

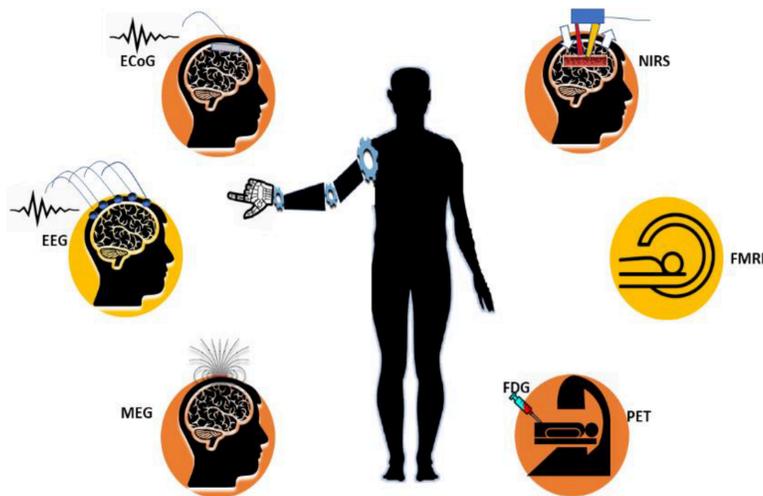
Memory
Prof. Manish Kumar Asthana
Department of Psychology
Indian Institute of Technology Roorkee

Lecture - 9
Research Methods in Memory

Hello, I welcome you all to the lecture series on memory. Lecture number 9, will be addressing the research methods used in memory. Now, we know that the modern technology has helped us and is aiding us to understand and develop deeper insight about the underlying neural mechanism of memory processes. Not only memory processes, in addition to that, several types of cognitive processes can be understood using these modern tools and technologies. Neuroimaging method provide us and allow us to create images that demonstrate which part of the brain is working and which part of the brain is responsible for what type of cognitive processing or cognitive task. The underlying cognitive processing for a specific cognitive task can give us an insight to understand the normal and abnormal human beings and their neural processes. Understanding the underlying neural mechanism can give us an insight how to develop an effective intervention method or tools to safeguard the unhealthy and pathological brains. Pathological brains, pathological individuals such as people suffering from post-traumatic stress disorder, panic disorder and many more. What you see on your screen, the most commonly used neuroimaging methods in the discipline of cognitive neuroscience and such to name a few, EEG, electroencephalogram or encephalography, near infrared spectroscopy, ferromagnetic resonance imaging, PET, MEG and etc. Now, these methodologies we will be covering in detail. In addition to these, we will be also looking at some neural stimulation procedures which seems to be having a potential therapeutic aspects with respect to pathological learning and memory. The EEG method is not a noble method. In 1958, when the first time it was being recorded, the first EEG graph, then it gave us a hope to the individual to understand the neural signal, the electrical signal, which has been first time collected from the human brain.

These electrical signals are being conducted from across the scalp. The traditional EEG system is comprised of 128 channels. However, some researchers study the wave

patterns, some individuals study the temporal responses. Now, in all of these imaging tools, the two important parameters which an individual, memory researchers or cognitive neuroscience researchers study, put emphasis upon is the spatial information or the temporal information.



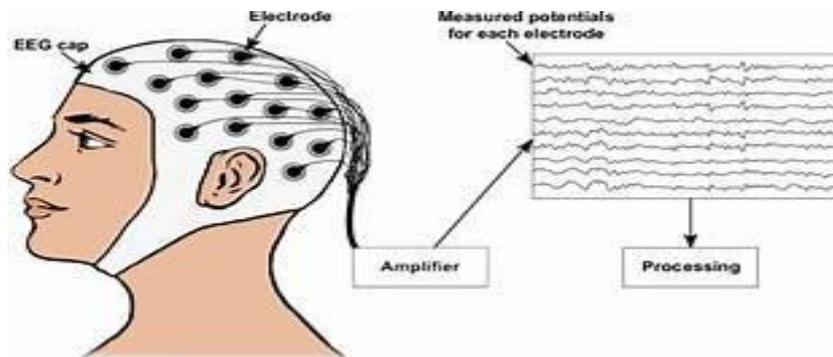
Source: [Pandarinathan et al. \(2018\)](#)

The entire neuroimaging tools and further additional tools used in the cognitive neuroscience has been classified and distributed across the temporal domain and the spatial domain. Temporal information, temporal domain provide at what time point the specific cognitive processes has started to take. Spatial information provides the information where and which part of the brain is responsible for such type of cognitive task. Now, it has been a concern and it is being also established that the tools differ from one another based on this temporal and spatial parameter. Some tools are very good with spatial resolution.

Some tools are bad with temporal resolution. Some tools are bad with spatial resolution. Some tools are good with spatial resolution and bad with temporal and vice versa. So, this temporal and spatial resolution parameter is a very crucial parameter. When we talk

about a tool such as electroencephalography or electroencephalogram, then its spatial resolution is not that good.

Temporal resolution is very very precise and good and because of this we know that what time humans are processing the phase. So the human is processing the human phase at 170 millisecond and the component which we call it as N170 which is a negative peak is



being seen to be generated at 170 millisecond. So this ERP is the event related potential. So there is a potential generated to a specific event. The event could be processing a phase versus a house or phase processing a neutral object.

Source: <https://www.psychdb.com/neurology/eeg>

Now, when there is a congruency, incongruency effect also, then there are different event related potential being generated. Researchers, when are designing their experiment, they put an emphasis at what time point or at what event related potential they will be interested in the investigation. The ERPs have been divided into two halves based on the curves. So, the scale goes from plus positive to negative. So, the negative peak is always top and positive peak is always at the bottom like this as you can see on your screen.

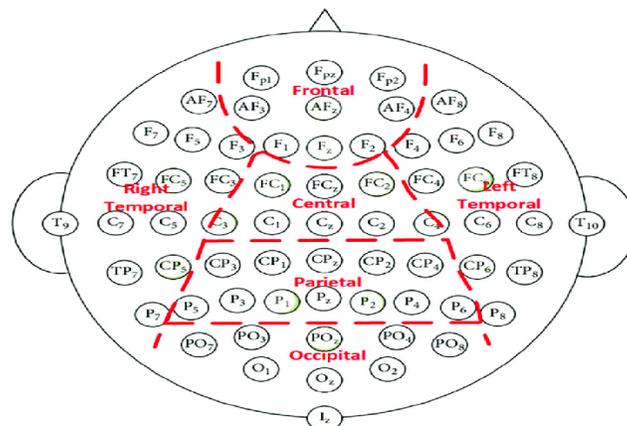
Now some responses just get generated within 200 milliseconds of time, approximately 200 and let us say 250 milliseconds of time or some responses just generated in 400 milliseconds of time. So, but there are some potentials, electrical potentials which are generated beyond one minute. That is late positive potential. Now, ERP is a very

common process, but it is very good and precise tool which gives us an insight to the memory researchers at what time point the information is being processed. When we talk about the brain waves because the channels if we talk about the initial studies started working with the brain and the easy way to remember this is D tab and G. D stands for Delta, T stands for Theta, A stands for Alpha, B stands for Beta, G stands for Gamma.

So what you see on your screen, the starting wavelength, the minimum wavelength is delta, which is 0.5 to 4 hertz. And this happens during a sleep. When a person is in a deep sleep or rapid eye movement state is there, then this is the potential. The another potential is the theta wave pattern which is from 4 to 7 hertz. When a person is sleepy, drowsiness, laziness, fatigue is there, then such wave pattern is being generated.

So imagine a person is given a high cognitive load task where he has to use his working memory and he has to solve a difficult complex mathematical problem. In that case person will feel little drowsy, people will feel little tired, and fatigue is there. As a result theta wave pattern should be higher number. So when the condition is pleasant, when the person is more alert state, conscious state and feeling very good, then the alpha wave pattern is seen.

This alpha wave band pattern is from 8 hertz to 12 hertz. The awake condition, so beta is the complete awake condition when you are starting your day early in the morning leaving the bed beta waves and alpha waves are high in number. When you go to bed then the theta waves and the delta waves are high in number. So in due course of time if you see then alpha beta is helpful when you start the day with and the theta and delta is at the end. Above the 30 Hz is the gamma wave patterns which is you know being studied but is not being of a prime concern.



Source: Hu & Lodewijks, (2020)

But these three wave patterns researchers have been studying and several studies have talked about the gender differences, several studies have talked about the cultural differences, several studies have talked about the illiteracy effect using these different wave type wave patterns. Using this EEG electroencephalogram also, one has to understand that the 10-20 EEG system is a very common method where the entire brain skull is being divided using 10 centimeter, 20 centimeter distribution, 10-20 centimeter, centimeter or 10-20 ratio distribution of the entire human skull. Human brains are different for different individuals. Some may have circumference size of 54 centimeter. Some may have circumference size 50 centimeter.

Some may have circumference size 60 centimeter. So, once you have a total circumference size, then you can divide this circumference into 10 centimeter or 20 centimeter. So, 10 centimeter. When we are doing this thing, we consider into the nasions to the nascent point to the onion point which is at the backside and then this distribution we do with the 20-20-20 distribution and this is the 20 percent, 20 percent, 20 percent, 20 percent and 20 percent.

This distribution is being done with the 20 percent and so there is this distribution and then from auriculus to the other side of the ear then also we do the similar distribution and then the circumference of the brain. So this way 10-20 EEG system we distribute the entire brain and this distribution is important for the localization of the different parts of the brain what you see on your screen. So if you divide this brain into two halves. Your left hand side holds the prime number and your right hand side holds the even number of the electrodes.

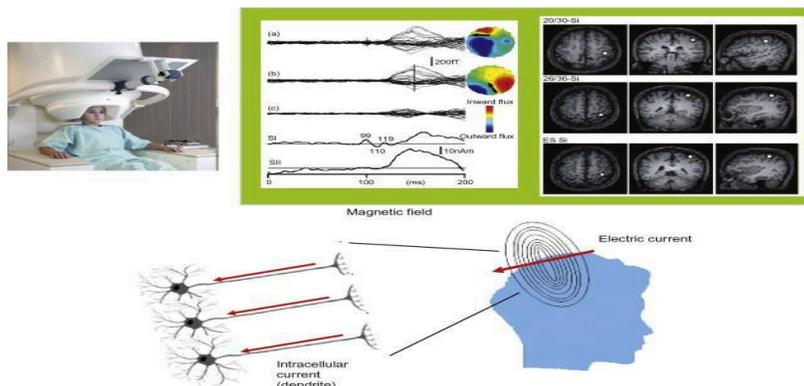
So even number of the electrodes, Fp2, Af4, F4, Fc4 and this is how you can see. The central side holds with the central area. Now electroencephalography is a very commonly used tool and it is started in 1970. 58 onwards people are using the gel you get the better recording however, handling such a device is very very complex in nature. So there are several types of EEG available in the market 8 channel 16 channel 32 channel 128

channel and 256 channel the another type of tool which works with the magnetic principle or magnetic sensors are there which captures the electrical changes due to the magnetic field presented.

This is in the magnetoencephalograph or magnetoencephalography. Magnetoencephalography unlike EEG has a better spatial resolution and temporal resolution. However, it is not very easy to conduct this experiment because the participant has to be seated on the chair for a long period of time. Now imagine a scenario where a young kid of 10 years old has to sit on that chair for an hour to do the recording. that is sometimes very challenging for the medical purposes MEG EEG is a very good tool for the localization for the identification of any sort of impairment or damage or deficit happen in the brain now what we see here is that the MEG measures the brain activity by detecting the magnetic field that the brain which is producing it

Now, the brain, we are passing the magnetic field to the brain and the alignment of the, as a result, the alignment of the ions which are flowing into the bloodstream in the brain, they try to align themselves as per the external magnetic field provided to them. External magnetic field then aligns the electric current, generates the electric current. As a result, the ions start to align themselves in the brain. So, the measurement is non-invasive just like the EEG. This is also non-invasive and it is being provided over the scalp.

MEG has a better temporal resolution and it can produce detailed spatial map of the brain unlike the EEG system as I told you earlier. so MEG is also an effective tool but it is non-mobile it is expensive unlike EEG which is mobile in nature you can carry it from one place to the another place easily but MEG systems are not now some of you may be using the EEG system and maybe those EEG system cannot be mobile but the modern tools and techniques EEG system it can be mobile and is even worked with is a wireless. But MEG system is not and this is very expensive in nature. Another method is the invasive method, positron emission topography.



Source: [VSM MedTech](#)

Here, a small amount of radioactive tracer or chemical is being injected into the blood stream of the individual. And once it is being injected, the individual is brought back to the field and this chemical or radio marker because of its chemical properties they try to generate the ions and these ions under the external magnetic field tries to align themselves accordingly and once the other person is in the scanner in the action these molecules are being studied now the Some researchers, memory researchers are little particular about using this PET methodology. Reason being, the traces, these radioactive components which is being used, they are injurious to health.

As a result, it may also have a deeper impact on the human body in the long run. the tracer travels to the blood stream to all parts of the body and the brain so it is also not so much localized if you are giving 100 milligram of radioactive tracer that entire body because of the blood stream it is going to be there it is not very much localized unlike the EG system and MEG system which is very much you know only receiving the electrical signal from the brain rather than from the entire body part The areas that are more radioactive are associated with cognitive task engagement. This is a very established notion is that the area which is involved in complicated cognitive task, they try to engage more and more radioactive substance. As a result, it indicates that these are the sites of the human brain processing.

The another methodology based on magnetic principle is the magnetic resonance imaging. This magnetic resonance imaging is extensively used in different labs. Very good tool for the in the case of the tumor identification or any anomaly or aneurysm in the brain. Examining the structural damage in the internal organ is, this tool is very very effective and very very efficient. Early detection is possible with such tool.

It detects the tumor, growth of the tumor and other damage being made in the human brain. This produces a detailed picture of the intact human brain. This tool, this tool is having a better spatial resolution but bad temporal resolution and if we talk about the positron emission tomography, this is having a very good spatial resolution and very good

temporal resolution but because of the radioactive substrates, this is not a very popular tool in the human research, okay. The extended version of the magnetic resonance imaging is the functional magnetic resonance imaging.

In this functional magnetic resonance imaging, we are measuring the oxygenated and deoxygenated blood. Whenever a cognitive task is there, whenever an individual is processing the information, he is engaging the, he is consuming lot of oxygen. When the oxygen is being consumed at the time of cognitive processing, then blood is having different spectral properties and when the blood is having carbon dioxide in it, then different spectral properties are there. As a result, it provides a very beautiful spatial resolution. Give us an insight which part of the brain is involved in specific tasks such as memory task, which part of the brain is responsible.

As we have been discussing about the three important brain regions, frontal cortex, hippocampus, amygdala. So, if emotional task is there, then amygdala will consume more oxygen and its spectral property will be reflected in the fMRI. Frontal cortex, when it is involving in decision making, more oxygen will be consumed at the frontal cortex and then it will be reflected in the fMRI. Similarly, the hippocampus.

Of course, the analysis with the fMRI is not that so easy as it is being shown on you here on the screen. It requires several signal to noise ratio analysis and clearing and also the correction on the data set. fMRI show functional components occurred by the tracking blood flow, heat gas, great spatial resolution, then other neural imaging techniques. FMRI can re-scan the brain in every 0.2 seconds. 0.2 seconds means 200 milliseconds.

In 200 milliseconds time, it can only scan the brain. 200 millisecond is a huge amount of time. With EEG we understood that 170 millisecond time person can process the face. Now imagine if in every 2 seconds fMRI is recording then how the task is going to be there. Moving ahead with the fMRI we know that there is another tool which is very good and which works on the similar principle of oxygenated and deoxygenated blood having a better spatial resolution having a better temporal resolution unlike the fMRI.

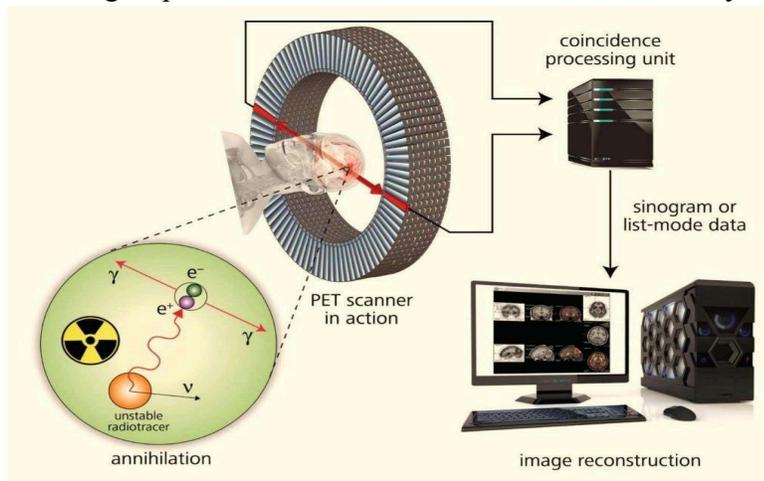
This tool is functional near-red infrared spectroscopy. It works on the hemoglobin change in the brain tissues. So, these electrodes, diodes are being placed over the entire scalp. It works with the principle of infrared spectroscopy. So, it just collects the wave patterns.

So, from one electrode, the light is being penetrated from one diode and from the another diode the light is being captured because of the presence of and in the change of the hemoglobin in the blood stream, the wavelength which is being retrieved back changes now this is being placed just like the EEG system this is also not mobile the device is fixed and it is very expensive and costly however as I said the precision is there with the spatial and temporal information So, near-infrared spectroscopy emits from a source probe. So, the source probe could be red color or the source probe could be blue color. It passes and scatters through the brain tissues.

Relatively low absorption of light is there. Blood absorbs the light which is being given to the source channel and the oxygenated blood will absorb some light. Deoxygenated blood will absorb some light and then it is being received by the receiver electrode. So, as we see, absorbed by the blood hemoglobin in a small vessel, a detector probe detects the scattered near-air spectroscopy and then plot it, which part of the brain is responsible and where. if we so as I was telling you earlier that there are different tools neuroimaging tools are there and they have been divided on two scales, one is the spatial scale another is the temporal scale some tools are better on the spatial scale some tools are better on the temporal scale. So if you see if you take the four tools fNIRS fMRI EEG/MEG together and PET then

we can see the signal, here we call it as bold signal, blood oxygenated level here and then the electromagnetic response, cerebral blood flow, glucose metabolism is being seen in the PET scan. Spatial resolution if we talk about, this can go up to 4 mm in size. So, it can precisely locate it to 4 millimeter in size area while the fMRI can do it in the 0.3 millimeter voxel area. So if you are talking about the small scanner and it is being these it's been divided into these layers and columns, then this is small voxel size is this point three millimeter the fNIRS covers the area of two to three centimeter two to three centimeter is a big area in the human brain and this two to three centimeter brain region

the signal is being captured this two to three centimeter underlying cortex can have



thousands and thousands of neurons projection and coordination and integration.

Source:

<https://www.slideshare.net/mustafaalbayati923/positron-emissions-tomography-pet-scan>

So, thousands of neuronal assemblies are there under this brain regions. So, the precision which neuron is responsible, how many types of neurons are responsible, how many neurons are engaging themselves or integrating themselves for a specific cognitive task that becomes a little challenging point here. EEG and MEG, you can see 5 to 9 centimeter. And as the size area is so big, that is why their spatial resolution is very bad. And we cannot localize the function so precisely that this is the brain region responsible for this facial processing task or language processing task or syntax processing task or semantic processing task.

So this is an important concern here but the temporal resolution of these devices are very good which can precisely tell us at what time point the semantic processing has occurred, at what time point syntax processing has occurred. Penetration depth if we talk about the brain cortex whole head and brain cortex here we are talking about and then the PET is also talking about the whole head. We should be aware that when the PET radio tracers are being injected into the body then entire body the tracers are moving because of the blood stream. So whole head is taken into account. Temporal, if you see, then up to 10 Hz, 1 to 3 Hz, 1000 Hz and less than.

1000 Hz means, if you talk about the frequency, it is equal to 1 by time. Similarly, time is equal to 1 by frequency, so 1 by 1000, which means that 1 millisecond. 1 millisecond processing it can give us a precise information or up to 1 millisecond 10 to the power of minus 3 time point if any cognitive process is happening and above that. So robustness if you talk about the motion it is very good, here fMRI is limited, EEG is limited, and PET is also very very limited range of possible tasks, fNIRS is a seem to be a very good tool. fMRI, EEG, PET seems to have a limited task not everything can be done range of possible participants everyone can be do done fMRI you know challenging for the children and participants and patients

and particularly somebody who is claustrophobic fMRI since you have a little problem. PET is also very limited you do not know the radioactive traces how much you know impactful it could be and can be lethal to the human body. EEG can be done with everybody that is an easy part, sound if you talk about the sound fMRI is too loud and that makes participant very uncomfortable and EEG, the sound in the EEG is silent and others are very silent. Portability, if you talk about, yes, EEG is portable. PET is not portable. You have to be admitted in the hospital.

fNIRS is also portable, but the system is too heavy. If you have seen it, then you will find that it is difficult to handle. fNIRS, you cannot move it. Cost, if you talk about, fNIRS cost is, I mean, the cost of normal fNIRS these days is around 90 lakhs, which is not that cheap.

But still, in relation to fNIRs, it is considered to be cheap. EEG is cheap, but MEG is very, very expensive, as I said earlier also. And the PET is also high because of the usage of radioactive tracers, which is not easily available. Now this brings me to the neuro-stimulation method because it is important for us to understand that the imaging tools are different set of research methods which is being used in the memory literature. Neuro-stimulation is used to stimulate the brain to initiate the neural activity to excite the neurons which are at resting state or dampen, douse or attenuate the excitatory neurons.

	fNIRS Functional NIR spectroscopy	fMRI Functional magnetic resonance imaging	EEG/MEG Electroencephalography/ Magnetoencephalography	PET Positron emission tomography
SIGNAL	HbO ₂ /HbR	BOLD (HbR)	Electromagnetic	Cerebral blood flow Glucose metabolism
SPATIAL RESOLUTION	2-3 cm	0.3 mm voxels	5-9 cm	4 mm
PENETRATION DEPTH	Brain cortex	Whole head	EEG: Brain cortex MEG: Deep structures	Whole head
TEMPORAL SAMPLING RATES	Up to 10 Hz	1-3 Hz	>1000 Hz	<0.1 Hz
RANGE OF POSSIBLE TASKS	Enormous	Limited	Limited	Limited
ROBUSTNESS TO MOTION	Very good	Limited	Limited	Limited
RANGE OF POSSIBLE PARTICIPANTS	Everyone	Limited, can be challenging for children/patients	Everyone	Limited
SOUNDS	Silent	Very noisy	Silent	Silent

So, neurostimulation seems to be a very good method and in brain stimulation, two types of neurostimulation procedures are commonly available. One can be seen as non-invasive, another can be invasive in nature. In non-invasive and invasive also, the two types, one based on electrical principle, one based on magnetic principle. So, based on magnetic principle, transcranial magnetic stimulation.

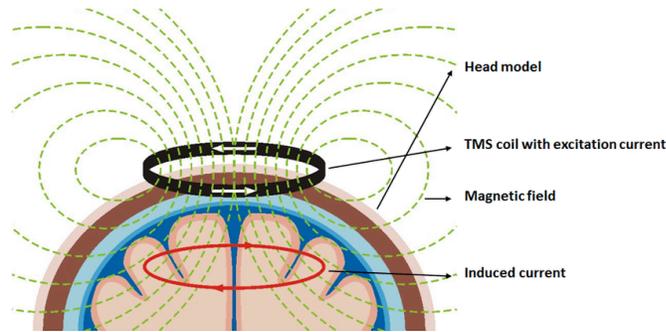
Source: [P. Pinti, et al. Ann. N.Y. Acad. Sci. \(2020\)](#)

Based on electrical principle, TXSSXX stands for transcranial alternating current stimulation, transcranial direct current stimulation, transcranial random noise stimulation. In this lecture, I will be paying more attention to TDCS which we talk about as transcranial direct current stimulation procedure system. So brain stimulation procedure in recent past seem to be a therapeutic tool for treating brain diseases. Now understand neuro stimulation is not a noble method. In the period of 42 AD Roman Empire period that time the electric eel were being used to treat the chronic pain.

So the electric eel is you know the fish, which generates an electrical current. If you touch it with your bare hand, you will get a high amplitude electrical shock. So this electric eel is being placed in the clay pot and then the Egyptian doctors or Roman doctors were asking the person, patient suffering from chronic pain to insert their hand or body part which is having severe pain into that clay pot. Once the electric eel is generating high amplitude of current, it is passing and stimulating those body parts.

Those stimulation actually were providing a cure or a therapeutic procedure. This was extensively used in the ancient time, well documented in the literature of Roman archives. Moving forward, in the modern era, around early 19th century, when electricity was being at boom and Tesla brought the electricity, people got very excited and then they started to use electricity to treat the patients. Now, ECT, electroconvulsive shock therapy, very well-known method, very established method till date. So, somebody suffering from seizures, somebody suffering from blackouts, somebody having radical mental problems, then ECT seems to be a very effective tool where high amplitude of current is given. The only challenge with these high amplitude of current is the loss of

memory information which leads towards the amnesia. As a result, individual seems to have a problem and they start facing memory loss on the long usage of ECT. The another method which came that very period was the transcranial direct current stimulation, where a low amplitude of current was being given to them. A Russian psychiatrist started



to use this procedure.

Source: [Holvoet \(2015\)](#)

However, over usage of electricity towards the mental health and the high adverse advertisement of the electricity resulted into the failure of the electrical brain stimulation procedure and when the transcranial magnetic stimulation came it gained lot of popularity till 2000 or 1990s when again the direct current stimulation, a weak amplitude of current started to gain attention that it can mimic the neuronal processes of the brain. Of course, TDCS can target the cortical excitability but TMS can target the cortical plasticity. Because the plasticity can be directly affected using the magnetic stimulation, so TMS gained a lot of attention and relevance and importance in the memory literature.

However, TDCS, because it can only target the excitability of the neuron, it gained less popularity. One should note here that in long usage of cortical manipulation of cortical excitability one can manipulate the cortical plasticity. So, it involves passing of electrical current to the cortical and subcortical brain areas use of non-invasive as well as invasive method. One important point here is that TMS focality is very high than TDCS. TDCS electrodes are little bigger and when the electrical current is being passed, then it gets diffused in the entire brain.

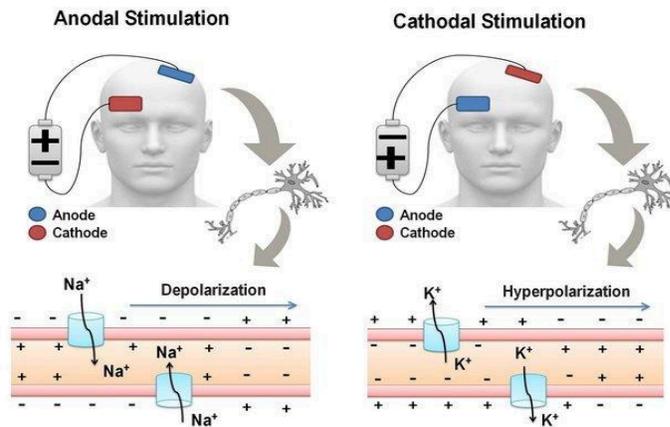
So, focality is a big challenge here. And due to the limitation of the electrical current and human brain, you cannot pass electrical current for too long because it may result into other neurological problem. Okay. So, working on the magnetic principal transcranial magnetic stimulation, TMS uses large transient magnetic field to induce focal electrical current. So, when you bring the magnetic coil near the brain, it generates the magnetic field.

As a result, the electrical current just get generated. This electrical current is generated because the ions present in the blood stream or the ions present in the brain starts to align themselves. When they align themselves, then the movement of these ions generate an electrical current inside the brain. It can produce changes in the excitability of the cerebral cortex as mentioned earlier, locally as well as the neurons at areas far from the stimulation side, also sometimes not only at the site of the stimulation but also far from the site depends on the flow of the electrical current and intensity of the magnetic coil so the magnetic coil could be of different types c shape eight shape cone shape different types of magnetic coils are present in the market

and based on the literature choice, based on the researcher's choice, the coil also varies. And also based on the task effect, the size of the coil also varies. Another important, as I said, it can induce the synaptic plasticity which directly affects your learning and memory processes rather than cortical excitability which takes little longer than usual to alter the processes. TMS may inhibit or enhance the task performance. Always remember one thing, whenever memory task we are talking about and any sort of intervention is being provided at this time point, so memory can either increase or it can decrease or it remains as it is.

Only three procedures are there. So when you treat the memory, when you treat the learning, when you treat the cognitive task, there is a possibility that the cognition can get better, cognitive processing can get better, memory can get better or it can get poor or it remain as it is. Only three possibilities are there with these interventions. So, as we were discussing about the another non-invasive procedure that is the transcranial direct current stimulation procedure, based on the polarity of the current, transcranial direct current stimulation are of two types.

Transcranial direct current stimulation, here the direct current is being passed to the scalp using a 9 volt battery. As you can see here, it can be done with using a 9 volt battery. Based on the polarity of the current, the stimulation TDCs are of two different types. One stimulation is the anodal stimulation which has the hyperpolarizing effect as we discussed yesterday or in the previous lecture about the action potential, the hyperpolarization, repolarization and then the depolarization effect and then the cathodal stimulation effect is there based on the cathodal. So when the active site or the target site is having a negative electrode so the it will negative electrode and the positive electrode is the frontal side so the current will move from here to the negative side inside inside the scalp the current is flowing from anode to cathode but outside the scalp current is flowing from cathode to anode and cathodal stimulation, which we are calling it as depolarizing effect, it seems to dampen the cortical excitability, attenuates the cortical excitability. It douses off, it reduces. So if too much electron excitability is there, lot of cortical excitability is there, you do the cathodal stimulation, it will lower the cortical excitability. Okay, so this is, sorry, so this is we are calling it as hyperpolarization. Please make a correction, this is



not depolarization.

Source: [Ripoll Rozisky et al. \(2016\)](#)

And when we talk about the anode stimulation, this is the depolarization effect. So what we are doing basically here, inside the electrode, the current is flowing from, again, from the anode to cathode and outside cathode to anode. This is how the current is flowing. So

inside flow is reverse than the outside flow. So here anodal stimulation seems to have augment the effect or enhance the learning effect.

Cathodal on in contrary is reducing the learning effect. So, when you want to learn more, then you have to do anodal stimulation. When you have to reduce the learning, interfere the learning process, then you do the cathodal stimulation. Now, based on the design of the experiment, based on the researcher's hypothesis, both types of stimulation researchers use differently in their design. One has to also ensure that the TDCS is task dependent, which means when an individual is doing the task, then you do the stimulation to see the robustness in the effect.

If you are doing the stimulation pre or post the task, then the results may vary and results may be inconclusive also. So, in order to ensure that neurostimulation engages themselves with the task, then it has to be done during the task. Transconductor current dissimulation low amplitude of current 1 to 2 milliampere. In some studies you may also see the value may go from 0.5 milliampere also. The size of the electrode varies and decides the current density also.

So the current density has to be decided. So the current passes through the two surface electrodes. In this electrode stimulation, we have to also talk about the ipsilateral and contralateral side. So contralateral side and the ipsilateral side. So when we are talking about the ipsilateral, contralateral side, so contralateral side means one electrode you have placed it on your right hemisphere, another electrode you have placed it on your left hemisphere or vice versa.

This is a contralateral side. If the electrodes are on the same side, like one electrode you have placed, Here on the left frontal side and the reference electrode or the second electrode we have placed it on the occipital cortex. So it is the ipsilateral side. Now being a memory researcher doing a neuro simulation one has to ensure the space between these two electrode should be minimal 5 centimeter.

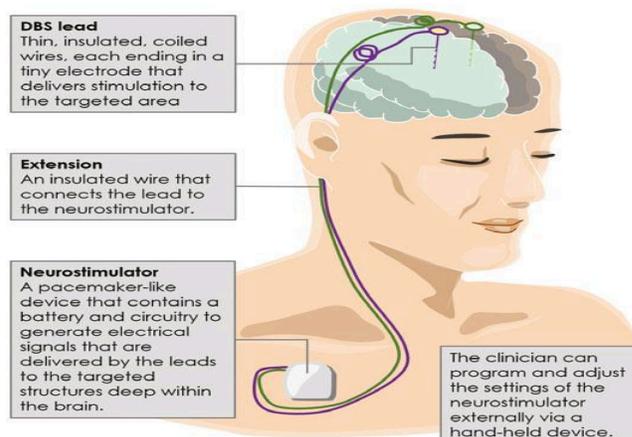
5 centimeter distance should be there. If they are too close the focal or the current density you may increase. As a result what may happen is that the chances of cortical seizure increases. Also, the time is an important parameter. 10 minutes to 20 minutes is enough.

10 minutes minimum time because literature has talked about as I was telling you earlier, memory processes depends upon the protein synthesis or time dependent protein synthesis to occur. 10 minutes is sufficient for the process to start with. So, you can do the stimulation from 10 minutes minimum. 20 minutes is okay. 30 minutes can also be reached.

This 30 minutes 10 minutes, 20 minutes depend upon the current density. Current density depend upon the amount of current and the size of the electrode. So anodal increases the cortical excitability. When the cortical excitability is increased, which means more firing of neurons are there, more firing of neurons are there, more depolarization is there, which means learning is going to be enhanced.

Decrease in excitability means that lowering of neural excitability is there. Neurons are being suppressed, doused, attenuated. As a result, hyperpolarization is happening and neurons are reaching at the resting state. So, they are more relaxed. So, cathodal stimulation sometimes gives a relaxation feeling.

So, if you are coming from your office, very tired, stressed, you do the cathodal stimulation, you feel relaxed and relieved. Now, deep brain stimulation procedure is deep brain stimulation procedure is an invasive method and what researchers have noticed person suffering from depression they there where the neurons are so lethargic where the neurons are not integrating where neurons are not coordinating in that case such system is seems to be helpful or in the case where hyper excitability is there where the neurons are keep on firing the electron electrical current. So we reduce this thing.



Source:<https://www.ndcs.com.sg/news/medical-news-singhealth/parkinson-disease-deep-brain-stimulation>

So in deep brain stimulation, a device is implanted directly into the brain. It sends electrical impulses to the brain specific regions of the brain. DBS is exclusively implanted for medical reasons. Okay, now very simple DBS leads, so it is implanted which means you have to do the surgery and this is there. From time to time defibrillator or the neurostimulator pacemaker which is there, the price could vary.

So, you know these implantations when it is being done. It is very important to ensure where it is being planted and what type of you know cognitive processes is being targeted. In many cases what people have realized is that it influences the cortical processes at much higher level sometimes and affects the cognitive processes in many cases. Let us summarize here of this talk. So several neuroimaging techniques which we discussed today is the electroencephalograph, magnetic encephalograph, positron emission tomography, magnetic resonance imaging, functional magnetic resonance imaging, functional near infrared spectroscopy.

All these methodologies which we discussed today, they have been classified or distributed based on two crucial parameters, spatial resolution and temporal resolution. Some tools are good in temporal resolution, some tools are good with spatial resolution. Till date, only few tools are very good with spatial and temporal resolution. Why spatial and temporal resolution is important for us?

To know at what time point precisely the cognitive process has started and precisely which part of the brain region is responsible for such processes. We also discussed about the neuroimaging modalities, different tools, techniques which people have used in recent past and we are progressing in this direction. So new and novel techniques are coming. Along with that we have also understood that the neural stimulation technique can be used to impair certain part of the brain region to understand the functioning of the other

brain region. So, in this case the tool which people have been using is the non-invasive neural stimulation or invasive neural stimulation. Invasive neural stimulation tool we talked about the deep brain stimulation technique. And in the non-invasive brain stimulation technique, we talked about the transcranial magnetic stimulation and transcranial direct current stimulation.

I will stop here. And in the next lecture, we are going to talk about the neuromodulation of memory processes or modulation of memory processes. Thank you all. Have a good day.