - B probes may indicate the innocence of a suspect.

Conclusions

The BEOS system was developed for examining a suspect with least amount of stress of being tested as the procedure does not require any response from the subject, except to listen to the probes presented by the system. The verbal statements presented by the system cue the remembrance of an original experience, provided the person has had it. Otherwise there will be no remembrance cued by the statements, even if the person knows about the episode. There are large number of neuroimaging studies which have shown the significant differences in the neural activation patterns between recognition and remembrance. The general effects of these localized changes are partly reflected in the electrical activity on the scalp, which is recorded and analyzed by the BEOS system. Remembrance of most of past episodes, if experienced by one, automatically occurs when it is cued by related information, auditorily presented in this procedure. Though one may choose to deny such involvement, or alter the nature of one's engagement in an activity, one cannot alter the remembrance of the original experience, which occurs automatically. Additionally, the probes could be presented in a positive or negative manner, which does not affect remembrance of the earlier experience. Remembrance is obviously absent if the person has not gone through the experience, even if he has come to know of the episode from any other source. Presence of remembrance of Experiential Knowledge of a specific episode alone is captured by the BEOS system. The BEOS system makes several frequency and time domain analyses for making inferences about the presence of sensory registration of the probe, its encoding, attention being directed inward, accessing source memory, recreation of sensory and/or motor imageries, and their emotional effects from the frequency and time domain analyses. The system also blocks probe presentation if the background EEG activity shows that some neurocognitive processing is already taking place in the person. The program allows estimating the roles played by different persons, if they were present in an activity, provided they are all tested by BEOS. The initial validation study was followed by regular use of the technique on several hundreds of cases. The "EK" findings of BEOS, which are often repeatedly obtained by using the same list of probes, have helped to solve several hundreds of cases by further helping the investigators recover primary evidences indicated or suggested in the BEOS findings. Absence of such selected EK responses seen in suspects during investigations have also rendered several suspects innocent. The test is not administered if the individual has memory problems because of any memory debilitating conditions and/or a disease process affecting his or her brain functions.

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