Lec 10 - Neural Signal Processing: Demonstrations

Hello everyone, welcome to this continuation module on Neural Signal Processing of the course Microsensor Implantable Devices Rodent Surgery for Biomedical Applications. I am Ratheen and this lecture we will see some of the demos in continuation with the previous lecture. So, just to give a quick recap what we have seen last time, different anatomical levels and what are the techniques, how much temporal resolution, spatial resolution and invasiveness of the different techniques, modalities and all which is useful where it should be used and all we have covered. Also we have seen why there is a you know rodent experiments are conducted, what is the flow especially when it comes to neural engineering or neural research. So, from rats, cats, primates, non-human primates and human. Further, I have briefly discussed about some of the applications, if you know how to read an interferon neural signal, what are the additional things you can check or you know make the system of.

So, this we I have discussed each of them in detail. So, just a quick recap further I have explained about how applications, modalities, different approaches and methods are correlating with each other in order to solve the purpose for any neural system. So, and I also mentioned that there are some of the applications or demonstrations, few of them shown you the list of tentative things briefly explained about the hearing screening and epileptic seizure detection. So, we will see some of them in today's lecture.

As I already explained that each application can be achieved by several different bio-potentials or neuro-potentials using this all signal processing approaches and these methods. So, now we will see some of the demos very quickly from the list I have shown. So, this is basically and list of demo, you can see that there is first thing is MMN, where you can see there are 4 same kind of sound shown in red color and one deviant occurs. In response to that that blue color trace shows little negativity compared to the red color which shows the negativity and that is called mismatch negativity. Now we are going to show that how we can read the data and get this kind of response which is known as event-related potentials.

So, before moving to signal processing aspects I will quickly show you how the experiment is being performed. So, this is just a quick demonstration of the first of the 3 demos what we are going to see today. So, for your sake of simplicity and understanding for this MMN and ABR both the similar form of acquisition or you know experimental setup is required. However, acquisition system is different which professor Hardik Pandya would have talked in detail. So, I will just play the video so you will get an idea about the how experiment being performed.

You can see a subject wearing a headband with electrodes and there is one electrode here on the ear lobe and further the data channels is connected to the acquisition system which is wirelessly connected with the computation using this BLE dongle blue to low-energy module. This is open BCI open source GUI which we have used for 3 channels and this blinking of this digital I O shows that at what period or what time which kind of sound was presented. So, this is just a brief overview of demonstration because I strongly believe last time also I mentioned that without doing any of without knowing any of the experimental protocol or experimental design it is of no use if you directly start doing signal processing or something. So, give you people an idea that how many channels were there, what are the different kind of sound is being presented and how the final result should look like. Now we will see our first aspect of performing MMN extraction and how it is being performed.

So while going through the extraction signal processing steps in MATLAB I will be keep on discussing about the experimental protocol as well but in a nutshell this 4 standard and 1 deviant the same format or same pattern is repeated 100 times to get to get read of neural variations. Our brain reacts to sounds, images, touches in a different way so to and with like you know variable responses. So, to avoid the variable response and extract only the neural sense out of it, averaging is being performed. However, research is going on to minimize the number of iteration for in terms of ERP research or event-related potential research it is called number of epochs. So, that research is going on so I will come to that.

Basically very briefly in a simplistic term 2 different kind of sound is being presented to a subject and EEG is recorded in response to that sound and what we are going to see in this demo is how to read that EEG and how to identify that when the sound was presented how the brain reacted. So now we are ready for the first demonstration so I will just switch it to MATLAB and here we will see the first demonstration. Here you can see that one particular subjects data is already been acquired so and also there is a software called EEG lab which is specifically used to analyze EEG and you have to download that and add it into path. Now where to download, how to add it into path I have already covered in one of the video so that link I will put it in the description you can go ahead for those who are beginners for those who are following my YouTube lectures and all it would be easy for you to understand this thing. So, you can go through that quickly that link and identify how to download EEG lab.

Once you download EEG lab it should be added into path like I have done with folder and subfolder. Once that thing is done you can quickly verify by just typing EEG lab in your command window that will give you an idea that whether the EEG lab is installed or not. Additionally one more important thing ERP lab also should be included or ERP lab

is one of the plug-in to EEG lab so I strongly encourage all of you to go through the plug-ins based on your application. EEG lab is a combined platform provided for any neural signal processing which relies on EEG or any bio potentials it can process ECG as well. Even if the name is EEG lab does not mean it cannot do operations for ECG.

We have performed eCOGs on that we have performed SCEG on like you know sigma processing steps of SCEG on that. So, it does not mean that it is only limited to EEG but once you have it installed properly and then it is added to the path you should be able to see a home screen. So, additionally I was saying ERP lab is very important because whenever you are doing any evoke potential or event related potentials it is very important to have a plug-in ERP lab. So, once you properly install your ERP lab it will be here in a menu bar. One additional menu icon will come as a ERP lab.

So, meanwhile that EEG lab is getting open I would just wanted to let you know that your EEG lab should be added into the path and this is where in my case it is added. So you can see that it has its own set of functions. There are different types of functions there are some of the GUI like graphical user interface functions, some admin functions, some statistical functions, sigma processing functions. All these things you can go through and change it accordingly. There is a repo in GitHub where you can update that.

Again plug-ins are there as I mentioned ERP lab should be added at this level and once it is done you can see this home screen. So now once you get your EEG lab working and fine you can see the same reflection in the command window as well. It shows that some of the extra updated version are available. If you find it stable and without any issue you can add that version or update that version as well and also newer version of EEG lab is also available now. So, you can check that as well.

For now I will be just showing you that how we can read or you know process this data. So, MMN data so I will go back to my directory when my MMN data is been stored. It is taking a bit of time for now. So, we will go there. So, here I have already recorded this file from this is the txt file which has the values from which I have already generated mat variable.

So, it is nothing but it will just take the 5 columns again it is there in one of my previous lecture and same lecture for which I am going to put the link in the description. You can feel free to see that. For now I will directly import the data for importing the data you have to go to file import data using EEG lab functions and plug in from MATLAB array because we already created a MATLAB array as a name of S1. Now wherever you know work with any kind of biomedical data I am next to that you do not put the same name either it will be the subject 1, subject 2, subject 3 just to keep the privacy and you know

it should be anonymized data. So, this is like a work ethics for processing any MATLAB-based data.

Just import this data S1 which is already been taken. Also the important thing what we need to add is sampling rate how many samples have been taken. Now when I have taken this data my acquisition system was having 250 hertz as a sampling rate. So, I have given the remaining inputs I will keep it as it is and I just hit ok. So, it will in the background the already existing function of EEG lab will process and they will ask you for the name.

So, we will just give the name S1. So, instead of no current data set now we have S1. Now S1 if you can see there are adequate amount of information here the total number of channels are 5, frames per epochs this much, sampling rate is 250 and that is how the total epoch or total number of sample is 78533 right. And if you put it here 78533 divided by 250 is your sampling rate. So, you will get an idea that 314 seconds data is there, 314 is nothing but around 5 minutes data ok.

And the same 314.13 you will get here as well 128 ok. So, add again the size of the data set. Now once you get the data it is very important to have an idea what is there in the data. So, when I have extracted the data it has I showed you that has 3 data channels and 2 event channels or 2 different kind of sound is being presented. So, quickly I will import the event information here.

Event information you can import it is in the form of data channel. So, you can import the event info from data channel. Now I know that fourth and fifth channel has my event information. So, I will just hit 5 here and I will also allow to delete old events if any. So, I will just place ok here what it will does this number of channel 5 has become 4.

Still there is one more channel also if you can observe the number of events have become 101 from earlier one 0. And I will add one more channel from here which is like this is 100. But I told you 100 time deviants and 400 times standard will be presented to a subject. So, I will just put again here from data channel 4 I will extract. This time I will not check the delete old events because old event whatever has been extracted now are the deviants which are important.

Deviant is nothing but I have shown you that 4 straight you know 4 same kind of sound and 1 different kind of sound. In response to that different kind of sound you will be getting negativity. So, that is like overall aim. So, now I am going to take event from channel number 4 and as I mentioned do not forget to uncheck this thing. Otherwise, your previously added deviant channels will be missed.

So, now I will extract in a channel from one more information and then you see this 100 has become 500 number of events. So, and that number of channels have become 3 from 5. So, that earlier the data what we imported that consist of 3 data channels and 2 event channels and we have successfully taken 2 event channels and generated the events. The next step is to check the data. Now mostly this data is taken in a constrained environment with minimal electrical interference.

However, there will be some line interference and also this EEG whatever has been recorded they are having a micro volt magnitude that is why likely to get influence or you know get deteriorated by the power line interference. So, we have to check first whether there is any power line interference or not. Using ERP lab you can plot an amplitude spectrum to get that idea that what now we have 3 data channels right. So, we can check in all 3 data channels and our sampling rate is around 120, 250.

So, we can put here as 120. What if I put 250 here? It will throw error. Let me just show you for the sake because it is a very important point. Sampling rate is 250. If I want to plot amplitude spectrum till 250 what happens we will quickly see. You can see that it is a wrong input error has come.

Why that F1 and F2 must be lower than the Nyquist frequency? Nyquist frequency is FS by 2. So, there is a Nyquist criteria which I hope all of you are aware that when the data is recorded at FS sampling rate in order to reproduce it can only reproduce still FS by 2. So, when you have a data which is recorded at 250 you cannot expect your amplitude spectrum till 250 you have to give a number 120 or 125. So, here we are giving it 120 just to have an idea why not 100, why not 50. So, 50 is my first power line interference.

This data was recorded in Indian region right. So, there power line frequency is 50 Hz. If the same data is recorded in western countries where power line frequency is 60 Hz then you have to take care of 60 Hz. Additionally apart from 50 Hz there are highly possible that you will get multiples of power line right. You have to check at 50 Hz, 100 Hz, 150 Hz, 200 Hz etc.

So, currently I will be checking for 3 channels from 0 to 120. So, I will quickly plot that yeah. So, yeah that is what I wanted you people to show. You can see a peak here right. You can use a marker just to verify that it is a peak at 50.08. You can also see one more peak here which is around at 99.86 okay. So, this both the peaks are the multiples of power line. So, our first aim is to remove that right to make the data more clear because this is definitely not a neural signal.

50 Hz peak is not a neural signal. Generally for neural signal what we consider is 3 to

30 Hz. So, first job is to remove this. I will not close this. I will just minimize this just to give you a better idea how do we do that, how do we remove one particular frequency that is been done using filters right.

So, we will apply the filter. It has an inbuilt filters here. Now when you want to remove one particular frequency you have to use band reject or you have to use notch filter. So, I will just enable the notch filter from here and we have to give frequency. Let us say if you want to remove 50 Hz we will give cut off frequency 49 and 51. What it does? How would be the frequency response or phase response and all this thing.

So, that is why I enabled this thing to get an idea that what exactly it will give me amplitude spectrum and phase spectrum. Very important your phase should be linear in the range of operation. Wherever you are taking the frequencies your phase should be linear. So, I will just plot this thing.

We will see two things. First is data would be having this kind of notch filter. They will ask me the name. So, we are applying notch filter first time. So, I am just giving n1. I will say okay and we will see this again that amplitude spectrum here you see it will allow all frequency except this 50 Hz frequency and very important to see that phase is linear.

If phase is not linear at one particular frequency you will get some delay and your final waveform will be deteriorated. So, very important point is your phase should be linear. So, here you can see that this is band reject filter is used. Again I will minimize it and we will compare this.

Earlier this was my raw spectrum or initial spectrum. So, now we have applied one filter of 50 Hz. So, let us see whether that component has been gone or not. So, same command I am using it right now. So, you can see that 50 Hz here there was earlier a component I will just show it to you. It might be at a different scale, but you can see that this is before and this is after filtering.

So, here that value was around 50, 49.50 that is almost 50. Whereas here that almost that particular component has been gone. Same thing will apply for this 100 Hz filter as well. So, again I will minimize this just to illustrate the steps of filtering. Again we will do this filtering of 100 Hz like we did it for 49 to 51 we will do 99 to 101.

I will plot the filter and I will again apply a notch filter. Do not forget to apply the notch filter. Once it is done again you observe that amplitude spectrum and phase spectrum give the name and second time we are applying notch filter. So, I will just give a name N2 and

I will just say ok. Let us re-verify the amplitude spectrum drawn here. So, once you see that amplitude spectrum that part is almost gone right.

Further if you want to remove it you can do one more time filtering and again here there is a default filters are used. I am not going into detail considering the time constraint, but there are different form of filters Chebyshev filters and other filters you can use whichever filter you want to use. You can also give stiffness of your final amplitude spectrum. You saw this amplitude spectrum right. So, how much should be this distance stop band frequency or what is the distance between stop band age, what is the stiffness of that everything can be controlled in order to get a better filter if you want, but that is again a separate lecture can be taken by filters or which kind of filter should be used.

So, coming back to this thing neural range is from 3 to 30. So, we have put two bands of filter. Let us try for one more bandpass filter. So, again same filter we are applying. If you are interested check for this function pop eegfiltenew search it in Google you will get to the function and you can see on observe the changes. Again that we are applying 3 to 30 hertz filter and I want to see frequency here we will not check the notch filter.

This is third filter we are applying which is a band pass filter you can see it is a different response and stop band is around 100 minus 100 dB or something. So, difference between pass band and stop band is 100 dB make sure it is dB. So, when you talk in decimal it will be like 10 to the power 5, 10 to the power 10 like that and if you still want to go further behind and below you can change the filter settings and you can always go there. And also during the pass band you can see there is a linear phase which matters.

So, that is also verified and this again I have to give the name. So, this is the first time we are doing band pass filter same process check the amplitude spectrum quickly. So, you can see the very nice you know curve which is in the neural range. Also there are some papers and work done that how amplitude spectrum should get degraded over the you know neural frequencies and all. Kai J Miller and some other researchers have worked on it I would encourage you interested student can look at that paper.

So, now it is in neural range. Next step is to see how the data is looking like. So, plot channel data scroll once you do that you will get this kind of response you from here you will see you can change the timing length to 20. So, currently, it is 5 seconds it will make it to 20 seconds and this is a very important thing you can see that all events 4 4 4 5 4 4 4 5 it is being repeated which means 2 types of sound is being presented like this. So, when you are how your brain reacts to that change auditory change.

So, that is what is all MMN is all about. So, again this is your data. Due to scale you are

not able to see variabilities of EEG but if I put it 200 you can see this different kind of variabilities of EEG. These are nothing but blinks which is more prominent here because this electrode was near to your forehead. So, this and all you will get an idea once you see the data more neural data. So, like as I mentioned we can see that yeah okay this is not due to the neural response but this is due to eye blink.

So, we have to remove this right. So, there are several steps which we need to process and which we need to perform in order to remove the unwanted non neural things. One of them was filtering one of them is artifact rejection that I will see. Filtering is allowing selective frequencies whereas artifact rejection is allowing certain selected magnitude. Prior to that we need to create there is something called event list. So, you have to just go to EEG lab and create event list and here you have to go to advanced setting and you have to tell there are 2 kind of sounds.

Channel 4 had a sound which is called standard, channel 5 had a sound which is called deviant and then you have to apply this. Once you apply this E-list will be automatically added to the name and then you have to hit ok. You will get another data set and now you have created event list. Once event list is created you can again see the channel data from here you can give it to 20 and yeah you can see there are different similar thing.

We will create an next step is to create a bin-based epoch. Once events are created you need to tell that I want when sound was presented I want 50 or 100 millisecond pre stimulus and 400 millisecond post-stimulus. So, this is how you can select this epoch range or bin epoch and then you run it. Once you do that epochs will get created and this again the name will get changed automatically. Once this is done the next step is as I mentioned you have to remove that eye blinks and all. So, for that you have to change this duration change this time interval make it minus we have gone from minus 100 to let us say 396 and we do not want anything above or below 50 or minus 50 micro volt for all 3 channels ok except this.

So, you can see that again that same name will be like added and you can see here it will tell you out of 400 standard sounds 330 passed your artifact rejection criteria. Out of 100 81 passed your 100 deviant 81 passed your criteria overall from 500, 411 passed like 411 epochs are within the range or neural range or expected range right. So, I will close this unwanted channel unwanted images I will come back again and I will again plot this thing. So, now you see there will be a difference that initial unwanted thing has gone also this is coming like a highlighted why it is coming like a highlighted because it is rejected. Why it is rejected if you hover over here you will see somewhere the value which is not in the range let me just put it in a better resolution.

So, now you see here right the value is 60.94. So, it will not consider this particular epoch it will let it go same way or all epochs this process has been done. So, now whatever data is been recorded with respect to a particular sound we have an idea that which is a good data which is a bad data. So, now we have to do is final thing as I mentioned brain reacts to different sound images touches in a random manner. So, we need to perform averaging computing average ERPs.

So, once you compute the average ERP it will ask which data set. So, this is the latest data set what we have 7. So, you have to select that particular data sets as data set 7. You have to check mention that this thing is very important exclude epochs marked during artifact rejection which is highly recommended as I mentioned because that those are the epochs which is not within a neural range. So, then we will keep it as it is and remaining things are defaults you run this particular thing it will generate something called ERP I will name it S1 and I will also save it as the same name as ERP I will just say S1 MMN.

So, it will be saved. So it is saying the same name is already exist. So, I do not want to replace that I want to rename with another name. So, that is done once that is done we have to plot it to see how the final waveform looks like. So, this is some of the parameters which you can play with 2 bins are there standard and avian 3 channels are there as we have seen in the demo which kind of plot you want whether you want SEM or not SEM is very important something called it shows the variability I will tell you how in a coming this thing.

We want it in the 3 rows. So, we can correlate it temporally or time axis-wise. So, that 3 rows and 1 column I will directly plot it. So, now you can see this is like your final trace which is very important to analyze. So, thatMMN generally comes within 100 to 300 millisecond in terms of negativity. So, in all 3 channels, you can observe this negativit. Even your SEMs this red is the main trace and this shaded region shows the variability during 100 trials how much positive or negative it would have gone.

So, in all 3 channels which is plotted at the same scale we are able to see the negativity. So, this is first approach of how you can extract your ERP using your obtained data. There are much more to this, but due to time constraints I will not go into the detail, but this was first approach out of this thing what we have discussed. This thing what we have discussed yeah. So, this first MMN extraction using GUI that thing we have seen.

Now, I wanted you to understand one thing that this thing we have used GUI right. We have used GUI and how many clicks we have performed you have to remember all this thing and suppose you have 100 subjects data whether you will be able to do that or not or how much time it will take right. So, there is something called batch file processing

and all. So, when you have multiple data's you do not have to perform all this thing. Prior to moving that I want to show you one thing. Whatever thing we have performed using GUI, if you press eeg.history it will tell you all the things all the commands that I have performed in this session. See first we open eeglab we have imported the data then we have added event channel at 5 then we have added fourth column as event channel. Then what we did we plotted amplitude spectrum this 4eeg is amplitude spectrum function.

We realized that there is a line artifact. So, we have removed 49 to 51 with notch filter. Reverse filter is 1 with dotted the frequencies amplitude spectrum we have named it S1N1. Further we have done the same thing and again we have done the power line multiple of 100 hertz. To remove that we have performed a band-stop filter named it S1N1N2. Then we perform a band pass filter that is why this we have performed this thing and here you do not see reverse filter 1 because the default value is 0 and you have given it to 3 to 30 and you again named it. Furthermore you have edited the event list given the names, generated epochs, performed artifact rejection and then you have plotted the things.

So, whatever thing you do is been mapped in terms of one command line. So, whenever you want to perform more number of file or batch file processing or anything you can use this kind of commands to do the batch file. So, the second thing or second module of today's thing is using a script you can do ABR extraction. Now ABR extraction is slightly different than MMN it is only one sound and it is even more sensitive response which you can get. So, I will just show you that thing. Yeah, so this is basically ABR extraction you see it is getting generated within 10 milliseconds of 0.1 microvolt amplitude which Professor Hardik will anyways cover into his lectures. What I wanted to discuss is the signal processing aspect. Once you see the data it will be very noisy data and then you have to put band pass filter check for power line artifact. In the previous case it was good that sampling frequency was 250 hertz and response was coming within 300 400 millisecond. So, we just have to take two power line artifacts right. Whether in this case as I mentioned response gets generated within 10 millisecond which demands for a sampling rate of 10 kilohertz or more than that. So, when you are dealing with that kind of sampling rate there will be around 20, 30, 40 power line multiples.

So, you have to read the amplitude spectrum you have to check whether there is a neural peak or non-neural peak and accordingly you have to remove. So, there is something called adaptive filtering what we have tried to done. So, this is like first band pass filter when check the spectrum then there should not be any non-neural peak. Until and unless there is a neural non-neural peak you keep on rejecting the you know those peaks by band reject filters and then clean spectrum will go here and then the same thing what we

have performed. If you see from bottom like this ochre yellow color step is what we perform now. I showed you previously whereas this thing is what we are using script because this is very difficult as I mentioned to perform it using GUI.

There will be 40, 30, 40 peaks how will you go back to GUI remove all peaks one by one and come to a conclusion right. So, that is why it is advisable sometimes to use a script and more advisable when first of all then when is a complex processing second of this thing is that when you have more number of subjects. In India basically just to you know reduce their diagnosis time or you know for any neural examination reports takes some time. So, in order to remove that you should have overall you know kind of automation in biomedical signal processing on neural signal processing.

So, to serve that purpose this is another approach. So, this everything whatever I have written each and every block is being converted into code and that is being applied to get the final response and again it is the same thing. Sound will be presented to a subject your data will be recorded it will be extracted and interpreted. So, this is it will be looking like this as I mentioned it is of few tens of microvolt here it is like 0.04 micro volt peak is there and it is getting generated in 10 millisecond.

It is used as a gold standard for hearing screening it is used for newborns as well. So, we work on both the aspect. So, I will just show you how we can process the data of course it is very difficult to explain each and every line of code considering the time constraint, but I will show you what we have developed and we will switch to the next aspect. This you get an idea it is very important EEG dot history shows you whatever you have done and using this only you can develop a script. So, now we have a function ABR extraction demo and which uses ABR subroutine up which is like ABR subroutine updated.

So, I will just walk through the code. This is the my function it requires 4 inputs. First is where your data is input directory what is your sampling rate what is your event channel and data channel easy. So, there will be 2 columns and data channel and all this all is like to check where txt files are there in that it will check where the data is there and do some processing and all this is like a more or less lower cognitive task if you put this thing somewhere and known automated platforms like ChatGPT it will give you this kind of some of this how to get this txt file from one folder is a MATLAB and all I call it managerial coding or something just to check whether these things are there or not and get the file. Main problem or main processing starts from here you take the data we have performed several tasks it will do the same thing it will also generate event list, epoch bin, artifact rejection all this thing will be performed and in between this is a function ABR subroutine. So, ABR subroutine is nothing but it will read your amplitude it will see it will first generate your amplitude spectrum, it will read the data from that it will find

some peaks then perform some operation based on peak processing and all it is slightly you know complex for now to understand and then it will give you that okay this this is peaks are non-neural.

So, that is what the logic which has already been developed. So, I wanted to show you how we can perform this using batch file earlier you have seen one approach which is GUI now we will see one approach which directly uses the batch file processing. So, without further I will just give you the command of ABR before that I will just show it to you that our data lies here there are two data of infants of you know very like you know less than one month of age all these experiment have been performed with the ethical clearance from institutes. So, then this data was obtained by two infants as I mentioned. So, let us see what kind of data and how results will be getting. So, this without doing anything I will just press ABR extraction demo. Again when you if you just hit this what will happen I am just intentionally doing some common mistakes.

So, you do not do the same thing okay if I do that it is a not enough argument because a br extraction has as I mentioned four inputs right. So, we will just go there and we will give four inputs one is where the data is I already showed it to you this is my input data okay same thing this is where the data is. So, I will give that data as my input. What is my sampling rate which I knew at the time when I have done perform the experiment it is currently 8000 hertz it can be 10000 16000 based on some of the system has even 40000 that cost around 17 18 20 lakhs whereas you know we are trying out or attempting to get this thing done within 2 lakhs or something again. So, then which is my event channel data channel all. Everything I have defined code is ready. So, I will just run this code it will show you in between whatever process happens how much time it will see this is your initial data which is like very noisy this is your spectrum which has a multiple power line interference then if you see I minimize this you see it is performing filtering 38 percent done 44 percent done 50 percent done 56 percent done.

So, this and all it will like some of the filters, bandage of filters everything is identified. So, that this kind of peaks line this peaks non-neural peaks will not be observed then you can see that this is like a overall data and this is like a spectrum comparison this is row spectrum slightly processing faster than what I am explaining. So, just give me a minute I will come back to that this is my final waveform prior to that I will close the earlier ones this is important this is spectrum comparison and this is another spectrum comparison as well. So, you see this I will just close the earlier ones so to you know explain you people in detail. So, this was like initial spectrum after performing you see very small very minute values are here which is actually of interest and which is actually of you know cleared spectrum which will be useful to generate ABR and finally you will get this kind of data.

I should have closed all before I will do it again over your you know sake of simplicity now it is done. So, if you can see here this is your ABR where you can see these are different peaks and value is around 0.6 or something so that is like within the range and let me just close all this thing. So, you can see that in the process EEG lab is also closed but you can see here it is already their final PNG is being created. So, if I just open it outside MATLAB because if you open the PNG file in MATLAB it will input as an image and you will get numbers not the final graphics.

So, this is what the final image will look like. This is 1, 2, 3, 4, 5 is time domain in time axis in millisecond here it is an amplitude also wave 4, 5 wave 3, 4, 5 it is like coming as expected. So, the only thing which is pending is to send this data remotely to your audiologist or you know to ENT specialist doctor. So, this also can be done and you know usage of this is you just have a currently I have shown for two subjects. Let me again delete this thing and repeat the experiment.

So, you people will get an idea as now the unwanted files are not there. So, earlier MMN files what we processed is also closed. So, I will just go back to MATLAB and I will rerun the command once for you know. So, you will get an idea. One by one I will just tell you first it will plot a row data, then it will plot row spectrum, then it will plot clear spectrum, then it will plot a comparison, then it will do usual steps and finally the waveform.

This process will remain for both the cases. So, I will just hit it, hit the run button. So, you will get the final values. This is a row pile, this is a row spectrum, then clear you know pre-processing or clearing of spectrum is in progress here like we have seen earlier. This number denotes the percentage filtering is done. In the background, it will read all the frequencies, peaks and identify whether it is obeying the peak prominence and all just to get an idea whether it is neural or not. Finally, this is your, yeah this is one by one we will see all figures. This is what basically the catch of the script that it is used to know identifying the spectrum and then removing the non-neural component only this part is of importance.

That shows that how precision you know is required in order to obtain the neural data. That is why I mentioned that not only signal processing aspect you should also know that what are the experimental protocol, what modality you are targeting, what is the expected range, how much latent it should occur and all this thing. So, now that is performed and you can see this final two figures which as I mentioned both the thing if I plot this generator also ERP is generated which you can play with later. ERP is event related potential data type which is basically a structure but developed by easily ERP lab so then

you can check that thing also. So, these are like two separate waveforms what we have got for two infants or two babies using ABR.

So, our first approach was to use GUI and do it. It is good for research purpose, it is good when you have very few or steps to process but for problems like this where it is very difficult to process everything one by one we should go for some other approach in the batch file processing and that is why I have you know kind of thought of showing you this particular ABR example for batch file processing. Right? So, this is also another point or aspect of that. Now we will move to the third part of the today's demo. So, we were here and this is now rodent experiment. As the subject or course name involves rodent experiment I wanted to cover little bit on rodent trace analysis, how to read it, how to quantify the obtained response.

So, we have performed the experiments with rodents of 10 with 10 channel. Again this is a biodegradable MEA. MEA stands for microelectrode array. So, what is MEA, why it is useful, how it is made right. So, that everything will be covered by Professor Hardik, how neurosurgery performed, how rodent neurosurgery performed, where to put electrodes and all will be covered by Dr. Shabir Gireshan who is a neurosurgeon. I would be showing if we get the data after fabricating micro electrode array, performing neurosurgery, placing your implants on the at a proper or you know desired level anatomical level of rat's brain and then you get the data, how to read that data, how to show the differences of that data.

Right? So, this is a small setup like data would be acquired from rat's brain using some equation board which is like open BCI board and then it will be having some additional stimulation module and all if required and this is what important or you know kind of I wanted to put your guys attention is. Initially we will record baseline. Now what is the point of recording baseline? Baseline shows that your contacts are intact. You know your electrode or you know array electrode array has placed at a correct position where your contacts are intact.

So, you are getting a proper baseline. It is conducting fine. So, that is your initial baseline. Then you will wait for some time and then you generate epilepsy. Now how to induce seizure? That itself is a separate topic of research. There are different methods using drugs you can induce seizure and also you should know why you are inducing.

Seizure is not good. Seizurer is disease. Right? Then why should we induce seizure even in rodent model? Right? So, that is to know the efficacy of anti-epileptic drugs. Once seizures are there, how quickly your anti-epileptic drug can you know resume your normal state? So, in the previous module also I discussed with you very quickly N1, N2,

N1, N3, which AED is useful to you know resume or get to the normal previous step. So, that is from epileptic from discharges once you give AEDs after AED anti-epileptic drug you will be getting your baseline back. So, how do you quantify that baseline has come back and all this thing? So, that was the demo.

So, I will show it to you is a third part of our demonstration. This is rodent data. I have put it all data. Again as I mentioned it is acquired using known systems and all. Now this is pure MATLAB-based analysis which now after getting a data or processing using EEG lab you do not require EEG lab for this.

So, we will be using signal analyzer app in MATLAB. So, I have cleared the other things. I just want to put the data what I have. So, I will be loading it. It is taken from second rat R2 and these are some of the Neumann culture and then you need to open your signal analyzer app because before opening I will just show it to you how it looks like in EEG lab.

Let it, it will take some time to get open. Yeah, less than last time. That is good. So, in order to import the things into EEG lab it should be saved as a MATLAB file, right? So, I will quickly save this. Let us say only for time being only one thing I will be showing it to you.

So, this is epileptic data. I will just give the name rat2 epileptic data dot mat file. It will be here and now I can import that. Also, I am aware of the fact that it has been recorded at 125 hertz. So, I will just change this thing to 125 and I will browse the data and I will take this R2 R dot mat. So, from no current data set, once I give the name and hit OK, from no current data set it will give you the name R2, okay.

Again, you can check, feel free to check here your amplitude spectrum, but you cannot keep 120. Why? Because your sampling rate is 125. So, your f1 and f2 should be less than 62.5. So, let us keep it 62 and now there are 10 channels.

So, this should be 1 to 10 and I will just, yeah, this is how it is looking like, right. Luckily, there is no power line interference in this case. So, that is good thing. So, but still we can perform more operation if you want and it is already cleared or you know filtered data. That is why we are not able to see any kind of power line interference using some script.

It has already been cleared. So, how it will look like? Directly plot to general data, scroll and you can see this kind of thing, right? 7th channel is showing a flat line, highly possible that there might be some issue with connections or something in one particular

channel also shows that yeah and you can see this kind of hardware, right. If I change this thing, scale to 100 or something, you will see more better realistic pictures, right. This is mostly the case of Caesar, right. Because if I even give to 500, it will look like, yeah, see this kind of, you know, Caesar kind of spikes or something.

Again, spikes, sharps, waves and all are different form of Caesar. So, this is how it is looking like. But how do we convince person that yeah this is different than baseline. So, how to quantify the changes, time, frequency, parameters, features and all this thing. In order to do that, we use something called signal analyzer app in MATLAB. For the sake of simplicity out of 10 channel, we will be only showing one channel.

So, I am like quickly opening the signal analyzer app to show you the change. As I mentioned, it is specifically important when you are dealing with Rodent data and to quantify the difference. So, it is available, you can hit command here as well or else you can go to apps and open signal analyzer from here as well. Both the things is possible. Once you do that, you can generate FFTs or amplitude spectrum using that.

Also, you can generate different time frequency analysis known as spectrogram and all. So, I will one by one in a chronological order, I will first put a baseline here.

It will take some time. Yeah, there are 3 boxes. So, I can put all 3 one by one. After baseline, generated epilepsy. So, I will put an epileptic waveform here. After doing that, I will put finally after AED what was the value.

Now, you can see spikes are there in all 3. Is all 3 epileptic? No. You see this y-axis here. It is plus or minus 350. So, we should keep all 3 at the same axis to get a proper idea. So, currently let me just put all 3 of them from minus 400 to plus 400.

Then I will put this first one also baseline minus 400 to 400. And I will put this also minus 400 plus 400. Now, you can see the difference. There is a clear difference when a seizure happens. So, again these are samples. If you want to go in detail, you can put a time values and tell them this is a sampling rate.

We know the sampling rate of 125 was used while acquiring this data. Once you do that, it will show you in terms of time, not in terms of sample. Again, when you do that, you have to again redo your limits 400 to 400. You can do the same thing for epileptic data as well as 125 and again this is minus 400 too. Why I am doing the same exercise again? I will come back to that and why I am giving a sampling rate to all 3 that is also there is a reason behind that.

125 hertz here you go and again you change your time axis from minus 400 to 400. So, you can see the difference. There is a clear difference. But still if somebody wants to further emphasize or let inform that what are the frequency components inside that and all. So, you can plot the spectrum. So, in 3 cases you can see the spectrum.

Now, you see this is looking same. What is the difference? But then in that case, I have to go to spectrum and make sure that my limits are same. If I keep it minus 200 to 50 in all 3 cases, I have been doing this thing for quite a while now. So, I am aware about the overall limits. So, I am directly putting that limits, but you can check it, observe it from yourself and then accordingly you can put.

You see here, this is in first of all thing to notice is in dB. Here it is going above 0 dB only in case of epileptic data. It is down in both the other cases. So, that also shows a striking difference between frequency components as well in time domain amplitude as well. Still if you want to further quantify it or draw a more neural interference out of it, what you can do is you can perform a time-frequency analysis. So, here you can see a time frequency analysis. It will take some time to get generated. So, time-frequency analysis is nothing but your x-axis will be time, the y-axis the frequency will be used and then the amplitude or intensity which will come in the form of heat map.

So, that is, we will be going to doing this thing for all 3 of them and again as I mentioned, the scale you see there is a more like yellowish here. So, you might say that yeah this is more proper more active or something, but that is again if you keep your values or if you keep your min-max ranges same, you can see the difference. See minus 200 to 50 here. If I keep it here again, minus 200 to 50 and again here minus 200 to 50. In that case, you can see this kind of more yellowish region here. Further if you go to spectrogram, you can play with the leakage, what leakage you should want to put, what is your resolution, this each thing I would encourage you to go to MATLAB website or Mathworks website and see how and what it indicates.

So, this thing is like you know in a way helps to summarize your result, identify your result. One last small point that let us say you want to put it this panner, you want to check it only from 5 to 15. Currently, it is how many seconds data? It is 40 seconds data.

So, you only want to see from 10 to 30 seconds. You put a panner, so you can see it is only now considering this data. Same thing, you can apply for the others as well. So, basically, you can focus in the region of your interest and do the same analysis again. It is also a good feature when you have a specific region of interest identified that only that thing will be plotted. Again you can keep the same spectrum ranges and all it will give you more beautiful nice results.

You can copy this display and paste it wherever you want to finally document your result. That is one another point. You can generate the script. You can generate a script for spectrum. You can generate a script from spectrogram. You can generate a script for this panner and you can reuse it wherever you want to use it. So, this is again GUI, EEG lab GUI script was getting generated in the background which you can use it for a batch file.

Similar thing here, this is a GUI where script is being generated which you can use it in a background. So, more or less these are related things and very important and very basic for neural signal processing which is there very easy to use. You can try also you can change this spectrogram to you can explore this thing.

You want spectrum or persistence spectrum. You want to plot spectrogram or skelogram. You can check it and accordingly based on your data and application you can change it. So, this is like third part of that what we were discussing about. So, this is a third part of that aspect we have seen. Further if time permits I will try to take or cover some or the other processing in another TA class. That is it I believe I have for now. So, yeah quickly what we have seen is how GUI-based EEG lab works, how we can perform a batch file processing using ABR and how we read the rodents neural signal what we obtain and we have seen the script implementing this thing.

There are still some points to you know like as I mentioned first two is just to extract the response neural response. Second is to extract and interpret which is more important to draw neural inferences. Yeah that is it for now if time permits I will see you in some other TA class or lab class. That is it for now.

If you have any questions feel free to ask me on forum. I will try to put the data some of the data in the YouTube link description or as a comment in a Google drive link. So, you can play with by your own self, but you need a MATLAB for that. There is a research going on with Python as well to make it like there is already people working with Python based EEG processing and all. So, that we can check it let us see, but for now if you have any doubts anything feel free to write me in the forum as I mentioned I will try to put the data in YouTube as a Google drive link or something so you which will help you to play with it. That is it for now. Bye. Take care. Thank you. Bye.