

# Forensic Applications of Recording the Neurocognitive Processes of Remembrance



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Received: 📅 September 19, 2018; Published: 📅 September 24, 2018

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## Abstract

Knowing may be considered a virtual process as it is devoid of any experience composing emotion and sensory-motor contacts. Everyone may have enormous knowledge bank, without any accompanying sensory-motor experiences, with a need to recognize the external presence of the same signals. Multiple sets of events one may personally engage in everyday life are not later remembered, as they do not have any person significance. Acquisition of knowledge may take place in multiple contexts and methods, without any sensory-motor and emotional experiences, an individual comes to know of a new piece of information in multiples of semantic exchanges that may occur, though one may not have sensory-motor experience and any associated emotional effects about it. Remembrance on the other hand, is a process of retrieval of such autobiographic episode when one could have a reexperience of the earlier episode as the same brain areas representing the same sensory-motor experiences and emotional effects are reactivated. One could have an experience only by taking part in an activity, where as one may have close sensory experiences by witnessing an activity, both could be remembered by one. Ability to remember a previous experience therefore occurs only when one has participated in an activity, or partly present when was physically present in the event that took place. Mere knowledge of an episode would not help source memory activation and recreation of the sensory-motor events.

**Keywords:** Remembrance; Knowing; Cueing remembrance; Sensory-motor activation; EEG frequencies; EEG correlates of cognitive processes

## Introduction

Knowing and remembering have been considered two different neurocognitive processes (Mandler 1980), as knowing is essentially a process of recognition where the external model is identified as a known internal model [1]. Remembrance take place when sensory-motor imageries reactivated along with the earlier emotional effects in the individual. It was later supported in several brain imaging studies [2-10]. Registration of signals at the subcortical - brain stem areas evokes Brainstem Evoked Potentials, followed by the middle latency evoked potentials arising when the sensory signals arrive in the cortical area, for primary recognition. When the sensory signals reach the middle cortical layer, beyond the brain stem areas, cortical sensory registration of the signals take place, which also leads to attentional arousal, and these processes repeatedly occurring produce a positivity representing continuous sensory (visual) registration (P100/P80) followed by a negativity (N100/N140) representing attentional arousal towards the auditory or visual signals, and another positivity (P200). The time taken for auditory stimuli, these potentials occur faster at 70ms (P70), 100ms (N100) and 160ms (P160) [11]. Recognition of the incoming signals is

the next processing stage, when a P300 is generated. What may be recognized could be mere change in the signal characteristics, which may serve a novelty effect or mere detection of the difference. The latter is seen when one must make a response to any change in the input signal. Such need state facilitates detection of even a minor change in the input characteristics, whereas detection of such changes may not occur, if the subject does not need to attend to such minor changes. Recognition of input signals is therefore the most important component of getting to know the changes, wherever such input signals could come from. However, the typical P1-N1-P2- and P3, are brief cerebral potentials associated with specific functional roles initiated in the cortex, and these potentials manifest transiently or form only when the signal inputs and their processing are of short duration.

## Neurocognitive Processes in the Brain

The two major functional domains within the brain are related to drive or arousal, which propel the organism to make sensory-motor contacts, and the second is the cognitive processing system which help process and organize these relationships positively

facilitating or negatively debilitating to the self and others, and mold own drive in positive or negative manner, when we call them positive or negative emotional arousal. The sensory-motor contacts and own emotional arousal are experienced as positive or negative and one's emotional expressions through sensory-motor contacts are affected in the same manner. Recognition could be a simple to complex neurocognitive process. Recognition may start essentially as a modality specific simple to complex characteristic. However, if one may assign special meaning to specific characteristics, as in alphabets, numbers, and symbols, when one retrieve/convert what has been received as sensory change into a specific meaning, one has assigned or learned to the sensory inputs. What one retrieves from a knowledge bank using sets of recognized information is essentially knowledge, which remains as bank of mere knowledge. Knowing is essentially possessing information formed from the signals received through real sensory-motor contacts or virtual contacts, which may one attempts and assembles real and equivalent physical contacts and learn to experientially verify them. One learns to assemble the such value-based relationships at conceptual levels, and one learns to experientially validate the outcome effects. Sensory-motor contacts are made in virtual formats with the same relationships so that the outcome forms in predefined and predicted manner. Individuals store in memory huge knowledge bank and skills and retrieve relevant information and skills from the knowledge bank and skill-store for external expressions and creative works. What may be externally stored are often not mere basic information alone for facilitating knowledge, but huge capabilities for learning, managing, and creating new relationships with their positive and negative outcomes. Dealing with virtual realities, allow one to experiment as well as create new relationships.

### Experiencing Sensory-Motor Contacts

Experiencing sensory-motor contacts with reality and the cognitive interpretations and judgments of associated emotional arousal constitute experience of an individual. An experience has therefore molded emotional effects and interpreted sensory-motor contacts. Retrieval of an experience is remembrance of the interpreted sensory-motor contacts, and molded emotional effects, all of which are personally constituted. The brain activation in remembrance is almost recreation of the experiential effects in the individual, unlike mere retrieval of knowledge. Mander in the early years (1980) itself differentiated knowing from remembrance, which was later supported by several authors in their studies [2-10,12-23] while comparing episodic or autobiographic memory with knowing and semantic memory. Multiple memory systems were proposed [24- 27] [7-9,13-23] mainly for explaining the neural process remembrance. Remembrance of past personal events require activation of the source memory [28-34]. Activation of bilateral middle temporal lobes along with hippocampus and medial frontal regions contribute to remembrance of autobiographical episodes [35-41]. Gilboa [18] 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, differentiating between routine episodic recall and recall of autobiographical events. Cabeza et al. [17] found that autobiographical recall produced greater activation of medial prefrontal cortex, visual and para hippocampal region and hippocampus, representing self-referential processing effect, visual and spatial memory effect, and recall effect respectively. These studies showed that activation during remembrance generally extended across the anterior and posterior parts of the middle temporal gyrus spreading into superior temporal sulcus, temporo-parietal junction, middle and superior frontal gyri, anterior paracingulate and cingulate gyri and left inferior orbital frontal gyrus pars orbitalis. On the other hand, pure semantic retrieval always produced activation of bilateral supramarginal and inferior frontal cortices, left insular cortex, and inferior temporal gyrus.

### Remembrance of Experience

A Multiple Memory Trace (MMT) was seen to be produced in remembrance without presence of sensory inputs, leading to a reexperience, and the process could be repeated for longer durations and any number of times, unlike mere recognition of sensory inputs. Such MMT is a typical example of remembrance, whereas such repetitions do not occur during simple perception and recognition. Remembrance is often cued by external sensory-motor contacts, when one remembers an earlier experiential episode, with their sensory-motor imageries and emotional effects. Remembrance may occur almost instantly or with indefinite delays. During remembrance, one must look into the self and reexperience the recreated sensory-motor imageries, unlike directing attention outward to experience the sensory-motor contacts. Emotional arousal could occur both during recognition as well as remembrance. Emotional arousal accompanies activation of hippocampus, para hippocampus, and prefrontal cortex, in addition to amygdala, orbitofrontal cortex and anterior cingulate, which are multiple areas activated in all emotionally provoking conditions. Emotional arousal may occur during recognition (Smith et al. 2004), though one may generally attempt to avoid emotional arousal in normal semantic processing, unless the semantic processing is carried out for exchange of personally relevant ideas and experiences. Presence of emotional effects during recognition renders the perceptual episode to have personal significance and the presence of emotional effects render the episode capable for later remembrance. Absence of emotional effects in semantic processing and behavioral outputs render the perceptual and behavioral episode non-retrievable. Thus, one does not remember the regular food one eats every day, hundreds of activities one may routinely repeat, including semantic processing including conversations. On the other hand, presence of emotional arousal renders even minor sensory-motor contacts memorable for one, prosodic changes in

speech may activate various subcortical and cortical areas directly related to emotional arousal [42-44]. This has been also reported in multiple lesion studies [42-45]. Presence of the same emotional arousal in normal brain would then reactivate the same areas of the brain during their remembrance.

### Recreation of Sensory-Motor Activations in the Brain

Another important component of remembrance is the recreation of the various sensory-motor imageries that one recognized during an experience. The recreation of the sensory-motor imageries constitutes reexperience of the earlier experience, when and with the same emotional effects. There have been several studies which have shown such sensory-motor reactivation during remembrance based on the primary activation experienced [46-52]. Similar effects have been seen with regard to reactivation of motor imageries [53-59]. Sensory-motor reactivation of an original experience is a virtual reexperience of the original behavioral and perceptual activation, which the individual could semantically express again and become verbally aware of the entire experience, its genesis, direction, intensity, and outcome effects. Ganis et al. [47] in their neuroimaging study found that frontal and parietal areas have more specific roles in recreating visuospatial imageries and their integration. Remembrance of a past activity therefore, facilitates recreation of a virtual world based on the original experiences, and one could go through the reexperience of the virtual world recreated in the brain. However, such reexperience is possible only if one has had a real experience earlier. A semantic recreation of an experience may not succeed even in the recreation of a virtual world which may resemble the real original experience. One may partly succeed in the recreation of a virtual experience, even though the components may not be drawn from a real experience. This is indeed the reflection of the dramatic capability of an individual. One may be able to pretend that one is reexperiencing sensory-motor imageries, without having the recreation of the imageries in the brain. On the other hand, one may be able to recreate the brain imageries based on another similar experience, and pretend that one is remembering an original experience, which one has not had. However, one may need lot of practice and capability to recreate brain stimulation resembling such virtual experiences and emotionally react to them. Virtual recreation of sensory-motor imageries in the brain is indeed very different from the self-recreation of an earlier real imagery and its experience, which may take place automatically, while making online sensory-motor contacts.

### Recording Remembrance of Experience

An important forensic task has always been to elicit the truth from individuals, who may be taken in as suspects with some specific involvement in a crime already committed. It is a general phenomenon that the person who has really committed a criminal

act may want to hide his or her involvement in the criminal activity and pretend to be innocent. Detection of the crime and eliciting the truth and involvement in a criminal act has always been a most difficult investigative task, as individuals invariably hide the truth and try to implicate others as responsible for the criminal activity. Detection of significant physiological responses generally present when a person makes an untrue revelation has been the commonly used Polygraph method of lie detection. However, knowing that one may be telling a lie, may only partly help in the process of crime investigation. Another method that was tried out was related to recognition of crime related objects and information, when a person may produce significant increase in the P300 event related potential while recognizing such objects or information which one might have made use of. Another related method was to search for a memory recall while recognizing such objects or information. However, it was again based on an event related potential generally recorded in a single channel EEG system. Yet another method that came to be successfully used was related to recording several neural changes during remembrance of crime related events, which automatically takes place, even if the subject does not have to give any response at all. Cueing of remembrance takes place using short sentences referring to various stages of actions and responses that could have taken place. Remembrance automatically takes place while listening to short sentences (probes) which refer to the multiple actions and responses that could have taken place. Significant remembrance profile occurs only in those who were present in the crime scenario, including those who could have been directly involved in committing the crime. The remembrance responses are captured in multichannel EEG, which could reflect the neural changes from a total top of the brain giving a vast topographical representation of changes.

### Cueing Remembrance

Cued remembrance has been used as basic process for detecting presence of neural processes in the brain, which could be present only if one could remember or recreate the experience of a past response or action, which may also recreate an earlier emotional experience in a person. The presence of multiple neural processes associated with remembrance is taken to indicate the presence of related experiences in a person, which he or she could have acquired only if he participated in the related activity. Cueing is a process of prompting or triggering one to remember a specific act or event, when all the related neural processes will automatically be recreated in the brain. One may be cued by several short sentences, so that one is prompted to remember sequence of experiences related to events or actions. One is not expected to respond to the verbal cueing. The sequentially related probes are arranged in a scenario and different scenarios contain different formulations or episodes. The probe does not convey any complete sentence but gives a reference to an experience. For example, the probes may "I ran fast", "I was almost behind him", "Finally I felt I was reaching

him", "I stretched out my hand". and so on. It is a general practice that one may present more than one formulation describing one's participation in an act. The epoch length for each probe is 10sec, of which the first 3secs are used as pre-probe base line followed by the probe epoch. The next probe would be presented from 3sec and each probe may last maximum another 3secs. The total epoch duration is 10secs with 3secs of pre-probe base line. The EEG power of each channel is divided into 10 frequency ranges (0.1-85Hz) and the total power of EEG for each frequency range is determined for multiple EEG segments in sequence. The total power in the left and right electrode leads, separated from the midline electrode leads is compared with the pre-probe base line power. The power spectrum analyses and their statistical comparisons were carried out separately for the total power in the left and right electrodes, and for each individual channel separately for each probe epoch compared with the pre-probe power for multiple data segments in each second. The total power in each frequency range is divided into multiple segments in each second, and the statistical significance of the difference of power in each sequential segment is compared to that of the pre-probe base line segments.

### EEG Correlates of Neurocognitive Processing

Electrophysiological studies with surface electrodes have been for recording Event Related Potentials for understanding various cognitive functions. Surface recording of EEG has been used for differentiating remembrance from knowing in a few earlier studies [60,61] using event related potentials. They presented certain specific narratives in a session and expected the subject to identify the same in a second session of related and unrelated words were presented. Remembrance of earlier narratives were associated with the strong positivity in an ERP paradigm in the 600-1000 millisecond range. The positivity was bilaterally predominant in the frontal areas and lesser in the parietal areas, which was absent in the other conditions tested. The ERPs could differentiate between true and false remembrance of words, whereas ERP difference was not seen between true and recognitions. The EEG recorded from the brain surface may be the reflection of several changes in the functional state of the various subcortical and cortical areas, and hence could only be taken as possible reflection of several such changes. This could indeed be seen more specifically in neuroimaging studies. Excess beta oscillations have been often looked upon with clinical significance, and hence its neurocognitive importance has not been adequately understood. Excess beta oscillations have been suggested to show an excitation-inhibition imbalance in the cortex in alcohol dependent subjects [62] and it is commonly known condition in various barbiturate/hypnotic drug induced states.

Desynchronization of alpha is always accompanied by increased beta activity and hence increase in beta activity has been considered associated with the presence of cognitive processing, when greater neural resources are utilized in the brain. Changes in

the power of delta, theta, high alpha and gamma oscillations were considered to be of cognitive significance [63-69] found that delta band frequencies have such specific association with awareness of internal processing. Robinson [70] reported that 4Hz activity is related to behavioural arousal and it is negatively related to 10 Hz activity. The cognitive roles of theta and alpha frequencies ranges have been demonstrated in several studies [71-74]. Rohm et al [75] found that visually presented sentence processing caused greater theta activity whereas upper alpha increased only when there was semantic demand during the processing. On the other hand, beta activity is induced in all conditions when there is cognitive demand, and the activity subsides when the demand is completed. It was found that beta activity has been associated with mental motor imageries, which has been repeatedly seen in BEOS tests. Increase in beta activity was seen over the primary motor cortex even during action observation [76] indicating the possibility of presence of motor imagery produced by mirror neurons. In a comparative study of PET and EEG Nakamura et al. [43] found that beta power was positively correlated with rCBF in the prefrontal cortices including the anterior cingulate, while participants listened to music. Olufsen et al. [77] found that gamma (30-80Hz) and beta (12-30Hz) rhythms occur successively and may have important roles in the maintenance of cell assemblies requiring neural binding. Haenschel et al. (2000) reported interdependency between gamma and beta activity while listening to novel auditory stimuli. The role of gamma activity in the 35 - 85Hz range during retrieval of information, especially visual mental imageries has been demonstrated in several studies [78-83]. 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 for common functional involvement, during remembrance of visual mental imageries (Mukundan 2005). The frontal participation is associated with the use and recall of the verbally transcoded information from which the visual mental imagery can be reconstituted, which is accomplished in the posterior brain areas.

Desynchronization of alpha rhythms is always noticed, while listening to auditory probes. This is considered to indicate the registration of the probe in the brain, which is always seen in the very early stage of probe presentation in all channels. While listening to probes, this is always followed by significant increase in the high alpha and beta rhythms, indicating presence of encoding process, needed for interpretation of the meaning of the inputs. These changes may be followed by occurrence of remembrance of a past experiential episode, if at all one has had such experience, which may also be accompanied by significant increase in gamma activity as one would need to produce sensory-motor imageries while remembering. This results in significant increase in the phase relationship of gamma activity between pairs of selected electrodes, compared with the phase relationship in the pre-probe segments in the same channels. This relationship must be present in the left and

right fronto-central, fronto-temporal, fronto-parietal, and fronto-occipital electrodes. Significantly high phase coherence between the same gamma frequency bands of these pairs of electrodes, when the two electrode sites are being activated together, indicate the participation of the two locations associated with electrodes in the brain, in common functional tasks such recreation of imageries, as seen in the various fMRI tests already discussed. Source memory activation and inward direction of attentional arousal are important other components of the presence of process of remembrance taking place.

Significantly increased power in the theta frequency range during probe presentation, in comparison with the pre-probe power levels, has been taken to indicate such inward attentional shift. Yet another significant increase in theta power that may occasional be seen is the significant decrease in the accompanying power of various other frequency ranges for extended data segments in sequential manner. It was found through post interviews that such decrease occurs when the individual becomes emotionally activated. Emotional arousal or trauma causes continuous reduction in the power in various frequency ranges, which indicate absence or blocking of cognitive processes in the individual because of the traumatic emotional effects. This has been identified and labelled as indication of Emotional Response in the BEOS recordings. Yet another important indication of remembrance taking place is the presence of significant positive Event Related Potential that emerges mainly in the anterior areas and also spreading to other areas, based on the presence of the sensory-motor components remembered [84-107]. However, this positive potential could occur at any point in time, after the onset of presentation of a probe and it lasts generally for 2000 milliseconds or more. The ERP may appear peak anywhere before the epoch gets over. Individuals have reported remembrance of an event or experience taking place even after several hours. As the epoch length is only for 7 secs, with additional 3 secs pre-probe time, if remembrance takes place beyond the 7 secs range, it does not get recorded by the system, unless it has started within the 7 secs. and has peaked well before the beginning of the next probe. Such positive response does not generally accompany or follow a P300 response representing mere recognition, unless the recognized information cues a remembrance. The long width of the positivity makes it mandatory to measure and confirm the morphology of the waveform, so that a slow or artificial shift in the EEG rhythm would not be misidentified as the remembrance ERP. A minimum number of 3 adjacent channels from the left or right frontal areas are considered necessary for the system to accept a late positivity indicating occurrence of process of remembrance taking place in the individual being tested. BEOS system accepts presence of remembrance occurring during a probe presentation only if all the parameters of remembrance are significantly present. Absence of significant presence of even a single variable, takes the system off

the analysis process. Once the analyses are completed, the BEOS system automatically prints out the final report with interpretation of the findings on each probe.

The non-invasive procedure used in regular EEG procedure without having to give any response to the statements one is expected to listen to, allows a subject to take part in the study for long duration, as well as carry out repetition of the procedure. A suspect would sit and listen to the probes silently without any apparent anxiety or objection as he is not expected to give any response. Further several of the probes refer to actions really carried out by a person, which the subject would fully agree with. Forensic investigation in which the suspect only needs verbal statements without having to give nay response is during forensic investigative procedures. That the BEOS is a procedure, in which the subject has to only hear the auditory probes, whether one may agree with it or not, do not cause discomfort as one could listen to the probes without giving any oral or behavioural response, which gives immense self-confidence to a person to submit oneself to the test procedure. The BEOS test could be repeated on a person using the same probes and could obtain the same results. That a person may be subjected to listen to the probes constituting different formulations of actions further strengthens his or her willingness for the test. A subject may try to think of other events or carry out other mental processing such as preying etc. However, the system continuously measures and online analyses the EEG, and any indication of a person carrying out an alternate cognitive process, blocks the automatic presentation of the probes. Each suspect is given a task that he or she must listen to the probes and try to remember the probes after completion of the test, by writing them down from memory. BEOS findings are currently recommended not to accept as direct evidence in a court of law, as we are making an interpretation based on the presence of neural changes of remembrance that the person has carried out a specific task. The test findings are used for further interrogations and investigations leading to confessions as well as other evidence, acceptable in the courts of law. This has been a highly successful task as several hundreds of cases could be solved by conducting investigations based on BEOS findings. Such repetitions have become a common and useful method as they strengthen the examiner's points of view of a case with adequate supports for the explanations. With the use of BEOS, the examiner may often suggest alternate or additional lines of investigations, which may yield new results and the case could be solved in a different line, which might not have been earlier considered. The remembrance specific ERP may occur the moment the person gets the cueing effect and the components of remembrance of the related experience could be instantly recreated. In BEOS technology the remembered component is called "Experiential Knowledge". Even the virtual world one creates, and lives may have experiential components, though weak and unreal, as they may be unlike real experiences.

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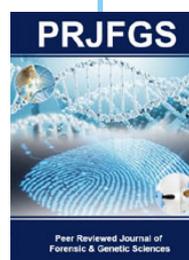
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DOI: [10.32474/PRJFGS.2018.02.000140](https://doi.org/10.32474/PRJFGS.2018.02.000140)



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