Opinion

Neurocognitive processing steps during remembrance

Abstract

A method of recording several of the electrophysiological changes seen during remembrance of experiential components of autobiographic episodes has been developed for use in forensic investigations of suspects and accused persons. The technique has called Brain Electrical Oscillations Signature BEOS profiling and has been successfully used in several hundreds of cases as aid for investigation. The two important facilitating aspects of the test are that[1] remembrance can be automatically cued by presenting short verbal statements referring to various components of an experience, and remembrance is automatic and mandatory when a cue is presented, in normal individuals.[2] There is also no need for any response from the subject while receiving the cueing information. Knowing the occurrence of an activity in the past does not trigger any remembrance of own participation. Remembrance of participation in an activity occurs only if the person has participated in the activity referred by the probe. Remembrance has several neurocognitive components, which are reflected in the scalp EEG of a person. Sets of verbal probes representing different formulations of the episode and the different roles of individuals, as they are essentially possibilities arrived at by an investigating team, when more than one person is suspected to be involved in the activity are presented to the suspected persons. Each multichannel epoch of EEG time locked to each probe, acquired with its pre-probe baseline, is acquired and analyzed to determine the statistical significance of the differences in the different components across the EEG channels of each epoch, related to each probe, is analyzed and statistically compared. Presence of Experiential Knowledge is arrived at if all the changes indicating multiple neurocognitive processing components are significantly present.

Keywords: multichannel eeg, cueing of remembrance, sensory registration, encoding, source memory, attentional shift, sensory-motor imageries

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Mukundan CR

Emeritus Professor, Institute of Behavioural Science, Gujarat Forensic Sciences University, India

Correspondence: Mukundan CR, Emeritus Professor, Institute of Behavioural Science, Gujarat Forensic Sciences University, Gandhinagar, Gujarat, India, Email crmukundan@gmail.com

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Opinion

Brain Electrical Oscillations Signature BEOS profiling is a two decades old method, developed for testing presence of 'Experiential Knowledge' or remembrance of a past episode in which a person participated and acquired knowledge of the even through experiencing or participating/carrying out an act. Small verbal statements referring to proposed participation in an act are presented as probes, for auto-cueing remembrance in an individual,[1,2] possible only if the person has really taken part in the said activity, while his or her EEG is simultaneously recorded. Frequency and time domain analyses of small epoch of EEG time locked to the probe and comparing the changes with the immediate pre-probe baseline, time locked to each probe, indicated statistically significant changes in various EEG values. The EEG was recorded by a 30 channels system with 2 additional channels for recording vertical and horizontal eye movements. The subject listened to the auditory probes, while sitting with eyes closed and he was not to give any response to what he heard. Each probe was presented only when the EEG did not indicate any other processing taking place. The probes are presented in a sequence, indicating the temporal sequence of occurrences of the different stages of an action. The normative study conducted for determining the sensitivity and specificity of the technique indeed showed sensitivity of 94% and specificity of 95%. However, there have been several hundreds of cases successfully investigated using the procedure, which helped in solving complex forensic problems and solve the cases through elicitation of additional information based on the presence remembrance of occurrence and participation of individuals, elicited by the BEOS test.

Several years of use of the BEOS procedure has revealed that the test can be used with alternate forensic formulations, and positive findings are elicited only with the formulation of events that really happened. Similarly the different roles played by different individuals in an episode can be elicited from them. The same positive findings can always be repeatedly elicited from the same individual by using the same probes over a second time. Hundreds of probes may elicit no experiential knowledge or indication of remembrance if the probes refer to actions in which a particular individual has not taken place. However, the decision of presence of Experiential Knowledge is arrived at only when significant changes are detected at several independent stages indicating changes in different cognitive processes. The different neurocognitive steps looked for with specific significant changes in an EEG parameters are that of sensory registration, encoding or semantic processing the probe, accessing source memory, shift in attention to internally retrieved remembered information, and recreation of sensory and motor imageries. Additionally, an individual may also show 'Emotional Responses' after semantic processing starts, when the integrated power values in all frequency ranges in all the electrodes significantly decrease compared to the preprobe base line for about 7seconds. Occasionally individuals may show total activity suppression, evident from the beginning of the time locked point of probe presentation, when there is significant decrease in the power values of all frequency ranges, from the probe onset for the 7seconds duration of the epoch. This has been named Activity Suppression. Emotional Response is taken to indicate the traumatic effect of a probe presented, which starts only after encoding of the same probe is initiated.

Semantic interpretation or Encoding of a probe is seen as significant increase in the integrated power values of High Alpha, Beta-1, Beta-2, and Gamma range up to 85Hz of frequency ranges, continuously present either in both the hemisphere or one hemisphere electrodes. The effect is looked for all the left and right side electrodes using 0.01 level of significance. This is followed by comparison of the Theta and Delta range of frequencies after removing slow body swinging movement effects while sitting and listening to the probes. Significant increase in the integrated power of Theta range is interpreted to show effort for accessing source memory, while increased slow wave power is interpreted to show shift in attention to processed and remembered contents. The significant increase in the integrated power must be present for minimum 500 – 750milliseconds duration compared the preprobe baseline levels of each probe. The next stage of analyses consists comparison of the coherence between frontal and central and posterior electrodes on the left and right side, and significant increase in the coherence values in the preset epoch duration compared to preprobe base line coherence is interpreted as presence of recreation of sensory-motor imageries in remembrance. The previous studies, which have supported these computations are already discussed in detail in several of the earlier publications.

The final step of analysis is the determination of time domain changes of positive and negative responses. Remembrance itself produces significant positive response, which is totally different from that seen during recognition. Remembrance is a slower process and the positivity seen has gradual increase and later decrease to the base line. Determination of time domain response detection of the the morphology of the wave form and its amplitude is extremely important stage of analysis. Presently BEOS test is the only method that determines and uses such waveform morphology for identification of time domain changes. The probes presented for cueing remembrance include probes cueing remembrance of important life events, which are noncontroversial. Presence of EKs in the responses to such probes cueing noncontroversial episodes or experiences in life enhances the acceptance of the test results by the suspects, which later prompt them to disclose those aspects of their involvement in an episode, if at all present. Presentation of probes, which cue remembrance of episodes, which a suspect may claim that he has really gone through, facilitate elicitation of EK responses related to those probes, which support the suspect's version of revelations. Interestingly no conflicts have so far emerged between a suspect's version and investigator's version, even after examining several hundreds of real cases. The details of the BEOS profiling methods and the theoretical framework within which the test has been invented (International patent PCT/IN2008000344/WO2009/144735) and developed have been reported in earlier studies.[3–8]

Differentiation of knowing from remembering was first postulated by Mandler,[9] in which remembrance of autobiographic episodes would always consist of utilizing source memory of the episode,[10–15] which provide the time and place details of the occurrence of the event. Several neuroimaging studies have demonstrated clear evidence of extensive activation of the brain areas during remembrance in comparison with knowing or recognition.[16–33] Activation of bilateral middle temporal lobes including hippocampus and medial frontal regions [34–40] have been reported in remembrance of autobiographical episodes. Pure semantic recall may produce activation of left frontal and temporal areas. Gilboa[20] obtained activation of left ventromedial prefrontal cortex during autobiographic recalls, whereas a right mid-dorsolateral prefrontal activation was seen in the recall of familiar words, pictures, and faces. This differentiated between routine recalls episodic recalls and recalls of autobiographical events. Cabeza et al.,[21] found that autobiographical recall produced greater activation of medial prefrontal cortex, visual and para hippocampal region, and hippocampus, representing self-referential processing effects, visual and spatial memory effects, and recall effects respectively. Steinvorth et al.,[16] compared retrieval of recent, remote autobiographical information with remote semantic information, and found that recent and remote autobiographical remembrance elicited activation of large bilateral network. During remembrance, activation extended across the anterior and posterior parts of the middle temporal gyrus spreading into superior temporal sulcus, tempero-parietal junction, middle and superior frontal gyri, anterior paracingulate and cingulate gyri, and left inferior orbital frontal gyrus pars orbitalis. On the other hand mere semantic retrieval produced activation of bilateral supramarginal and inferior frontal cortices, left insular cortex, and inferior temporal gyrus.

Remembrance, may also have components of sensory and motor imageries, which need to be evoked and recreated. This involves activation of various primary and secondary association areas in the given sensory modalities, and that of primary motor cortex and other related motor cortical areas.[41–50] However, one may remember only those experiences, which have some emotional significance to the individual. The events are remembered as long as the associated emotions are important to the individual. Emotions being a subjective state of the individual accompanied by physiological and bodily responses, and may occur within the same cognitive context. Its repeat occurrence may be as real as the original emotional response in the individual. Emotional significance is therefore of crucial importance for one to be able to remember personal episodes. Remembrance of a certain experience can occur if it can be triggered by an external stimulus. Only that stimulus which has a relationship known to the individual with the original experience can trigger its remembrance.

BEOS tests conducted in several hundreds of subjects in the past decade and their verifications in forensic investigations have greatly supported the veracity of the changes looked for in the analysis of the electrophysiological data, while the subjects are cued by verbal probes. The fact these changes are found only by cueing remembrance without any need for a subject to respond to the probe, has enhanced their valuable application and the value of the findings. In the early studies, no attempt was made to further investigate if one or two probes elected significant remembrance labelled 'Experiential Knowledge' EK. However, today presence of even one or two probes producing EK responses have supported the need for reformulation of the probes and retesting of a suspect. Two or three different episodic possibilities are now routinely tested and the final findings emerge to support one of those possibilities. The units of information thereby collected help in the reinvestigation of a case, which foster a final solution for the investigation and acquisition of evidences, which can be used by the investigating agency. The issue of using BEOS findings as evidence in a court is hardly considered, though social approval for this may gradually emerge. Its present application is only the use the findings as aid for further investigation by the investigating team.

The present application of BEOS indeed reflects the forensic use of the procedure. The medical application of the procedure is noncontroversial and it may present valuable evidence of the remembrance status of the brain of an individual. The test cannot indeed be used in a forensic context with subjects who are drug or alcohol dependent, or patients who have dementia or other mental disorders in progress. Our early research[51] using some of the components of BEOS profiling in a hundred of alcohol dependent patients in the mid 1998s, has already supported the absence of some of the EEG changes over a period of two years indicating important neurocognitive deficits indicating early signs of presence of dementia. The present attempt is to develop a medical use of the same application.

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Conflicts of interest

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