Study on Electroencephalography (EEG) Past, Present & Future

A Thesis submitted in partial fulfillment of the requirements for the Award of Degree of Bachelor of Science in Electrical and Electronic Engineering

By

Mehedi Chowdhury

ID: 131-33-1238

Supervised by

Md. Mahmudur Rahman

Assistant Professor

Department of Electrical and Electronics Engineering

Faculty of Engineering

Daffodil International University

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

FACULTY OF ENGINEERING

DAFFODIL INTERNATIONAL UNIVERSITY

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Certification

This is to certify that this thesis entitled "**Electroencephalography (EEG) Past, Present & Future**" is done by the following student under my direct supervision and this work has been carried out by him in the laboratories of the Department of Electrical and Electronic Engineering under the Faculty of Engineering of Daffodil International University in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering. The presentation of the work was held on.

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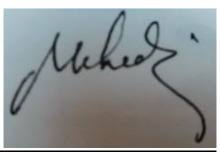

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Name: Mehedi Chowdhury

ID: 131-33-1238

Countersigned

Md. Mahmudur Rahman

Assistant Professor

Department of Electrical and Electronic Engineering

Faculty of Engineering

Daffodil International University

Dedicated To…

My beloved Parents

And

All of My Teachers

ABSTRACT

The field of electroencephalography (EEG) has witnessed a dramatic development during the last decade. Electroencephalography (EEG) has been in continuous development over at least 70 years and is firmly established as a tool in the management of epilepsy. The electroencephalogram that had been principally used as a ‘post-hoc’ diagnostic procedure is now fully used as an ‘on-line’ monitor of neural function with its excellent temporal resolution.

For a while, the technique fell into disregard because of difficulties with interpretation, specificity and sensitivity. Whilst clinicians have to be aware of these problems, they have been largely addressed by recent computer digitization of signals, which permits longer standard recordings and monitoring linked to a simultaneous video. Neurophysiological monitoring in the operating room, neurological intensive care unit (ICU) and during endovascular procedures allows early identification of impending neurological deficits before irreversible neurological impairment.

These techniques are not only an essential component of a specialist epilepsy service, where inpatient video-EEG telemetry is vital both for diagnosis and assessment before neurosurgical treatment, but also in general and acute medical settings, particularly for the management of status epilepticus. Further developments in computing will extend the use of EEG in all of these roles and long-term monitoring for diagnosis and management of coma will become more widely available. The advent of digital EEG with digital storage and the ability to manipulate data with digital reformatting, filter and sensitivity changes has allowed us to maximize the information and reduce artifacts. These changes have revolutionized the way in which EEG is performed and interpreted.

Keywords: EEG; Epilepsy; Technology; Telemetry; Clinical applications; Monitoring.

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Introduction to Brain Signal

Take a minute and put your hand onto your head and think about what you are touching. Within a centimeter of your fingers, there is a piece of the most mysterious and rarely understood matter in the universe. And that is our brain.

Inside each of our brains, there are roughly 100 billion highly specialized cells called neurons. They make about 500 trillion connections called synapsis. These unique cells transmit important information alarming us the sense and interacts with the world around us. If you want to take a closer look, you will see that this information is transmitted between neurons using chemicals called neurotransmitters where tiny structures called synaptic vesicles fuse with the membrane of one neuron and release chemicals signals into the gap. The second neuron can receive them.

Scientists already knew some about how this neurotransmission process works. But now after over 10 years of collaborated research of Stanford University and SLAC national accelerator laboratory along with the ultra-bright X-rays, scientists now have a better idea of exactly how these tiny vesicles might fuse with the membrane of one neuron to transmit their signals. The key to this fusion is the collaboration between special proteins called snares and synaptotagmin-1. They are then triggered by calcium to cause the vesicle of fuse with the membrane of the neuron. When a synaptic vesicle comes close enough to the membrane, the proteins connect with the two and enter a pre-fusion state. Next when the neuron fires, calcium arrives and triggers the proteins which bend the neural membrane towards the vesicle membrane and draw the two together. This finally triggers fusion allowing the neurotransmitters to leave the neuron. This experiment represents the first time when scientists have seen how synaptotagmin-1 interacts with the snares of the atomic scale and scientists are more confident that this protein resembles before calcium arrives allowing the fusion process and resulting neurotransmission to happen very quickly getting information from point A to point B in less than a millisecond. The end result is that our nervous system can work at an incredible speeds enabling us to sense, react to and interact with the world around us.

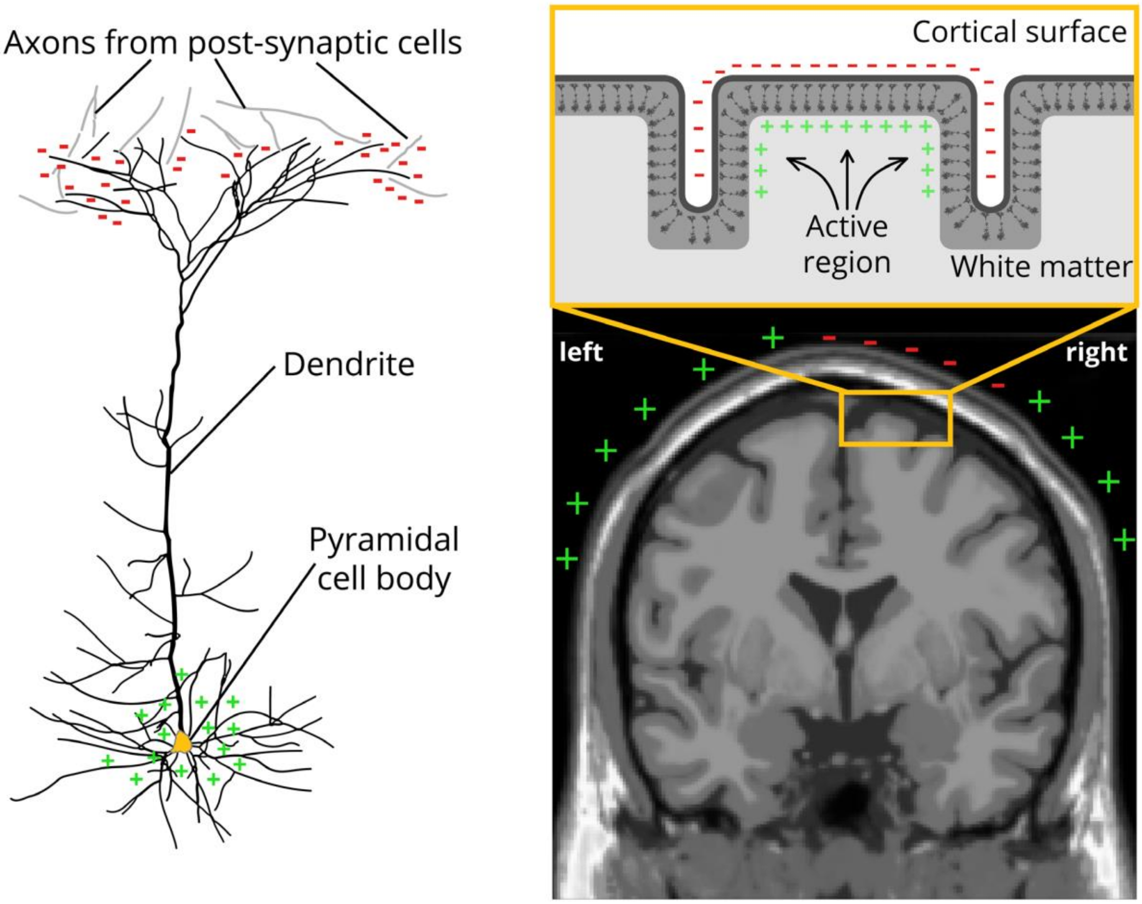

Fig: 1.1 Activities inside human brain

And now the scientists have been able to use the bright X-ray SSRL, the LCLS and the ANL light source to see how this particular process works. It opens the door to better understand our nervous system and ways that even our brains can think of.

Chapter 2
Introduction to Electroencephalography (EEG)

2.1 What is Electroencephalography (EEG)

- Electroencephalography (EEG) is the recording of electrical activity along the scalp.
- EEG measures voltage fluctuations resulting from activation of neurons of the brain.
- We can use EEG techniques to detect brainwaves.
- During the EEG test, small electrodes like cup or disc type are placed on the scalp.
- They pick the brain's electrical signal and send them to a machine called Electroencephalogram.

Fig: 2.1 Epileptic spike and wave discharges monitored with EEG

2.2 EEE generation

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The key to this fusion is the collaboration between special proteins called snares and synaptotagmin-1. They are then triggered by calcium to cause the vesicle of fuse with the membrane of the neuron. When a synaptic vesicle comes close enough to the membrane, the proteins connect with the two and enter a pre-fusion state.

Next when the neuron fires, calcium arrives and triggers the proteins which bend the neural membrane towards the vesicle membrane and draw the two together. This finally triggers fusion allowing the neurotransmitters to leave the neuron.

This experiment represents the first time when scientists have seen how synaptotagmin-1 interacts with the snares of the atomic scale and scientists are more confident that this protein resembles before calcium arrives allowing the fusion process and resulting neurotransmission to happen very quickly getting information from point A to point B in less than a millisecond.

The end result is that our nervous system can work at an incredible speeds enabling us to sense, react to and interact with the world around us. The key to this fusion is the collaboration between special proteins called snares and synaptotagmin-1. They are then triggered by calcium to cause the vesicle of fuse with the membrane of the neuron.

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2.3 Types of EEG

There are several different types of EEG and can be listed as the following:

2.3.1 Normal EEG

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This experiment represents the first time when scientists have seen how synaptotagmin-1 interacts with the snares of the atomic scale and scientists are more confident that this protein resembles before calcium arrives allowing the fusion process.

2.3.2 Sleep EEG

If you want to take a closer look, you will see that this information is transmitted between neurons using chemicals called neurotransmitters where tiny structures called synaptic vesicles fuse with the membrane of one neuron and release chemicals signals into the gap. The second neuron can receive them.

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2.3.3 Common Physiological Artifacts

Scientists already knew some about how this neurotransmission process works. But now after over 10 years of collaborated research of Stanford University and SLAC national accelerator laboratory along with the ultra-bright X-rays, scientists now have a better idea of exactly how these tiny vesicles might fuse with the membrane of one neuron to transmit their signals. The key to this fusion is the collaboration between special proteins called snares and synaptotagmin-1. They are then triggered by calcium to cause the vesicle of fuse with the membrane of the neuron.

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5.3.4 The Posterior Dominant Rhythm

The key to this fusion is the collaboration between special proteins called snares and synaptotagmin-1. They are then triggered by calcium to cause the vesicle of fuse with the membrane of the neuron. When a synaptic vesicle comes close enough to the membrane, the proteins connect with the two and enter a pre-fusion state. Next when the neuron fires, calcium arrives and triggers the proteins which bend the neural membrane towards the vesicle membrane and draw the two together. This finally triggers fusion allowing the neurotransmitters to leave the neuron. This experiment represents the first time when scientists have seen how synaptotagmin-1 interacts with the snares of the atomic scale and scientists are more confident that this protein resembles before calcium arrives allowing the fusion process and resulting neurotransmission to happen very quickly getting information from point A to point B in less than a millisecond. The end result is that our nervous system can work at an incredible speeds enabling us to sense, react to and interact with the world around us.

5.3.5 Provocation Techniques

When a synaptic vesicle comes close enough to the membrane, the proteins connect with the two and enter a pre-fusion state. Next when the neuron fires, calcium arrives and triggers the proteins which bend the neural membrane towards the vesicle membrane and draw the two together. This finally triggers fusion allowing the neurotransmitters to leave the neuron. This experiment represents the first time when scientists have seen how synaptotagmin-1 interacts with the snares of the atomic scale and scientists are more confident that this protein resembles before calcium arrives allowing the fusion process and resulting neurotransmission to happen very quickly getting information from point A to point B in less than a millisecond. The key to this fusion is the collaboration between special proteins called snares and synaptotagmin-1. They are then triggered by calcium to cause the vesicle of fuse with the membrane of the neuron. When a synaptic vesicle comes close enough to the membrane, the proteins connect with the two and enter a pre-fusion state. Next when the neuron fires, calcium arrives and triggers the proteins which bend the neural membrane towards the vesicle membrane and draw the two together. This finally triggers fusion allowing the neurotransmitters to leave the neuron.

2.4 The Developmental EEG: Premature, Neonatal and Children

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Figure 2.2 REM sleep is characterized by a more typically wake-appearing, desynchronized, mixed-frequency background, which may contain alpha frequencies, characteristic centrally dominant sharply contoured sawtooth waves, and rapid eye movement artifacts in lateral frontal electrode sites. Copyright 2013. Mayo Foundation for Medical Education and Research. All rights reserved. Figure courtesy of Erik K. St. Louis, MD.

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2.5 Benefits of using Electroencephalography (EEG)

Electroencephalography has several benefits. The main benefit of Electroencephalography is its high time conductivity. It can take hundreds to thousands of shots of electrical activity across within a second. It is very useful but it has some disadvantages too.

Chapter 3
History of Electroencephalography (EEG)

3.1 Invention of Electroencephalography

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3.2. Progress of Electroencephalography

3.2.1 Richard Caton's work

Richard Caton (1842– 1926) invented it in 1875.

3.2.2 Carlo & Emil Du's work

Carlo Matteucci 1811 and Emil Du Bois-Reymond 1818 invented it first.

3.2.3 First Electroencephalographic

Hans Berger 1873 discover EEG signals first.

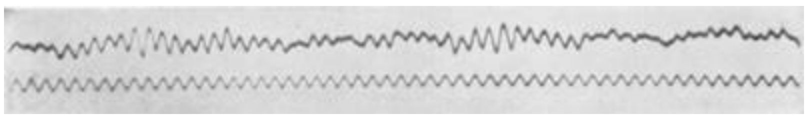

Fig: 3.1 The first human EEG recording obtained by Hans Berger in 1924.

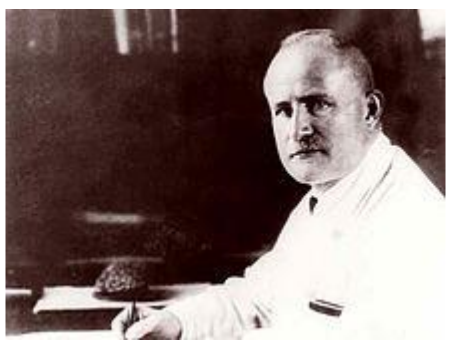

Fig: 3.2 Hans Berger(1873-1941)

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3.2.4 Limitations

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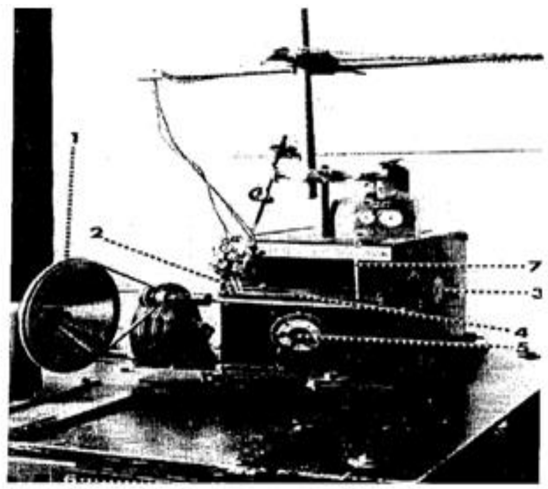

Fig: 3.3 Frist String Galvanometer with recording apparatus

3.2.5 Works by other scientists

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3.3 Brief History of EEG

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Fig: 3.4 Normal EEG recording from an adult using a longitudinal temporal and transverse bipolar montage.

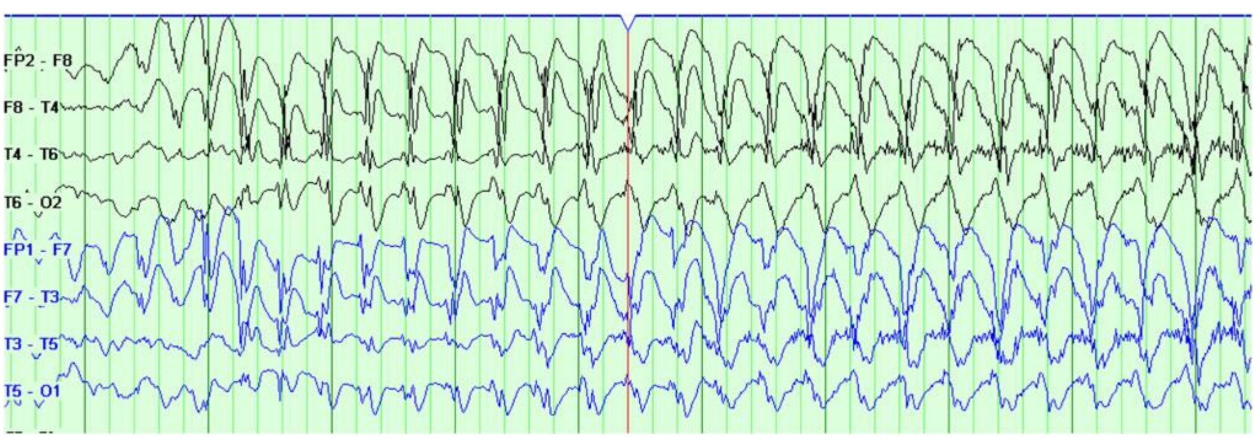

Fig: 3.5 Scalp EEG recording of ictal onset in a patient with absence epilepsy using a longitudinal bipolar montage.

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Fig: 3.6 Recording of ictal onset in a patient with right mesial temporal epilepsy due to hippocampal sclerosis using subdural electrodes inserted to cover the inferior surface of the temporal lobe cortex.

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Chapter 4
Electroencephalography (EEG) Signal Processing

4.1. Fundamentals of Electroencephalography (EEG) Signal Processing

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4.1.1 EEE signal modeling

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4.2 Various Bands

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4.2.1 Delta band (1-4 Hz)

Delta waves lie within the range of 0.5– 4 Hz. These waves are primarily associated with deep sleep and may be present in the waking state. It is very easy to confuse artefact signals caused by the large muscles of the neck and jaw with the genuine delta response.

4.2.2. Theta band (4-8 Hz)

Theta waves lie within the range of 4– 7.5 Hz. The term theta might be chosen to allude to its presumed thalamic origin. Theta waves appear as consciousness slips towards drowsiness. Theta waves have been associated with access to unconscious material, creative inspiration and deep meditation.

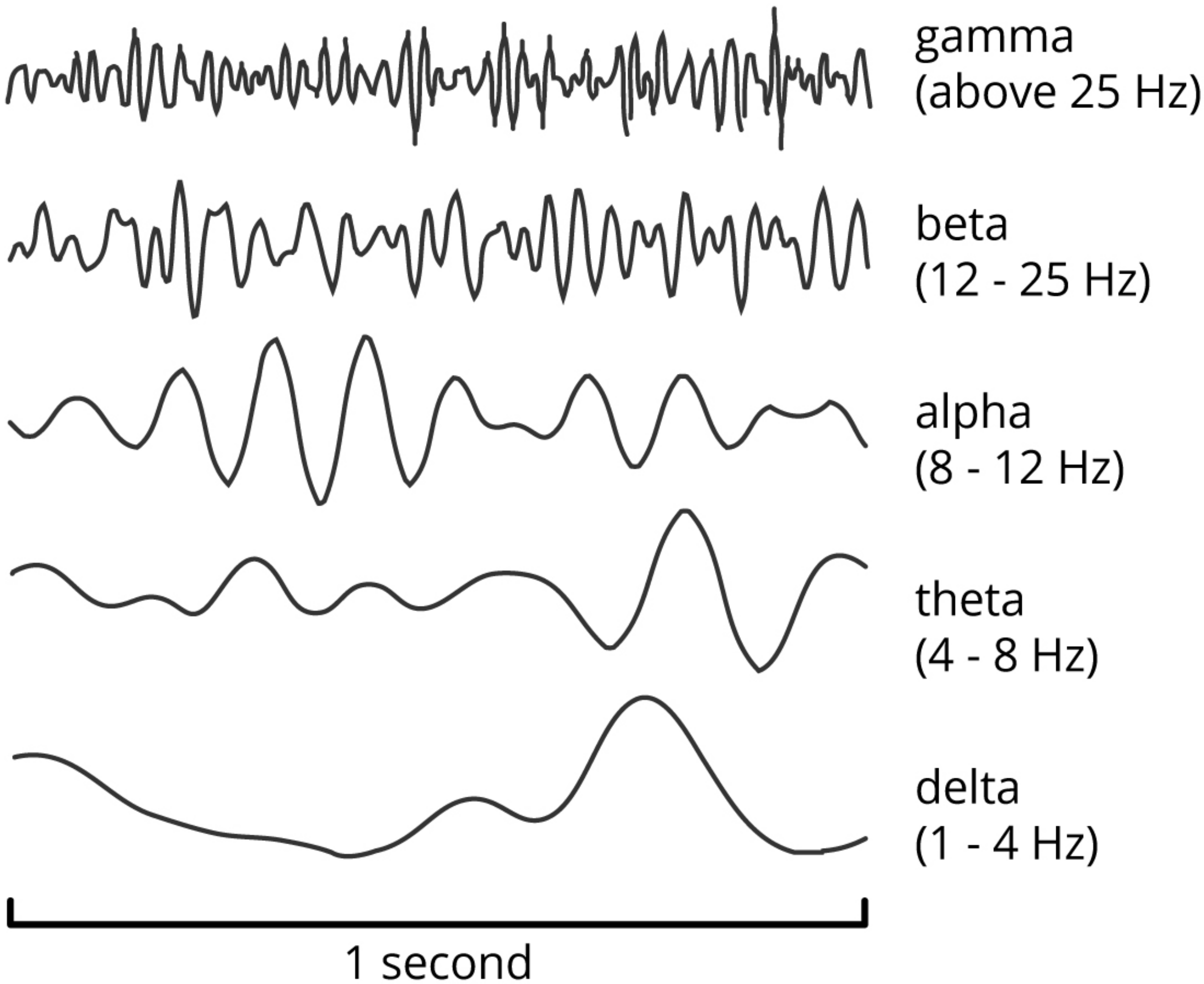

Fig: 4.1 Frequency variance per second

4.2.3. Alpha band (8 - 12 Hz)

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4.2.4. Beta band (12- 25 Hz)

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4.2.5 Gamma band (above 25 Hz)

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4.2.6 Other Waves

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Scientists already knew some about how this neurotransmission process works. But now after over 10 years of collaborated research of Stanford University and SLAC national accelerator laboratory along with the ultra-bright X-rays, scientists now have a better idea of exactly how these tiny vesicles might fuse with the membrane of one neuron to transmit their signals.

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Next when the neuron fires, calcium arrives and triggers the proteins which bend the neural membrane towards the vesicle membrane and draw the two together. This finally triggers fusion allowing the neurotransmitters to leave the neuron.

This experiment represents the first time when scientists have seen how synaptotagmin-1 interacts with the snares of the atomic scale and scientists are more confident that this protein resembles before calcium arrives allowing the fusion process and resulting neurotransmission to happen very quickly getting information from point A to point B in less than a millisecond. The end result is that our nervous system can work at an incredible speeds enabling us to sense, react to and interact with the world around us.

4.3 EEG Recording and Measurement

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4.4 Conventional Electrode Positioning

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Points to note in the 10-20 system:

Nasion (Nz)

The noise between the eyes at the top of the nose.

Inion (Iz)

The bump at the back of the head.

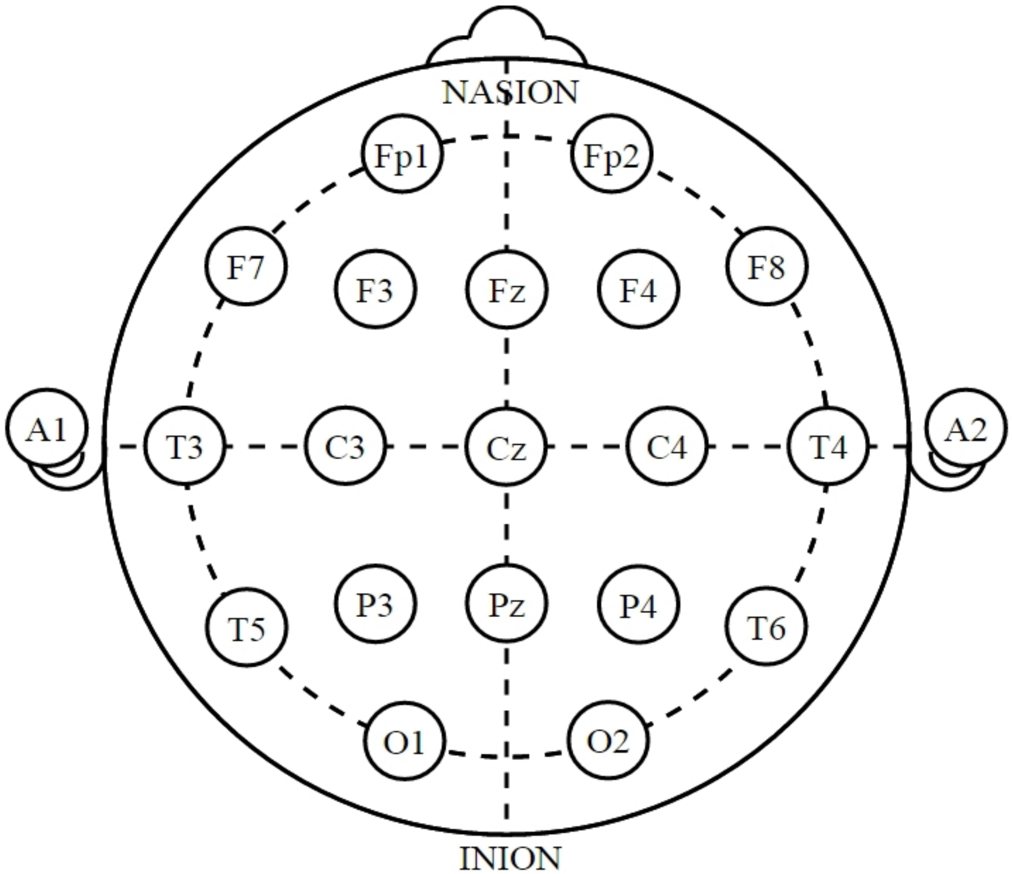

Fig: 4.2 Placement of Electrodes

The second neuron can receive them. Scientists already knew some about how this neurotransmission process works. But now after over 10 years of collaborated research of Stanford University and SLAC national accelerator laboratory along with the ultra-bright X-rays, scientists now have a better idea of exactly how these tiny vesicles might fuse with the membrane of one neuron to transmit their signals. The key to this fusion is the collaboration between special proteins called snares and synaptotagmin-1. They are then triggered by calcium to cause the vesicle of fuse with the membrane of the neuron. When a synaptic vesicle comes close enough to the membrane, the proteins connect with the two and enter a pre-fusion state. Next when the neuron fires, calcium arrives and triggers the proteins which bend the neural membrane towards the vesicle membrane and draw the two together. This finally triggers fusion allowing the neurotransmitters to leave the neuron. This experiment represents the first time when scientists have seen how synaptotagmin-1 interacts with the snares of the atomic scale and scientists are more confident that this protein resembles before calcium arrives allowing the fusion process and resulting neurotransmission to happen very quickly getting information from point A to point B in less than a millisecond. The end result is that our nervous system can work at an incredible speeds enabling us to sense, react to and interact with the world around us.

4.5 Number and distribution of electrodes

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4.6 Clean Electroencephalography data and artefacts

The second neuron can receive them. Scientists already knew some about how this neurotransmission process works. But now after over 10 years of collaborated research of Stanford University and SLAC national accelerator laboratory along with the ultra-bright X-rays, scientists now have a better idea of exactly how these tiny vesicles might fuse with the membrane of one neuron to transmit their signals. The key to this fusion is the collaboration between special proteins called snares and synaptotagmin-1. They are then triggered by calcium to cause the vesicle of fuse with the membrane of the neuron. When a synaptic vesicle comes close enough to the membrane, the proteins connect with the two and enter a pre-fusion state. Next when the neuron fires, calcium arrives and triggers the proteins which bend the neural membrane towards the vesicle membrane and draw the two together. This finally triggers fusion allowing the neurotransmitters to leave the Shell.

4.6.1 Physiological artefacts

The second neuron can receive them. Scientists already knew some about how this neurotransmission process works. But now after over 10 years of collaborated research of Stanford University and SLAC national accelerator laboratory along with the ultra-bright X-rays, scientists now have a better idea of exactly how these tiny vesicles might fuse with the membrane of one neuron to transmit their signals. The key to this fusion is the collaboration between special proteins called snares and synaptotagmin-1. They are then triggered by calcium to cause the vesicle.

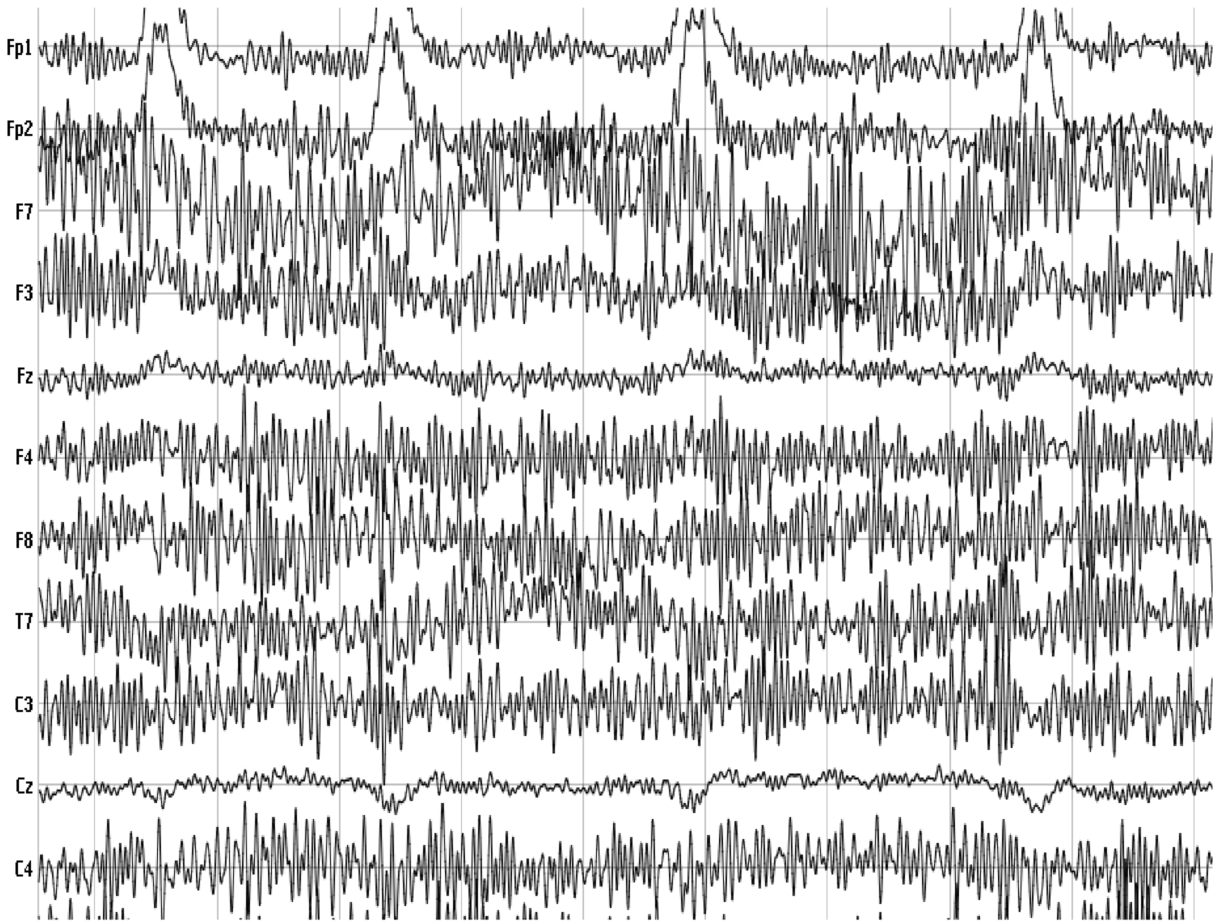

Fig: 4.3 Muscle activity of electric current

Eye movements

They are then triggered by calcium to cause the vesicle of fuse with the membrane of the neuron. When a synaptic vesicle comes close enough to the membrane, the proteins connect with the two and enter a pre-fusion state. Next when the neuron fires, calcium arrives and triggers the proteins which bend the neural membrane towards the vesicle membrane and draw the two together. This finally triggers fusion allowing the neurotransmitters to leave the neuron. This experiment represents the first time when scientists have seen how synaptotagmin-1 interacts with the snares of the atomic scale and scientists are more confident that this protein resembles before calcium arrives allowing the fusion process and resulting neurotransmission to happen very quickly getting information from point A to point B in less than a millisecond.

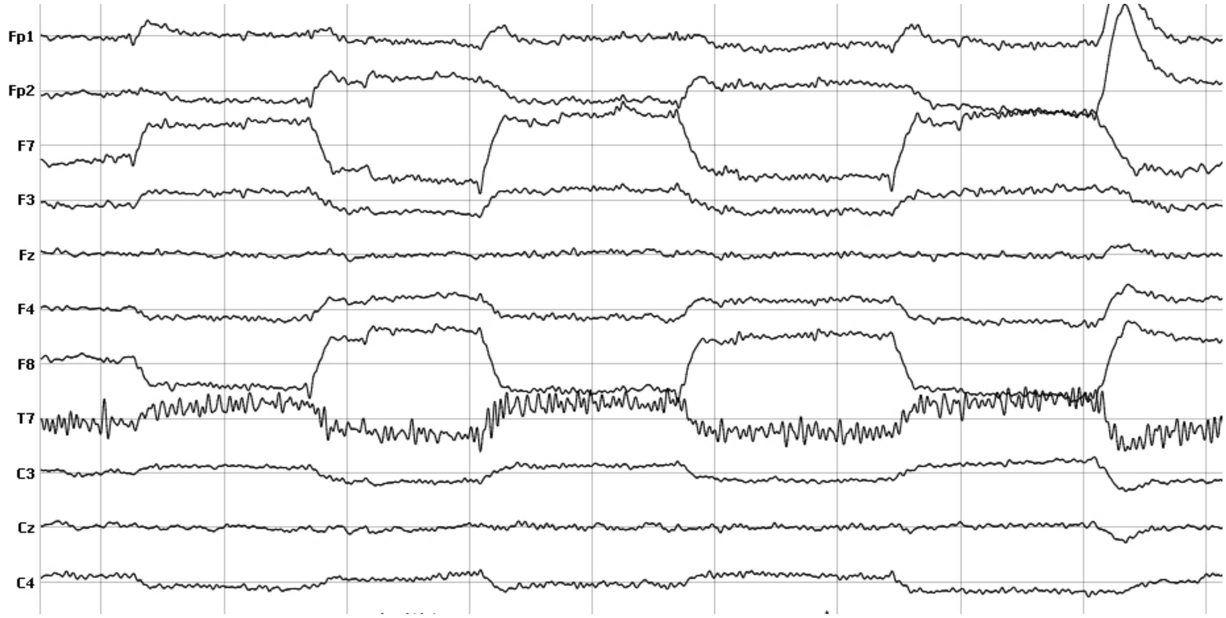

Fig: 4.4 Eye movement

Blinking:

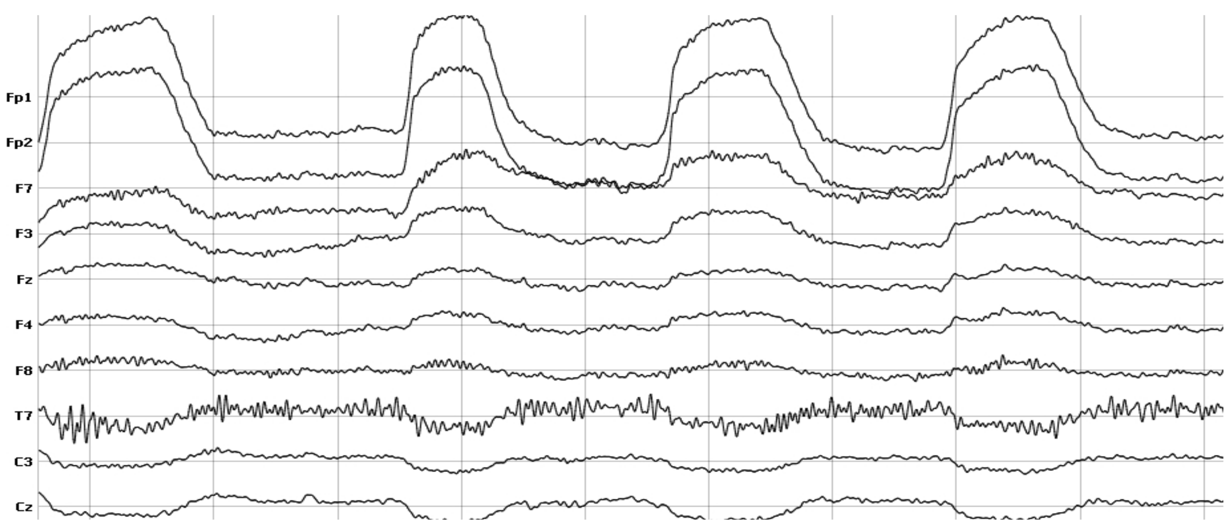

Fig: 4.5 Blinking effect

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4.6.2 External sources of artefacts

Movement of an electrode can cause many artefacts (Fig 4.6).

Fig: 4.6 Movement of electrodes

Line noise

Line noise (50 Hz in the United States, 60 Hz in the Europe) probably have strong artefacts on the electrode listing - it is quite common in the raw Electroencephalography data.

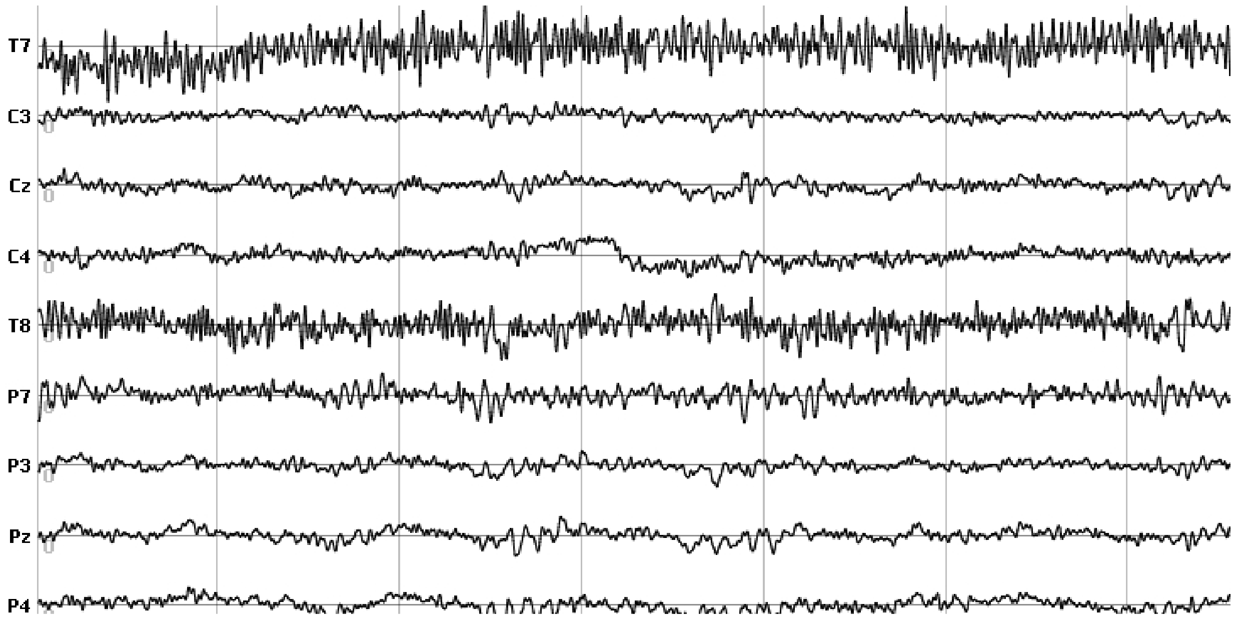

Fig: 4.7 Noise variation over frequency

Chapter 5
Application of Electroencephalography (EEG)

5.1 Medical or Clinical Applications

It has severe medical applications.

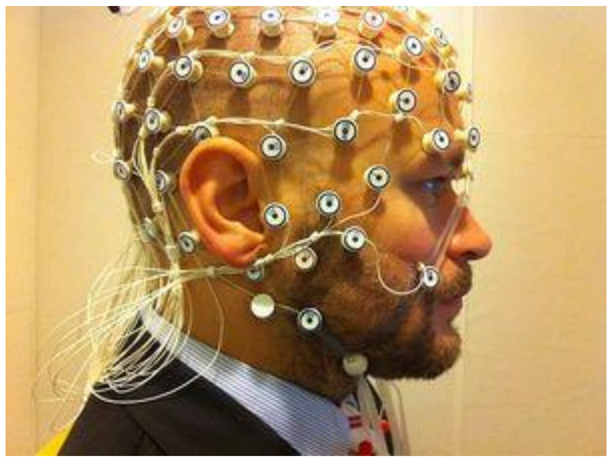

Fig: 5.1 An EEG recording setup

The key to this fusion is the collaboration between special proteins called snares and synaptotagmin-1. They are then triggered by calcium to cause the vesicle of fuse with the membrane of the neuron. When a synaptic vesicle comes close enough to the membrane, the proteins connect with the two and enter a pre-fusion state.

5.1.1 Dementia

Dementia is a syndrome that consists of a decline in intellectual and cognitive abilities. This consequently affects the normal social activities, mode, and the relationship and interaction with other people. EEG is often used to study the effect of dementia. In most cases, such as in primary degenerative dementia, e.g. Alzheimer's, and psychiatric disorder, e.g. depression with cognitive impairment, the EEG can be used to detect the abnormality.

Dementia is classified into cortical and subcortical forms. The most important cortical dementia is Alzheimer's disease (AD), which accounts for approx- imately 50 % of the cases. Other known cortical abnormalities are Pick's disease and Creutzfeldt– Jakob diseases (CJD). They are characterized clinically by findings such as aphasia, apraxia, and agnosia. CJD can often be diagnosed using the EEG signals. Figure shows a set of EEG signals from a CJD patient. On the other hand, the most common subcortical diseases are Parkinson's disease, Huntington's disease, lacunar state, normal pressure hydrocephalus, and progressive supranuclear palsy. These diseases are characterized by forgetfulness, slowing of thought processes, apathy, and depression. Generally, subcortical dementias introduce less abnormality to the EEG patterns than the cortical ones.

In AD the EEG posterior rhythm (alpha rhythm) slows down and the delta and theta wave activities increase. On the other hand, beta wave activity may decrease. In severe cases epileptiform discharges and triphasic waves can appear. In such cases, cognitive impairment often results. The spectral power also changes; the power increases in delta and theta bands and decreases in beta and alpha bands and also in mean frequency.

The EEG wave morphology is almost the same for AD and Pick's disease. Pick's disease involves the frontal and temporal lobes. An accurate analysis followed by an efficient classification of the cases may discriminate these two diseases. CJD is a mixed cortical and subcortical dementia. This causes slowing of the delta and theta wave activities and, after approximately three months of the onset of the disease, periodic sharp wave complexes are generated that occur almost every second, together with a decrease in the background activity [54]. Parkinson's disease is a subcortical dementia, which causes slowing down of the background activity and an increase of the theta and delta wave activities. Some works have been undertaken using spectral analysis to confirm the above changes [55]. Some other disorders such as depression have a lesser effect on the EEGs and more accurate analysis of the EEGs has to be performed to detect the signal abnormalities for these brain disorders.

The key to this fusion is the collaboration between special proteins called snares and synaptotagmin-1. They are then triggered by calcium to cause the vesicle of fuse with the membrane of the neuron. When a synaptic vesicle comes close enough to the membrane, the proteins connect with the two and enter a pre-fusion state. Next when the neuron fires, calcium arrives and triggers the proteins which bend the neural membrane towards the vesicle membrane and draw the two together.

5.1.2 Additional work done by EEG

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5.1.3 Epileptic Seizure and Nonepileptic Attacks

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Inside each of our brains, there are roughly 100 billion highly specialized cells called neurons. They make about 500 trillion connections called synapsis. These unique cells transmit important information alarming us the sense and interacts with the world around us. If you want to take a closer look, you will see that this information is transmitted between neurons using chemicals called neurotransmitters where tiny structures called synaptic vesicles fuse with the membrane of one neuron and release chemicals signals into the gap. The second neuron can receive them.

Scientists already knew some about how this neurotransmission process works. But now after over 10 years of collaborated research of Stanford University and SLAC national accelerator laboratory along with the ultra-bright X-rays, scientists now have a better idea of exactly how these tiny vesicles might fuse with the membrane of one neuron to transmit their signal.

5.1.4 Psychiatric Disorders

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5.3 Applications of EEG monitoring

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5.3.1 Long-term Video-EEG Monitoring

Dementia is a syndrome that consists of a decline in intellectual and cognitive abilities. This consequently affects the normal social activities, mode, and the relationship and interaction with other people. EEG is often used to study the effect of dementia. In most cases, such as in primary degenerative dementia, e.g. Alzheimer's, and psychiatric disorder, e.g. depression with cognitive impairment, the EEG can be used to detect the abnormality.

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5.3.2 Pitfalls in Video-EEG Monitoring

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5.3.3 Long-term Video-EEG Monitoring in a Preoperative Evaluation

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5.4 Various Applications

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Chapter 6
Advantages & Disadvantages of Electroencephalography (EEG)

6.1 Advantages of Electroencephalography (EEG)

EEG has two clear advantages for brain research. Dementia is a syndrome that consists of a decline in intellectual and cognitive abilities. This consequently affects the normal social activities, mode, and the relationship and interaction with other people. EEG is often used to study the effect of dementia. In most cases, such as in primary degenerative dementia, e.g. Alzheimer's, and psychiatric disorder, e.g. depression with cognitive impairment, the EEG can be used to detect the abnormality.

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6.3 Limitations

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6.4 Abnormal activity

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Chapter 7
Discussion & Conclusion

7.1 Discussion & Conclusion

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