A Review on Examination Methods of Types of Working Memory and Cerebral Cortex in EEG Signals

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ABSTRACT:
Brain is the most important organ in human body. All of our memories are saved on brain. Brain activity is analyzed by electroencephalogram signals (EEG). Brain activity and memory signal represent brain activity that can be recorded in different brain regions. Electroencephalography signal analysis can provide complete and comprehensive information about brain activity. Working of brain memory as an activity is analyzed by EEG. The main purpose of this research is to review the types of memory and especially working memory in humans by processing of EEG. In this regard, memory and types of memory have been discussed at the beginning. Then the brain activity and memory signal, recording method, electrode placement, brain potentials are discussed. Then, the complexity of the brain activity and memory signal in memory has been investigated. Then, memory and its relationship with brain activity and memory signal have been discussed. Areas affected by memory are expressed in the brain. After the researches about brain activity and memory signals in memory, it has been investigated.

KEYWORDS: Working memory, Cerebral cortex, Electroencephalography, Brain

1. INTRODUCTION

Memory is a complex system that includes several different functions and cognitive processes. Physiologically, the formation of memory in the human brain is caused by changes in the ability of synaptic conduction from one neuron to another[1, 2]. These changes, in turn, lead to the emergence of new pathways or facilitated pathways to guide messages in the neural circuits of the brain, and these new or facilitated pathways are called memory pathways [۲]. The importance of these pathways is that once the memory pathways are formed, they can be activated by mental thought to recreate memories. Experiments carried out in lower animals have shown that memory paths are created at all levels of the nervous system[3-6]. Even spinal reflexes can undergo slight changes in response to repeated stimulation of the spinal cord, and this is part of the memory process [۷]. Memory is divided into short-term memory (STM) and long-term memory (LSTM) based on the amount of time that information is stored[7-11]. From another point of view, memory is considered and that is working memory [۱۳].Working memory is a short-term storage system that involves the use of information as long as it is available in the environment. Working memory is essential for people's cognitive functions and means a limited capacity to store information for a few seconds in the field of cognitive function. Previous studies have shown that working memory capacity is of great importance in a wide range of high-order cognitive functions such as reasoning, problem solving, and language comprehension[8, 12-14]. When there is a disturbance in working memory, cognitive skills are also affected and the overall performance of executive activities is disturbed. If functional disabilities cause problems and disturbances in people's daily activities, it is said that the person has a memory disorder[۱۷].

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The purpose of this paper is to review Brain activity and memory signal processing methods in order to investigate the relationship between working memory function and brain EEG signal. Therefore, in the following, the Brain activity and memory signal is first introduced, and then the processing of the Brainactivity and memory signal and its relationship with working memory are examined. At the end, the research conducted in this topic will be analyzed. The conclusion of the article is presented in the last part.

2. ELECTROENCEPHALOGRAM

The human brain is the main controller of all reactions, feelings, thoughts, internal and external behaviors, which consists of many parts. Decision-making, planning and judgment are done by the frontal part in the front of the brain, and in the back of the brain, the visual perception area, and speech is also done in the temporal part of the brain. The cerebellum is also responsible for balance and coordination. Communication between different parts of the brain is done through nerve cells. Each nerve cell consists of three parts: cell body, axon, and dendrite, and cells communicate with each other through axon and dendrite. Nerve waves, which are the basis of any kind of function, are transmitted to the next cells through these axons and neurons. The transmission of these waves inside the cells is electrical and between two cells, chemical, which is done in a very narrow space between two cells, and when the nerve wave enters the end of a cell, a specific neurotransmitter is injected into the synaptic space. This neurotransmitter attaches to its special receptors in the next cell in the form of a lock and key, thereby causing the cell to undergo a change in electrical charge and finally leading to the transmission of the nerve wave along the next cell [23].So far, many methods have been used to examine brain function, such as positron emission tomography, nuclear medicine imaging, functional magnetic resonance imaging, and other methods, in addition to requiring high costs, sometimes Unpleasant pleasure from. They are also looking for injecting radioactive materials and placing them in a strong magnetic field[۲۴-۲۲]. In the meantime, electroencephalography, which records the electrical activity of the brain, is cost-effective and has no side effects.Electroencephalography or EEG is a non-invasive recording of the brain's electrical activity through the installation of surface electrodes on the head[15-17]. In general, in an EEG system, the electrical effect of the activity of brain neurons is transmitted to the device through electrodes installed on the head, and after amplification and noiseremoval, it is recorded and displayed as a time signal. The recorded signal can be analyzed directly or after computer processing by a doctor or neuroscientist. With the help of electroencephalography, it is possible to determine the amount of that activity and the failure of the involved brain areas in all kinds of brain activities [۲۰]. As a result, the examination and analysis of the recorded signal through electroencephalography plays an effective role in a wide range of diagnostic and research applications, such as the following:

1-Diagnosis and recognition of cerebral brain damage and determining its location.
2- Examining epileptic attacks.
3-Diagnosis and recognition of mental disorders
4-Studying sleep and investigating its disorders
5-Observing and analyzing brain responses to sensory stimuli.
6-Research related to Brain Computer Interface (BCI) [۲۱].

Table 1. Characteristics of frequency sub bands in the EEG signal.

The desired subband	Characteristics	Operating frequency
Delta subband	Seen in babies, deep sleep and in some brain diseases	Between 0.5 and 3.5 Hz
Theta subband	Seen in regional and temporal areas of the brain, and children, seen in adults who are depressed and under psychological pressure.	Between 4 and 7 Hz
Alpha subband	Seen in normal people and in a state of consciousness with closed eyes, recorded in calm conditions, presence in the back of the head	Between 8 and 13 Hz
SMR wave	Being seen in a relaxed state and reducing	Between 12 and 15 Hz

	anxiety	
Beta subband	Seen in intense brain activities in the frontal and parietal regions, seen during thinking	Beta 1 sub band: between 14 and 30 Hz
		Beta (gamma) 2 sub band: between 30 and 50 Hz
		Intermediate beta sub band: between 16 and 20 Hz
Gamma subband	Being seen in cognitive activities such as intense and focused attention, stimulation of emotions	Between 30 and 50 Hz
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Brain activity and memory signal recordings from patients are usually done while awake. However, depending on the type of test, the person may be asked to keep their eyes open or closed. With the eyes open, sometimes through a flashing light (photic), the patient's sensitivity to light stimulation is measured. An EEG is a dynamic ensemble that changes with any physical or non-physical change. The sensitivity of these signals is so high that they change even by blinking. In order to analyze these signals more precisely, they are divided into different sub-bands based on different frequencies. The EEG signal is usually in the frequency range of 0.5 Hz to 50 Hz [٢٥]. In the presented division, the created and known sub bands are: delta sub bands, their small beta sub bands, SMR sub band, beta sub band and finally gamma sub band, Table (1) shows the characteristics of these sub bands[٢٦].

3. BRAIN ACTIVITY AND MEMORY SIGNAL PROCESSING

The use of non-linear methods in the processing of Brain activity and memory signals has a relatively long history. Many activities deal with the calculation of the signal correlation dimension. However, the correlation dimension is only for stationary time series defined by a low-dimensional dynamical system moving around an Attractor[18-20]. Therefore, this criterion does not have a suitable ability in evaluating EEG performance, because EEG is non-static by definition and time-dependent changes of EEG power are modeled in different frequency bands with stimulus noises that have variable variance over time [٣٠]. Klinesh states that high-scale synchrony in the alpha band blocks information processing because many neurons' oscillations occur with the same phase and frequency. On the other hand, non-synchrony in the alpha band reflects real cognitive processing because different neural networks start to operate with different frequencies and phases [٣١]. Increasing a synchronicity while using memory leads to increasing complexity. Also, Li and et al. in [۳۲]showed that the fractal dimension value (as a feature expressing the complexity) of the EEG signal is inversely related to the activity of the neuronal population and can be used as a useful measure to reveal changes in the synchrony of tons under Specific mental conditions are used. The term complexity for nonlinear EEG analysis has been widely used for studies of cortical dynamics in different conditions. The degree of EEG complexity determines important information about the structural components of the data such as oscillatory components (such as diagnosing or predicting an epileptic attack from EEG, diagnosing Alzheimer's disease, visual cortex function, working memory dynamics, etc.). In order to clarify the complexity, two concepts are examined [۳۳]. The first concept is that the functional source is the part or parts of the brain that participate in the registration process from a sensor. Functional source is an operational concept that must not correspond to an anatomical part of the brain and is neutral to the local source and volume transfer, and briefly corresponds to a part of the brain that is measured in a specific location. The second concept is a functional network, which is defined as a complete matrix of all pairs of correlations between functional sources. Therefore, dynamic complexity is defined as random connections or lack of connections between dynamic elements of the system. This definition can be easily interpreted as the term functional network or functional resource introduced above [۳٤]. The dynamic complexity of a functional network is related to the lack of correlation between its functional resources. In other words, the higher level of synchronization between functional resources in a functional network corresponds to the low dynamic complexity [۳٥]. The EEG signal results from the sum of a large number of postsynaptic activities spread in space, which is functionally connected and interactive between cortical neurons and neural groups such as functional sources. Therefore, the time series has a complex structure that reflects the underlying complexity of neural generators. The greater the number of independent processes participating in the EEG, the greater the complexity of the time series. EEG complexity may reflect the number of states in which a system results from the interaction between elements. On the other hand, the dynamic complexity of a system can be interpreted by measuring the degree of freedom of the system.

4. MEMORY CONNECTION WITH BRAIN ACTIVITY AND MEMORY SIGNAL

Working memory means the ability to retain and maintain information in a short period of time, which is divided into the sub-sections of primary information encoding, retention and retrieval. Since working memory has a great impact on cognitive processes, many studies have identified neural substrates in various working memory processes [۳۶]. As stated, Brain activity and memory signal power can determine the degree of signal synchronicity and is actually a measure that can model the capacity or function of cortical information processing. Based on this, so far, many researchers have been conducted on the relationship between memory function and brain EEG signal power in different sub-bands, and the relationship between memory and different Brain activity and memory signal rhythms during the process of memorization and recall has been evaluated in many researches, theta rhythm is related It is known with memory [۳۷].

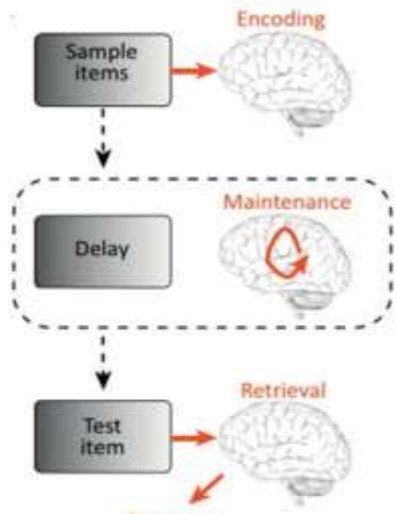

Fig. 1. Different stages of working memory including encoding, retention and retrieval of information [2].

For example, in the research conducted by Sarnthein and et al.[۳۸], an increase in theta band coherence between the prefrontal and back regions was observed during working memory activity.

Also, in [۳۹], an increase in theta power when responding to words and facial images in the memory process has been reported. In addition, an increase in theta power has been reported when working memory load increases. In [٤٠], an increase in the power of the theta band in the frontal area and in the middle area was reported during the increase of the working memory load. In several studies, gamma rhythms [٤١] and SMR [٢١] associated with memory have been introduced. For example, Howard and et al showed that during the process of temporary memorization of letters in working memory, the gamma band activity increases, and when the working memory load increases, the gamma band activity also increases, and vice versa after the subjects answer[٤٢]. Gamma band activity also decreases due to stimuli and reducing working memory load [٤٣]. Haarnan and et al [٤٤] also reported an increase in SMR band congruence between frontal and back regions during word repetition in semantic working memory [٤٤]. Honkanen and et al also showed that gamma band oscillations are effective in maintaining working memory information[٤٥]. Alpha rhythm related to memory has been reported in several studies [۴۷ ,۴۶]. Gevins and et al. investigated the activity of two subbands, alpha and theta, during memory activity [۴۶]. The results showed that with increasing memory workload, theta band activity increases in the frontal areas, while alpha activity decreases in the occipital and parietal areas, and the higher the memory activity, the greater the increase in the theta band and decrease in the alpha band (figure 2). Berger and et al showed that information processing in long-term semantic memory and information retrieval is associated with a decrease in high alpha band power, and better performance is associated with a greater decrease. They also showed that increasing the power of the high alpha band keeps the memory paths free from interference and unrelated activities[۴۷]. Meltzer and et alexamined the changes in gamma, theta and alpha band power during increasing working memory load. They observed that the power of the gamma band increases in all areas of the head, especially in the back of the head, due to the increase in the load of the working memory, but the power of the gamma band and the alpha band increases in some areas and decreases in some areas[۴۸].

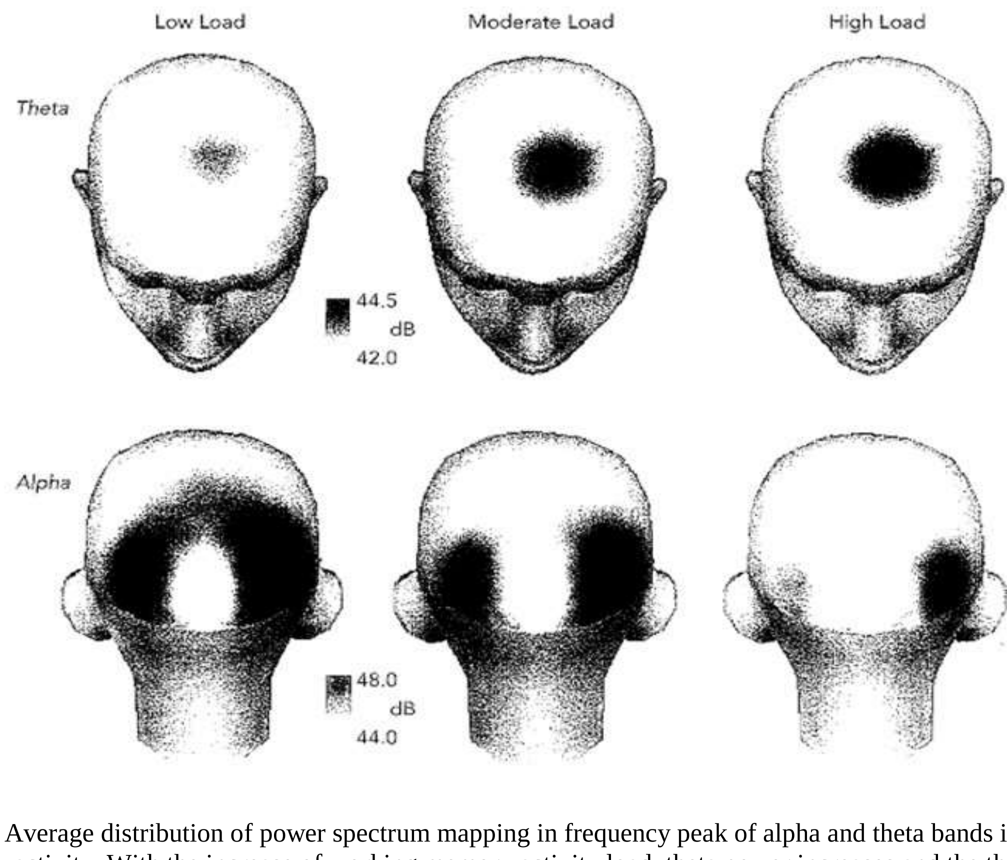

Fig. 2: Average distribution of power spectrum mapping in frequency peak of alpha and theta bands in working memory activity. With the increase of working memory activity load, theta power increases and the theta band in areas with medium and high working memory load has a higher level compared to low working memory load. But the power of the alpha band decreases uniformly with the increase of working memory load [۴۶]

It has also been shown in [2] that all three bands, gamma, theta and alpha, have an effect on working memory activity, but each one has its own task. They showed that gamma band oscillations are generally involved in maintaining information in working memory, while alpha band oscillations are responsible for preventing the interference of information from other activities with working memory information. Theta band oscillations also sequence information in working memory. Klimesch states that two factors can cause changes in the power of EEG signal bands [۳۱].

- Tonic changes such as age that cause changes in EEG.
- Phasic or event-dependent changes that occur as a result of performing an activity. Table 2 shows the changes in alpha and theta band power during two types of changes

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Table 2.Separation of tonic and phasic changes in alpha and theta band power according to cognitive function [۳۱].

	Decreased performance		**Increase performance**	
	theta power	alpha power	theta power	alpha power
Tonic variation	Decrease	Increase	Increase	Decrease
Physic changes	Increase	Decrease	Decrease	Increase

Klimesch has shown that the alpha rhythm is specifically related to semantic memory in that alpha activity is reduced after presentation of a semantic stimulus. Also, Klimesch has stated that during real activity demands, the amount of alpha power suppression is positively related to cognitive function (especially in memory function), while the opposite is true for the theta band, and the amount of theta band synchrony is related to good performance. has it. From Figure 3, it is clear that during the memory activity, the alpha power is suppressed, but the theta band power is increased. Therefore, if we compare the EEG power in the test state with the resting state, the power of the alpha band should decrease (non-synchrony occurs) and the power of the theta band should increase (synchrony occurs). Also, in an experiment of two groups of people with memory good and bad were compared with each other. The results showed that people with good memory significantly have higher alpha band power and lower theta power[۳۱].

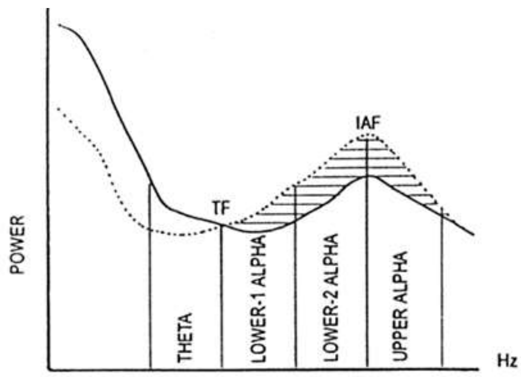

Fig. 3. EEG signal power changes during rest.

(dotted line) and during memory activity (solid line) [۳۱]

As can be seen, contrary to the many researchers conducted regarding memory and its relationship with Brain activity and memory signal, there is still disagreement regarding the choice of rhythm related to memory, which is due to the complexity of the memory structure and the influence of various cognitive factors such as mood, The level of intelligence and the level of attention of a person is on memory. Also, it is better to consider the EEG signal as a non-linear time series [۳۱]and use non-linear techniques for its processing. Therefore, research has been done on the relationship between memory function and brain EEG signal using non-linear techniques. For example, Talebi and et al. in [۳۵]used approximate entropy and quantitative regression analysis to investigate memory function and brain EEG signal during the injection of midazolam (a drug that causes amnesia) as a non-linear measure. The results showed that drug injection increases the complexity of the EEG signal. Abasolo and et al. in [۴۹]also used approximate entropy as a non-linear measure to quantify the time series signal routine to distinguish healthy people from people with Alzheimer's disease. They observed that the approximate entropy value is lower in Alzheimer's patients, which means less complexity reduction. This reduction in complexity is caused by the reduction of neurotransmitters and local neural network connections. They showed that approximate entropy is a suitable tool to reveal hidden characteristics of vital signals that are not revealed by linear (spectral) analysis. In [۵۰], wavelet entropy has been used as an EEG signal complexity evaluation tool to investigate changes in working memory load at seven different levels during the cognitive process. The results showed that the complexity of the signal increases with the increase of working memory load. Therefore, it can be seen that so far, the EEG signal has been evaluated with different criteria during the use of working memory. The common point of all the works done is that the complexity of the Brain activity and memory signal increases during the use of memory, and the higher the complexity of the signal during the use of memory, the better the performance.

5. CONCLUSION

In this research, the relationship between memory function and brain EEG signal was discussed. So far a lot of research has been done on the relationship between memory function and brain EEG signal power in different sub-bands.Relationship between memory and different brain activity and memory signal rhythms during the process of remembering. Despite the many researches done on memory and its relationship with Brain activity and memory signal, there is still a difference of opinion regarding the choice of rhythm related to memory. The reasons for which are the complexity of the memory structure. Another reason is the influence of various cognitive factors such as mood, intelligence and attention on brain. Research has also been done on the relationship between memory function and brain EEG signal using different non-linear criteria, which is the common point of all the work done is that the complexity of the brain activity and memory signal increases while using memory. The greater the complexity of the signal while using memory, the better the person's performance.

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