Introductory Neuroscience and Neuro-Instrumentation
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Lecture No. 31
Basics of BCI Experimentation - Introduction BCI Applications

Welcome everyone to the course Introductory Neuroscience and Neuro-instrumentation. I am Rathin Joshi, I am Ph.D. scholar at BEES lab department of electronic system engineering Indian Institute of Science. In today's module, we are going to look at the basics of a brain computer interface and how we are going to perform experiments based on a particular requirement for BCI.

This is a 4 part module in which in the first part we are going to see the introductions which includes the flow of brain computer interfaces and the various clinical or biological applications of brain computer interface. Furthermore, we are going to discuss about the different stimuli that are being generated. So, stimuli is a specifically designed system or specifically designed be it audio or video to get a required response.

So, your brain responds to a particular event. So, stimuli is nothing, but a group of events that has been presented in a specific manner. So, how we are going to get that particular stimuli, what are the hardware required to get that stimuli, how we can tweak the parameters related to be it auditory or visual stimuli all these things we are going to discuss in that stimuli generation part.

Additionally, there are couple of demonstrations for auditory and visual stimuli which will help you to design any kind of auditory stimuli you want to design. Once the stimuli generation unit is understood we will shift our focus to the experimental setup and biopotential acquisition. So, the experimental setup is one of the very important aspects of any neuroscience experiment.

So, basically how many electrodes you are going to use, where exactly you are going to put your electrodes, at what level or intensity you are going to give your stimuli. What is the rate of stimuli everything like checks the functionality of the entire system with some known things, compare it and then there should be you should then give a signal that now we are good to go with the experimentation.

So experimentation setup and finally the biopotential acquisition. Now mostly we are going to record EEG for this course. We are going to discuss about how EEG can be recorded, how it has been processed and also EEG is very, very low in magnitude. It is like microvolt in terms of microvolt range. So, how you are going to exactly get this much small amplitude voltages or this kind of biopotential that will be covered in the third module.

And once we acquire the biopotentials, finally how to process it in order to get a particular response that is something called event related potential. So, how you can extract those event related potentials from this obtained EEG. So, all these things will be covered in this particular module. So, considering the first introductions of module. Let us see what we will have in this module.

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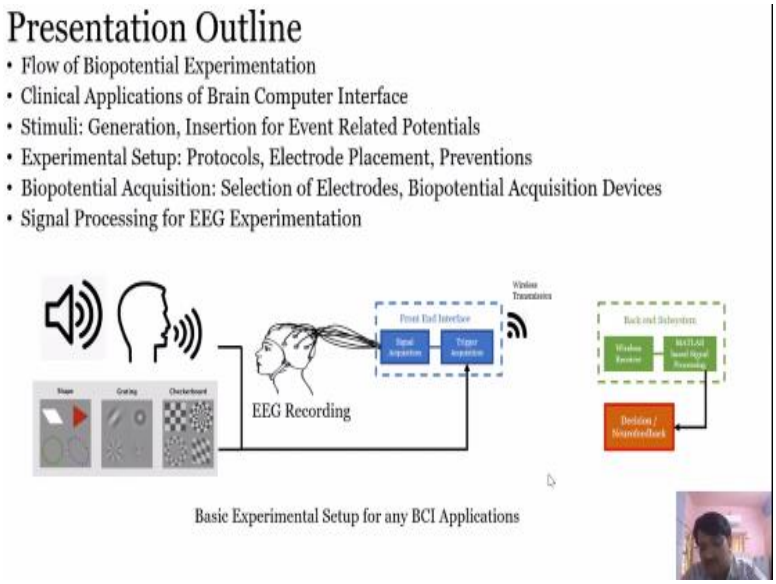

So this is the outline of the presentation. I have already discussed about auditory stimuli and how we can acquire the biopotential we will see in the details in case of auditory stimuli and biopotential single processing or EEG related single processing or even ERP event related potential related signal processing. We will also demonstrate few of the concepts so it would be easy for you to understand as well as implement.

So, I will show you one simplified diagram of any kind of brain computer interface system. So, be it any application of brain computer interface, this is the basic structure which will be followed. So, if you can see this part this is a stimuli generation part or stimuli generation unit. I have shown two of them two times. This is on this top part this is auditory stimuli

where two images are there. One is a normal sound image and human speech image. Both kind of auditory stimuli are used.

In some of the cases when patient is not that much cooperative in a way patient is not responding he cannot respond properly or let us say the worst case if a patient is in coma. It cannot respond that well to the sound that is being generated by some machines. Mostly this auditory stimulus is used to detect whether you can hear or not. Basically for hearing screening or your till what intensity you can hear.

So, that will decide your subjective threshold that okay we have two subjects out of which, which one can hear it even lower sound or at some places this is a check that whether a person can hear completely or not. So, that time there is something called tones, clicks, chops. This kind of tones are presented to know a hearing threshold for a particular subject. Whereas, for a patient who is not a completely healthy or its neural conditions or he is like kind of as I mentioned if a person is in coma or something at that time it is advisable to present a human speech sound be it is of some relatives or some other sound which is very much familiar to that person.

So, it is like this both kind of recorded, prerecorded stimuli, auditory stimuli as well as preprogrammed auditory stimuli can be used as an auditory stimuli generation unit. In the same way there are a different kind of visual stimulus so and it refers in various attributes like which kind of shape you are going to use. So, some standard visual stimuli has round shape and something called blue ball and red ball. So, these different events or different stimuli can form the final stimuli in which this instances the different images are being ordered in specific manner.

Other way in most of the eye-related conditions or eye-related disease that is something that you might find character recognition. So, this is a kind of customized visual stimuli as well as there will be stimuli with different intensity. So, same way like you define a threshold for your auditory screening you can define a threshold for your vision field. So, and one more prominently used visual stimuli is the checkerboard. So, the checkerboard is nothing like a chessboard if you have seen and inverted checkerboard visual stimuli is very prominently used in many of the visually of potential testing.

So, once you understood this stimuli generation I am talking flow wise. We will go into the detail of stimuli generation, how we can generate and how we can program it, but for now,

once you can understand how stimuli is generated with respect to your particular presented stimuli your brain responds and some form of potential getting elucidate. So, in order to get that biopotential, you need electrodes. So, here in this image, a proper set of EEG gap is shown with electrode based on it. All these electrodes will be recordings will be given to the signal conditioning circuits.

So, I already mentioned that being low in magnitude very critical to obtain all this EEG biopotential, so that is done with some smartly designed electronics consisting of combinations of filters amplifiers and mainly instrumentation amplifier and finally you are going to process it. In order to process it in your computer be at MATLAB at signal processing or any other processing, you are going to convert it into our digital form before transmitting. So, mainly this biopotential acquisition consisting of the instrumentation amplifier, your filters, your filters it will be having both kinds of filters band-pass and band-reject.

I will tell you why. So, mostly in this experiment happens in the specifically allotted room, but there also there is a high chances of getting power line interferences. So, in order to remove this we are going to use there is something called band-stop or notch filter with respect to your power law frequency 50 hertz. So, it will have an instrumentation amplifier, it will have your filters both kind of filters band-pass, band-reject.

It will have a broadband amplifier and finally, it will have ADC multichannel ADC in order to convert the obtained analog value into digitalize form. Once you convert it into digitalize form you have many wireless transmission protocol. Mostly in today's practice BLE that is Bluetooth Low Energy modules or else something called RF or this kind of modules are used to transmit the obtained biopotential.

And it is like most of the modulus you can have kind of receive the data using dongle into your laptop. So, further, you can process it using any of your software. So, this is the basic flow for brain computer interfaces. So, we will check each module in detail.

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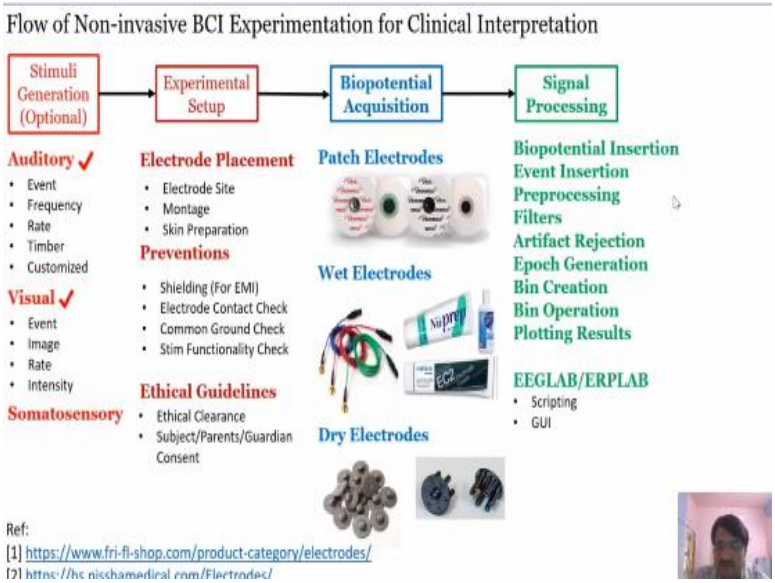

So, before checking each module in detail I have listed down some of the key points in each modulus so we will see every key point one by one. So, I have already discussed about auditory-visual stimulus, but there are some parameters with respect to that we can change the particular response and there are some potentials, biopotential that response to a change in your one of the parameter they are being generated with auditory change.

So, this auditory change can be characterized by frequency, it can be characterized by duration, it can be characterized by the presentation stimuli rate, it can be characterized a timber. A timber is nothing but if you play a particular chord in your guitar and if you play the same chord in your keyboard you will get a different sound. If you play bishop in guitar and bishop in the keyboard you will get a different sound. So, that is what timber is.

So, this kind of specifically designed or customized auditory stimuli can be used. Also in both the cases auditory and visual it is very important that we can find exactly how many number of events are used. So, in most of the cases as I mentioned it responds to the auditory change. So, we should have multiple auditory stimuli in a proper sequence. So, before starting our experiment you should have a clear idea of how many events you are going to use be it auditory or stimuli.

One more evoked potential is the somatosensory evoked potential where auditory and visual both potentials are localized at your ear and your eyes obviously, but somatosensory is global. It is related to your sensations. So, if somebody touches you, you will get a sensation so it is like a global evoked potential. Further, we will have a look at experimental setups. So,

before starting any experiment you should know where you are going to put your electrodes, how you are going to record it.

Before that is there any requirement or any change that needs to be done for a particular subject, which kind of electrode you are going to use? If it is a dry electrode fine, if it is a wet electrode how you are going to prepare a scheme for that. Every person has a different density of head with different density of hairs so which kind of electrode. There are different types of electrodes I will show it to you there is something called a flat electrode, there is something called a spike electrode, there is something called a comb electrode.

So, which kind of electrode you are going to use, where you are going to place it. And all these things should be finalized before starting any experiment. So, first you should know the site of an electrode where you are going to put your electrode on your head. You should also know the montage. Now montage is way to acquire different biopotential based on your electrode. So, if you directly put the recordings from your electrode it is like you are taking a monopolar value of that.

Now if you refer a particular value to some other electrode it is called reference montage and why this referencing and all is required is because if you take any nearby electrode as a reference most of the common noise will get eliminated. We will see this thing into detail. I will also show you an example of the same recording done for two different montages we will see that. And I have already mentioned on that for wet electrodes you need to prepare your screen.

So, generally, when a subject comes you have to know it depends on where you are going to take your recording. So, you have to wipe it up with spirit and there are some specifically available paste or creams which is being used. So, that will like when you perform an experiment that we will make sure you will get the best response with your electrode. Be it mostly in case of wet electrode the screen preparation and all will be required.

Further, if you move ahead there are few things which we must take care. First and foremost the biggest problem for any biopotential acquisition in open environment would be power line interferences. So, you should be using a shielding now how to use and exactly which kind of shielding we should use, how it can be used and how it stops your electromagnetic interference we will see. Also it has been recorded, observed many times in case of multi

electrode placed on your skin or scalp. One of the electrodes might get little bit disturbed or that electrodes recording will not come properly.

So, always make sure before you start an experiment that all electrodes are properly connected to the scalp very important point. One more thing your particular device will have several subunits. Like your acquisition unit will have one function to do, your stimuli generation will have one function to do. All these subunits must have a common ground also we will see when I will show you one example this is a mixed-signal electronic design. So, it will be having analog as well as the digital ground. So, both the ground should be separated and kept at a proper place.

So, all this thing will come into the picture when you design an electronic circuit or PCB in order to make your EEG acquisition or let us say ERP abstraction system, and also it is advisable to check your stimulus functionality. We will talk about more in the upcoming slides so and first like finally, you should have if you are performing any experiment this involves EEG involves a human subject. So, you must have an ethical clearance or performing any kind of experiment.

At the same time if you are performing this experiment in any of your subjects be it anyone even if it is your friend or anyone you should be having a proper concern form signed by a subject. Now some of the cognitive neuroscience experiment involves newborn or neonate. So, in that case, you should have a parents concern or guardian concern. So, ethical clearance and patient concern or subject concern or any of the guardian concerns are two of the very kind of essential step for research methodology. You must have this thing before you start your experiment.

So, we will see which kind of biopotential we are going to acquire, but you will see which kind of electrode we are going to use. So this is nothing, but a patch electrode. Some of you might have seen it in ECG recording it will be placed on your chest and ECG will be recorded. So, this is a patch electrode additionally mostly for EEG signals we are using nowadays we are using a dry electrode, but it is smaller than this. So, it will be something like this.

Already mentioned you have gently wipe with your forehead or wherever you want to put your electrode with spirit and then you can apply one gel that will kind of make sure that your skin impedance will match with like it will lower down your skin impedance and then further

you will use one adhesive gel which you are going to put it inside your adhesive conductive gel which we are going to put it inside your wet electrode. The wet electrode is shown here so this is a kind of wet electrode with the kit in order to perform any kind of experiment.

Further, we will see the dry electrode. So, the dry electrode there are two kinds of dry electrode are shown. This is when a person is too hairy it is difficult to get recordings with wet electrodes. In that case we are used this kind of spike or comb electrode. So, finally, this is the this is the site which will come into the contact of scalp and from here we are going to acquire the biopotential.

These are two use front use and back use. So, this will be summation of all this small spikes which is acquiring this biopotential where this is kind of comfortable electrode in case of if a person is not too hairy or you are going to record your biopotential from your forehead. If you are going to make any kind of hair band or something if you are going to put your electrodes on your forehead. I think dry electrode would be a great option, but yeah if you are going to measure it when someone who is very hairy and if you want to take a recording from your forehead it is good if you are going out with spike electrodes or comb electrodes.

So, once you get that these are the very basic step in order to get your final to extract your ERP. So, what are the steps? First if whatever you have biopotential and stimulus or event both should be inserted to your system on which you are going to process it. Further there are some preprocessing algorithms available to remove some kind of artifacts. Now if you record EEG if you have come across any kind of EEG recording even a small movement of yours can disturb your EEG. You can find out if a person is moving you can see in your EEG.

If a person anyone blinks you can properly see that kind of shape in EEG if a person is even kind of swallowing something or if a person is moving his eyes you can easily see this kind of things in your EEG, but the problem is while taking recording if a person even blink or something it will be a part of the recording. So, in that case what we can do is before performing some subsequent operation we should be able to remove all this artifact.

Like there are two kind of artifact one is getting generated by human subject. As I mentioned all this eye blinks, eye movements, some muscle movement those results in EMG and another type of artifact is artifact which has been generated by the other interference, environment as I mentioned electromagnetic interference, then it is highly possible that if you have not shielded wires or your wires are too nearby without shielded. Then there will be some

interference or cross off between the wires and all. So all these things will result in unwanted signals in your EEG and all these things will be removed by the preprocessing algorithm.

So, once you reprocess it, once you remove the noise maximally whatever noise you can remove you have to do filtering. So, filtering basically in most of the EEG analysis we do not want any component above a 70 hertz. Even in some of the experiments people used to 1 to 30 hertz or 0.5 to 30 hertz. So, these are the basic range for any brainwave or EEG processing. So, then you can filter it also as I mentioned you would have used notch filter of band-stop filter in order to combat the power line interference. If you want you can again use one notch filter for safety purposes in your software part as well.

If you are not using it in your electronics or in your hardware generally all modern-day EEG acquisition device has this option of keeping notch all for both the frequency 50 hertz and 60 hertz. So, in Asian countries 50 hertz if you go to US and all it is 60 hertz. So, both the notch frequency, band-stop filters are available in any EEG acquisition system in the current day, but you can still if you want you can put one more layer of safety by implementing it into your software in MATLAB.

So, and then further this EEG range as I mentioned EEG in the few times of microvolt. So, even after preprocessing there are some values which will go beyond plus or minus let us say 150 microvolts or plus or minus 100 microvolt. So, based on your application you can set this artifact rejection criterion. So, the values greater than plus or minus 100 or plus or minus 150 you can remove and replace it with baseline.

The baseline is nothing, but your normal ongoing EEG which is in a very smaller amplitude and without any kind of too much activity or too much higher amplitude and all. So, it is the average value of ongoing EEG that is the baseline. So, you can get rid of this kind of artifact and there is a provision to mention this kind of range. So, this way you can reject the artifact further very important step is Epoch generation.

Now I already mentioned that due to variabilities of EEG potentials we need to give a particular stimulus or set of stimuli multiple times to record the event and finally we will average it. Now how many times you are going to repeat this thing? Let us say you are going to repeat this thing for 100 time. So, to get that 100 different time intervals from the obtained run of EEG is nothing but your Epoch generation.

If your same kind of stimulus is presented 100 times and your one stimulus time interval is 1second then your entire experiment duration 100 second and from the recording of 100 seconds you are expecting 1 second for 1000 times that is nothing, but your Epoch generation. Bin creation, bin operation we will see in the signal processing module it would be little difficult for you to understand from now.

So, when I discuss about multi event stimuli 2 event and 3 event stimuli it would be very easy after that how you can operate through the bins and why bins are required first of all and what we are doing and finally, you can plot your outcomes. There are ways to plot EEG, you can plot it as a function of your head also. Head location like there are some landmarks in your head.

So, wherever there is some more activity you can show it in a different color that is one thing another thing you can show your standard error of mean because we are considering a 120 approaching some of the experiment and you should show like this is the average value, but what is the deviation in simpler terms standard deviation or how it is you know going up and down from the averaged value.

All these things are very important if I talk about signal processing aspects of the EEG recording system. So, this would be the final like very detailed view of any brainwave recording system or any brain computer interface system. We will quickly look at the applications and after that we can jump into the specific module.

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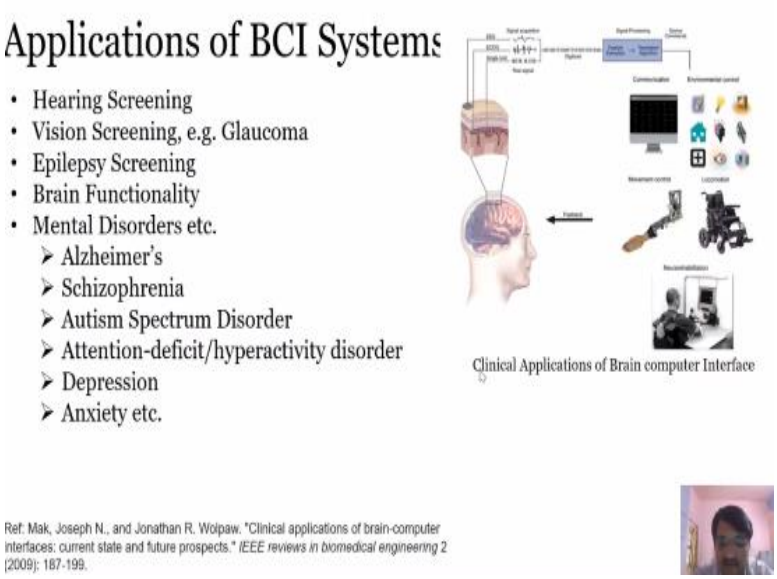

So, what are the basic applications this is just to give you a motivation that what you can do if you can record the EEG. So all this let us say sensory system like be it a vision or hearing or anything that will be processed in your brain in the cortex there is a visual cortex there is an auditory cortex. So, there the entire flow of your sound perception or your vision perception finishes.

So, by properly recording EEG you can give an impression that this guy can hear it properly. This person his vision is at this stage currently at this level and this person is like has some issue you can make a screening tool for hearing and vision. At the same time if the person is suffering from deafness or blindness you can even quantify the progression of the disease using EEG.

Yes there are few experimental protocols and stimuli generation practice which you need to follow, but once you know that you should be able to at least screen a particular subject or patient for hearing screening. Further there is few more brain related diseases epilepsy. So, if you have EEG way form there are some standard chunks of EEG which can be used as a biomarker for epilepsy.

Now epilepsy is very dangerous disease because sometimes in our patient or subject can even lost complete control of his body. So, if you can record EEG properly you can even make a tool or screening tool which can record the EEG and tell that this guy has more activities compared to normal subject. So hearing screening, vision screening, epilepsy screening are kind of very straightforward applications of brain computer interface.

And further if I go ahead there is something called brain functionality. So, your brain has different functions to do like sensing perception, auditory perception, visual perception, memorizing stuff and character recognition many things are there. So, if you can make some combined stimulus which we can using which we can elucidate this all kind of brainwaves and from brain you can tell that this guys brain works or this part of brain or this particular type of stimulus getting recognized by this guy very well.

So, it is kind of quantitative measure or result of your brain functionality or index of your brain functionality. So, this is also one of the possible applications of brain computer interface. There are several disorders Alzheimer's is there, Schizophrenia, Autism then ADHD, depression, anxiety all this thing can be quantified or captured with some

modification. There will be disease or application-specified changes which you have to do, but this is kind of all these clinical applications of the BCI system.

If I talk about some other applications. So, this is a very nice review on IEEE biomedical engineering a few see this thing it has shown that we will only focus on this EEG. If you go intracranially then you can record ECoG also Electrocorticograph, but we will be focused on EEG. It will get digitalized and then feature restriction algorithm and all that it can do if you follow the same.

It is somewhat exactly similar kind of structure or flow which I have mentioned what you can do is you can be based on your brainwaves or your thinking you can perform environment control if you think it like I would like to turn on the fan it is possible from your brain signals you have to train your network and all, but you can do that. You can control the movement if you want to make some kind of robotic arm or something you can do that. You can use it for locomotion as well as you can use it for neurorehabilitation.

So, all these applications is possible if you use this BCI interface brain computer interface. So, I hope you got some basic idea about how BCI is performed or at least the flow is clear now and the next sub-module we will see how to generate particular auditory stimuli, which kind of auditory stimuli are there. How it looks like and how to generate it using which hardware to generate and how we can alter the different parameters of auditory as well as visual stimuli.