Advanced Neural Science for Engineers

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Lecture - 42
Applications of EEG/ERP Experiment Design

Hello everyone. Welcome to the another TA class on the course Advanced Neural Science for Engineer. In today's TA class, we will see the experimental protocol for ERP based experiment, which we have already discussed. Also, I will quickly discuss some of the recent trends or application which you can use to assess a several thing. Let us say if you have epileptic history, then, how you identify that which kind of epilepsy you have?

Why it is important, because your medication depends on the type of epilepsy, of course, you need to club it with syndrome. So, based on seizure and syndrome information, you will get an idea that how you should be treated. Same way if you want, are not with the passage of time or as you grow old, your ability to hearing is getting deteriorated. So, how to identify whether you can hear it properly or not.

Let us say, how fast your reflexes, visual reflexes are. It has application in sports, in healthcare, and et cetera. So, all this thing can be identified, assessed, or quantified using ERP based experiments. So, let us quickly see that. Prior to that I will touch upon some of the basic experimental protocol aspect of that. So that an all, I will try to show you in this quick TA module. So, if you can see the screen, we are going to see Application of EEG/ERP Experimental Design.

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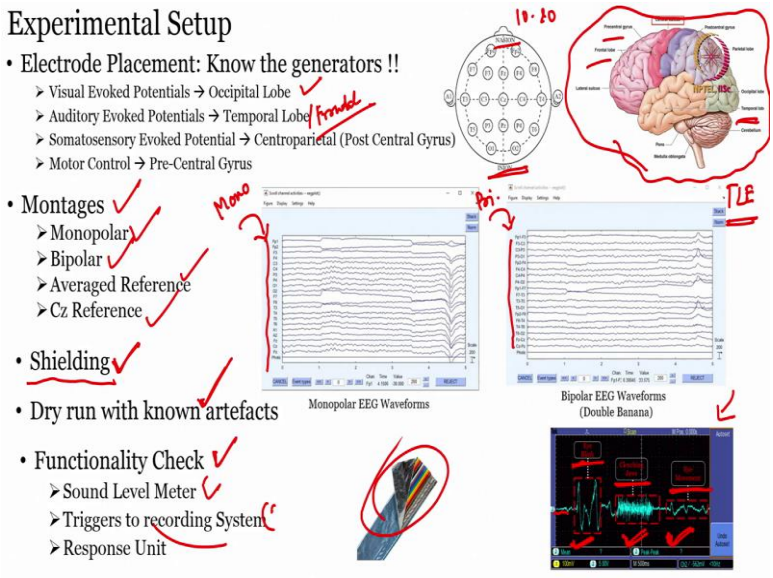

We are talking about three applications. This is already we have discussed in the signal acquisition model of the previous class. That where you are going to put your electrode. If you are working, I mentioned at that time, if you are working on visual evoked potential go for occipital lobe. For auditory it can be temporal, it can be frontal as well. So again, auditory experiment can be cortical, auditory evoked potential.

It can be brainstem evoked potential. So, depends which paradigm you are using, where what you want to measure, accordingly, you can select that what exactly you are going to acquire. So, that is why it is very important to know the generators or sources. Again, you can check for somatosensory is a motor whether you want to go on which side of central gyrus. This is I think already covered in the course. The 10-20 system very important.

All of you should know why it is 10-20, how it is 10-20, what is nasion, what is inion. You should also know in real practice where your inion is. Read about that slightly on anatomical side, but important. Which lobe you are using. For your, which lobe you are focusing upon, whether you are focusing your entire brain or whether it is only frontal lobe, parietal lobe, whether it is only temporal lobe.

There is a specific set of epilepsy called TLE, Temporal Lobe Epilepsy, which is more prominent in west side US and all. So how it is affecting a body, how it can be treated, all this thing. So, the spatial nomenclature is very important. What is 10-20? What is lobe? And all this thing. You should have a clear-cut idea about that.

And then montages, it can be monopolar, it can be bipolar, it can be averaged response, it can be Cz response. Now, this, if you see here, this is taken from one data set. So, here you can see a person's EEG and only channels monopolar channels are shown. Whereas here, if you see it is a difference between two channels. One channel access, a reference, other channel you are taking. So, that is why this is called monopolar, and this is called bipolar. Very important.

So, you should know that which kind of montages you are going to use before planning any experiment and where exactly you are going to put your reference and ground, your reference and ground should be slightly far enough from your recording or active site. So, this and all are important factors before going or diving to any of the experiment.

Also, this is like known thing, you should dry run with artifacts. Known artifacts. So, this I am talking about human experiments. And non-invasive human experiment, if you are performing, this is a snapshot from one of the CRO when we were considering this kind of application, when we were considering this kind of experiment. So, this is generally the baseline, what you can see here.

Then when person is subject is asked to blink, you see this kind of pattern. Very important. Further, when somebody clenches the jaw, we were getting this kind of pattern. And this is known pattern by the way. So, when you perform certain experiment, this kind of known artifact, you should check, this gives an assurance that your acquisition of bio potential is happening.

Of course, this is due to some movement of your eyes. Eyes muscle movement or jaw is some other muscle movement. It is not due to your brain, but after all, it is bio potential. So, you should have an identification that whenever you are performing one particular experiment, your acquisition works fine.

Also, shielding very important to all the beginners who are trying to enter into BCI. This is very important point that your wire should be properly shielded. Otherwise, there can be you are inviting a lot of power line interference and other things. Nearby devices and all should be minimally on. Those which is required to be on of course, you can turn it on. But the remaining things, unwanted things should be shut off and shielding is very important.

And there are several ways and approaches for shielding. Very small known classical point, but it is still exists and it is still one of the biggest bottleneck when you are entering into the field of

neural signal acquisition. Once it is identified, that is completely fine, but you should always take care of our shielding by trying to minimize your all the artifacts, mostly power line artifacts.

And then you should check the functionalities also, whether you are able to record your triggers or stimuli or not using your acquisition system, your response unit works fine. I mentioned some of the experiment you should click when particular thing happens. You should either remember the occurrence count or count the occurrences, this kind of thing. You should check it first that your clicks and all are working fine or not. And if you are going for auditory experiment, there are guidelines to give or present a certain amount of sound.

Especially if you are working with neonates or new-borns. You cannot simply randomly give any form of intensity or any kind of sound and present it. There should be a limit considering the anatomical picture or diaphragm of that particular new-born baby. Same goes for elderly subjects as well.

So, you should identify that, okay, I am presenting this sound, whether this is in the limit of the sound level, this is in the limit of the ethical approved version of each, and every experiment should have an ethical clearance. That is, again, a very important point. Before starting any experiment, you should get an ethical clearance from a particular institute. If you are working or collaborating with some hospitals and something, it should be on both sides, then and only then you should perform any experiment.

So, and those, here I have given an example of sound level meter. It is true for visual stimuli as well. Even there are ethical clearance or ethical experimental protocols, which has been designed for brain stimulation related projects. So, how much current is allowable? All this thing you can identify, you can explore before starting any experiment. Very important to know that how many number of electrodes you are going to use? Where you are going to put the electrodes? Where your reference and ground?

How you are going to, if you are going to present a stimuli what is your stimuli? What is the number of iterations you are going to give? What is the expected response? All this thing are really, really important. Whether you are giving the sound or any kind of image or any somatosensory, for any somatosensory evoked potential, any kind of a touch or some 4-PAR stimulation, whether it is like parameters are known or not. All this thing are very essential before starting any experiment.

So, this is like our last class I have explained about the basic fundamental building blocks of ventilated potential extraction system. This class, I would like to start with the list of pre-checks you should do before diving into any of the experiment. Now, we will see some of the applications. So, let us see. I am considering that now all of us are well aware about the basics of any experimental setup. We are ready with all the weapons, and now we should go for the application or to implement the application.

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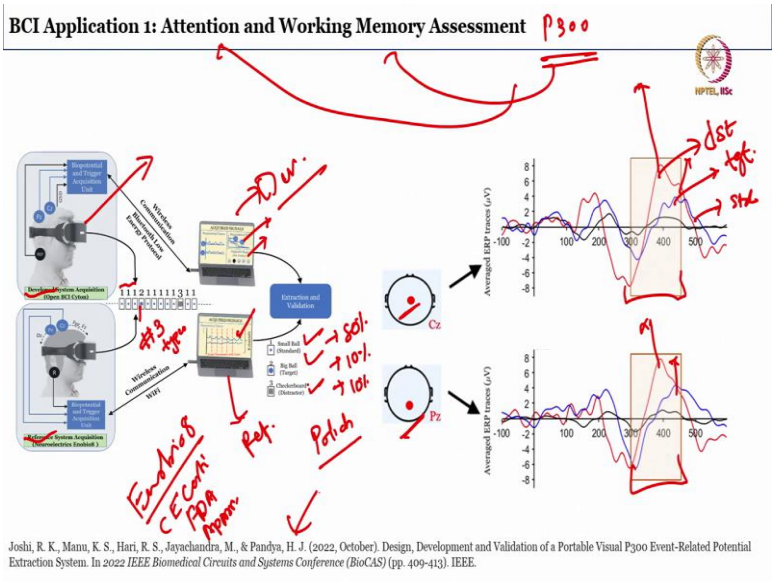

So, I will take a couple of applications for that to have a simpler ideas how to implement and all this thing. Let us quickly see one of them that is on attention and working memory assessment. So, you can see here a subject is shown with some head mount display or VR. It is just a way to present image stream. So, these are three types of image stream. Three types. If you cannot see here. One is a small ball. Two is a big ball. You can see in the image stream here. One is a small ball here.

Here when it comes to two, it is a big ball, and third one is checkerboard. Yeah, you can see it here. It is already there. So, that is okay. But the important point to notice it here is small ball is the standard. Big ball is target, and checkerboard is the distractor. It is presented with 80 percent, 10 percent, and 10 percent of probability. Now, why this 80 percent, 10 percent, and 10 percent? This is known paradigm by Polich to generate P300. P300 is a signature to assess working memory and attention.

Here you can see that this blue one corresponds to standard. It is not mentioned here. This red corresponds to checkerboard. So, I will write distractor. Blue corresponds to target. So, I will write, TGT. So, you can see that this thing peaks during the expected interval between let us, here I have kept 300 to 450. You can see that this is peaking here. This is peaking here, this is peaking here, and this peaks here. This is from the same subject taken from two different location. One is on Cz, one is on Pz. All of you know what is 10-20 system. You should know where it comes. You should also be able to map in your head where is Cz, where is Pz?

Now what else thing we have, other thing we have done is here is this is developed. You see this word developed system. This is reference system. So, this are like from two different systems, we have recorded for the same stimuli and acquire the signal. Here it shows the different GUI approaches when you acquire the signal.

This one of the reference system, what we have used that was Enobio. Enobio 8, it is CE certified, FDA approved system. To record neuro potential obviously. So, there you can see this kind of event. This are the EEGs being recorded from eight channels and this dashed line is nothing but your events. Whenever that particular image or sound came in this particular application, a visual image came, you can see it here. So, this is Reference System GUI. This is Developed Systems GUI, right? DEV. See it as EEG and the digital triggers separately.

So, whenever one particular image comes, that particular thing will be 1 or 0. Again, this is FFT also. Here, it is from two generates recorded, two channels FFT. FFT is used to monitor, that one is a spectrum for that particular period of time to identify. And further you can check that whether it is neural or not. For more details you can read this particular paper or recent presented that in BioCAS, Taiwan, Taipei. You can go through this. If you have more questions, feel free to ask us in forum also.

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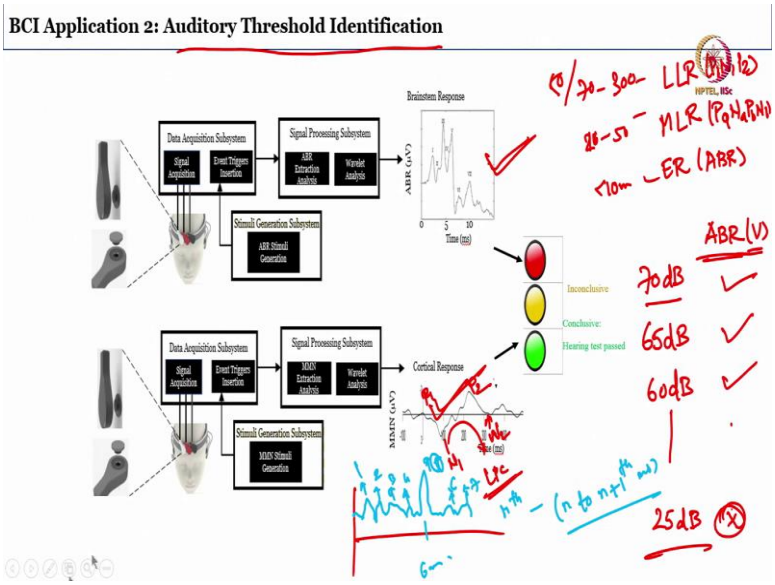

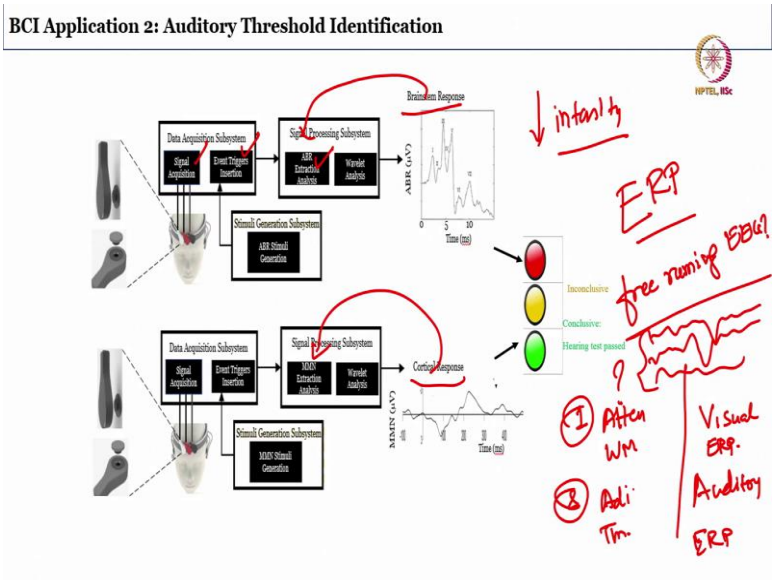

This is the second application. This is on Auditory Threshold Identification. Now, when I say auditory threshold identification, there are two sets of auditory potentials. There can be even more. One is called LLR, Low Literacy Response, middle latency response and one more is there early response or early return response you can say that, or this is nothing but your ABR auditory brainstem response. This is something called P0, Pa Na Pb Nb. This is P1 N1 P2. This comes within 10 millisecond. This comes after 10… let us say 20 to 50 millisecond or something. Beyond that 70 or 50, even 50 to 300 millisecond or 350 millisecond is your LLR.

So, based on your response, you will get a different auditory response and using which you can identify threshold. How to identify threshold when you are giving 70 db. You check ABR. ABR means the corresponding peaks, let us say 5 ABR. If I just draw the replica of ABR not the exact replica of ABR I will draw it in blue ink. So, it is generally like this. So, we will get peaks at regular interval. This is first peak. This is second peak. This is third peak. This is fourth peak. This is fifth one. This is sixth. This is seven. Generally, n th pick comes in between n to n plus 1 th millisecond.

So, let us say this fifth peak should come somewhere around 6 millisecond. But it has been observed that peak number 6, peak number 5 is the most prominent, and that is why it is used for all this auditory assessment and threshold identification. So, I was explaining this thing, 70 db, let us say you will get this wave 5, then you further reduce it down 60 db, you are able to see 65 db, it is there, so on and so forth. You go till 25 db. You are not able to hear this particular thing.

This can be your one of the threshold value of your sound. So, same thing, what you are doing, you are measuring ABR and try to address whether a person can hear it or not. Same thing, you can go for this also, this is nothing what your N1 negative one comes under 100 millisecond. This is P2. Prior to that P1 might be there might not be there, and this is nothing but your N2. N1, P2, N2 is known as late potential complex of your auditory evoked potential or cortical auditory evoked potential. So, you can record this kind of things.

This is block diagram. I already explained that you are taking signals. You are taking triggers. Then you will process it and try to extract the results. If I talk about brainstem, I am taking ABR. If I talk about cortical response, I am taking MMN or some other response. Further, you reduce it down, drop down the intensity and keep measuring this thing, you will get your auditory threshold. So, one more application to, first one, what we have seen? That is attention and working memory.

I will just write attention and working memory. Second one is auditory threshold. This was for the visual ERPs. This is for auditory ERPs. So, these are like two different set of application. So, to idea is to show some of the block diagrams to give you an idea that how you can use it, where you can use it, and just a glimpse of that.

So far, whatever we have seen that is application of ERP, is free running EEG, important. Now, what is free running EEG? Without any kind of stimuli or event you are just recording EEG from multiple channels. Does this thing convey any information? For that let us see the next example, next application.

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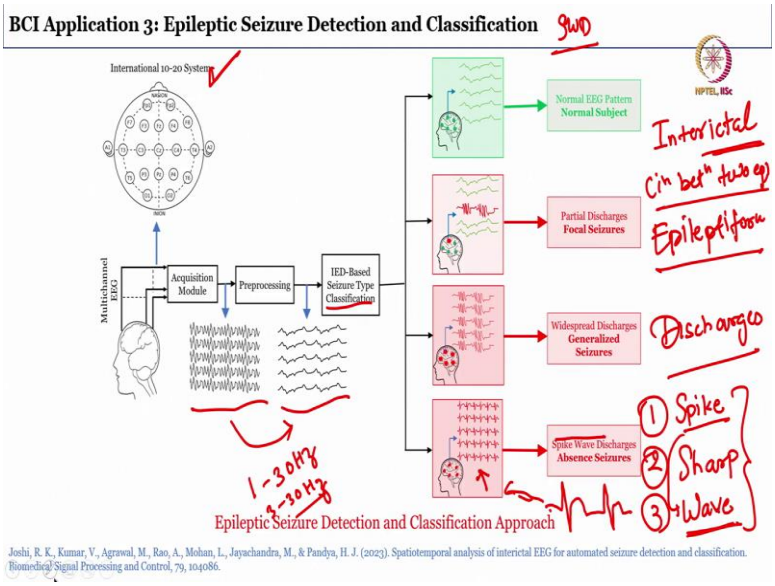

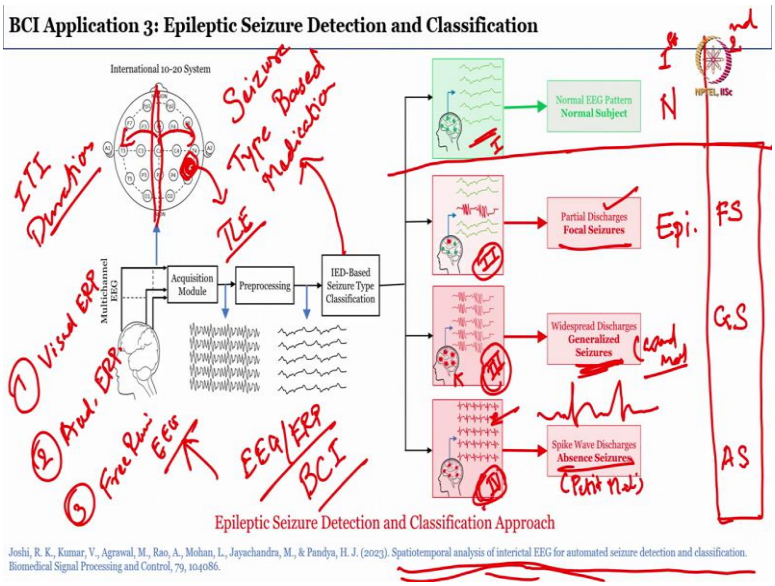

So, you see that, again, it is a very big figure, but very easy to understand. Let me help you. EEG is acquired from brain, from the of the scalp, from brain means of the scalp, not invasively a non-invasive way. You all know what is this? 10-20 system is used to take this different number of electrodes. Then this is like an illustration. How it will help you how you can have an idea, but if you observe it properly, it conveys a lot of information.

So, the thing is, you are acquiring the value, which has this kind of transient. Then you pre-process it, it will become like this. So, from this to this transition, it has removed some of the high frequency noises and pertain the amount of frequency what we want. Generally, for epilepsy we keep it 1 to 30 hertz. Or 3 to 30 hertz. So, this is to just have an overall idea that

pre-process will remove some of the non-neural part and pertain to the neural part. Then we are recording, or you are trying to classify your epileptic seizure based on IED. Very important.

So, IED is nothing but Interictal Epileptiform Discharges. Very important. Ictal something related to seizure or epilepsy. Interictal means in between two episode. Now, for epileptic person, seizure is something where you have uncontrolled neural discharges, or some excessive amount of electrical storm generated due to electrical activities inside your brain.

Ultimately results in some form of involuntary moment and you might lost control of yourself or end up in some of the unwanted repercussion and you might be currently I am talking with you suddenly for 10-15 second, I do not know what is happening around me. So, this is something called absence seizure very, very fatal when it comes to driving or for pilots, et cetera. So, this is in between two episodes.

Whenever this kind of excessive storm happens inside your brain, in between two episodes, we are trying to fetch information or trying to identify what else changed inside your brain, how EEG is changed, how EEG is changing before the next episode. So, that is why Interictal Epileptiform is related to epilepsy. Discharges is your potential, which we are recording.

So, this, again, the entire classification is based on IEDs. So, what is this IEDs and how many? So, there are some of the known patterns. Again, it is discharges mixed. It is like it is some form of neuro potential. Neuro potential is recorded by and monitored so that has some form of characteristic. So, what are this IEDs known as and what are the characteristic? So, one thing is called spike. Second thing is called sharp. Third thing is called waves.

Now, you might say all brain waves are waves, but yeah, there are known frequency ranges for this wave and also the combination of them. Now, what is a combination? Let us say spike followed by, wave followed by spike or spike followed by wave. That is something called SWD, Spike Wave Discharge.

This is a known signature for one particular type of epilepsy. You can see here which type of epilepsy? Absence seizure, and you can also confirm it from this particular figure. You are having this kind of spike followed by a wave. Again, spike, followed by a wave. So, this kind of thing is being repeated here. So, this is a classic case of SWD Spike Wave Discharge. Again, it is not actually EEG, its illustration, but just to give you a people an idea that how, what is the combination of IEDs and all.

Again, we were talking about IEDs. I told you all its discharges, like all these are neuro potentials. What are these IEDs? Spike, sharp, wave, et cetera and combinations of that in order to identify what kind of combination I am talking about, to exemplify that thing I mentioned SWD, that is your Spike Wave Discharge.

So, I believe now it is easy to interpret what is IED based seizure type classification. Also, what this particular application or this study does is we are not only identifying the seizure type, but we are also screening the patient based on this developed algorithm. You can have a look at this paper for detailed insight. It is a good read. Try and explain it. If you have any difficulty, feel free to ask the doubts. So, what we are ultimately done in the paper, or the application is based on your IED count we will identifying first thing, first check, there are two checks. So, this is first check, this is second check.

So, first check, what we are doing is whether the person is normal or not. So, this is normal. This is epileptic. Only these two things. There is a broad category. Second check. This is first check. This is second check what we are doing, specifically only for these epileptic patients, not for all. Epileptic, which type of epilepsy? So, is it a focal seizure? Is it a generalized seizure? Is it an absence seizure? So, two questions we have been trying to address in this particular study.

It is taken from cohort of 88, human subject performed in collaboration with AIIMS, Rishikesh. All those neuro, computational neuro enthusiast people, I would advise you to just have a look and try to understand and ask as much doubt as possible. So, this is normal, and epileptic is the first question. Second, in terms of epilepsy, which type of epilepsy?

Now, why which type of epilepsy is required? Because this entire exercise is because of Type Based Medication. And when I say type, whose type? Seizure type. You can see here in the second figure, this is a normal person. So, you can see spatially also I have shown five traces and five locations where all the thing are seems like baseline EEG within the range. This, I am talking about this thing.

Now, let us talk about this case here. You see most of the, 4 out 5 looks almost like a normal EEG signal, what you have seen above, but one has some issues. Same thing spatial has been mapped that the person has some issue with this red colour line here. So, the same it shows that it has a partially affected by seizure. So, that is why it is called partial discharge or focal seizure, where you have identified a focus.

It is slightly difficult to identify the focus when you are using EEG. If you cannot identify using EEG, you have to perform a neurosurgery and identify the focus or MRI or something. Whereas in third case, what you can see is, you can see this kind of spiky behaviour or epileptic behaviour in all the channels, same is being mapped spatially also it is called generalized seizure. Which is spread all over your head. And there are known patterns that generalized seizures are more dominant in this kind of midline. It starts with midline spreads bilaterally.

So, there are so much spatiotemporal pictures and topographic analysis you can do. You can find it here as well. I will not go into the, too much detail might be overwhelming. So, this is like widespread discharges, generalized status, as I mentioned. It starts from your midline spreads both the sides.

As you can see here, it is only one particular place. Let us say it can be only here more localized, this focal. If that is the case, it is again, as I mentioned, a case of TLE. So, that is about third thing. For four thing, it is slightly different. Again, it seems like a generalized seizure, but as I mentioned, pattern is the whole mark for absence seizure. Again, there are different names. These absence seizures can also be called as petit mal.

This can be also called as grand mal. You can check it in literature, what are the name they are using separate thing. But the thing is the spike wave discharge is only observed in this case, which is a known characteristic for absence seizure. So, again first two examples, what we have seen, first one was visual ERP. Second one was auditory ERP. Third one was free running EEG.

The main point is if you can record and interpret EEG and ERP. There can be many application you can do with the one system. That is why it is very important to record EEG/ERP. Understand EEG/ ERP. Design a very, very proper, and structured experimental protocol before moving for any experiment and identifying several aspects of ERP based or EEG based experimentation.

These are some of the basic applications which I thought you should know comes under a broader umbrella of BCI based on your application I believe you would be able to at least have a rough idea about how to approach one particular problem using BCI and move ahead. If you have any queries in any of the TA class, feel free to write us in the forum. This kind of things you should understand it properly.

You should also understand for ERP based experiment, what is ITI, what is duration, because those kind of things will be very helpful in designing experiment and your exam purpose as well. So, if you have any doubts, as I mentioned, write us into the forum, mail us, we would be very happy to address. Till then, try to understand this EEG ERP set up and all of you, I will meet you in some other TA class or lab class, till then, all of you please take care. Bye.