Affective Computing
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Week - 07
Lecture - 01
Emotions in Physiological Signals

Welcome friends, so in today's class we are going to look at the Emotions in Physiological Signals a very interesting and in fact very dear to my heart kind of topic. So, here is the Agenda for today's class.

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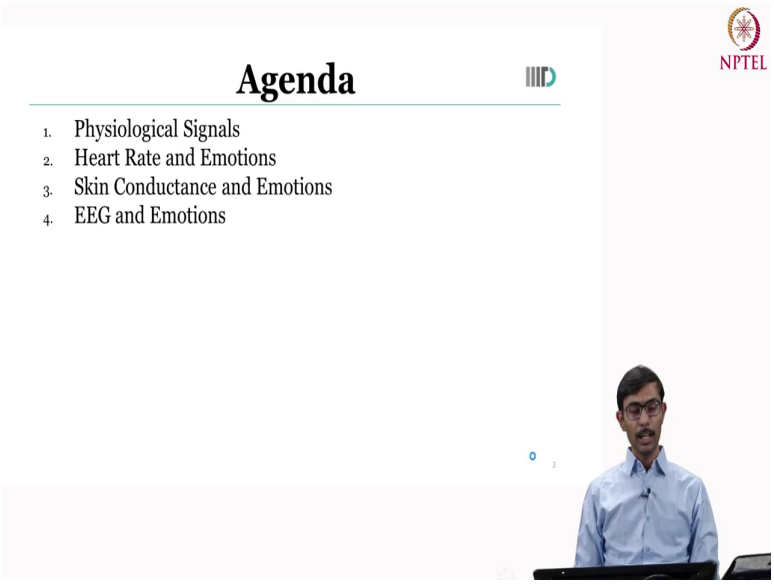

In this class, we are going to first look at why we are we have we are interested in looking in the emotions in physiological signals and what are some of the relevant physiological signals? We will be looking at the emotions in heart and not only metaphorically, but also

physiologically and also, we will try to understand the emotions in another very popular physiological signal which is known as the skin conductance.

And finally we will also look at the emotions in EEG signal, which is commonly known as the brain activity signals. And finally, we will conclude with the discussion of some additional physiological signals, that can also be used for the recognise for the emotions for understanding and analysing the emotions; perfect.

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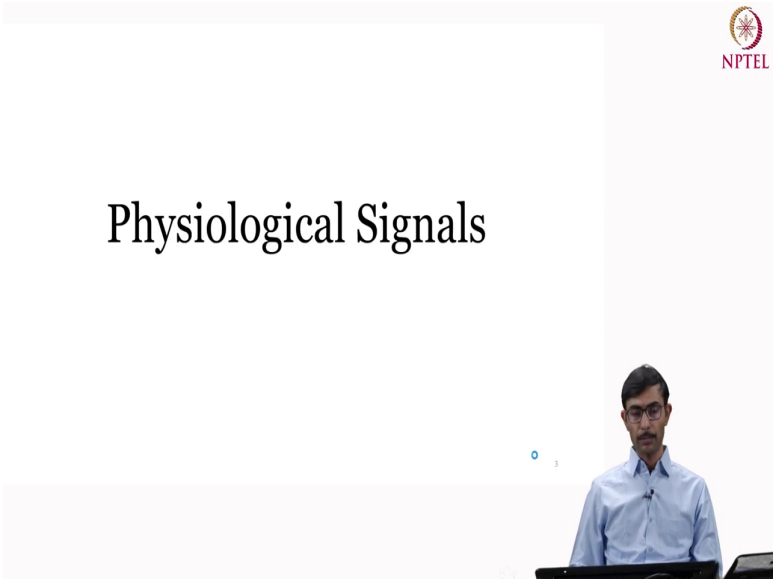

So, let us start first with the trying to understand the Physiological Signals itself.

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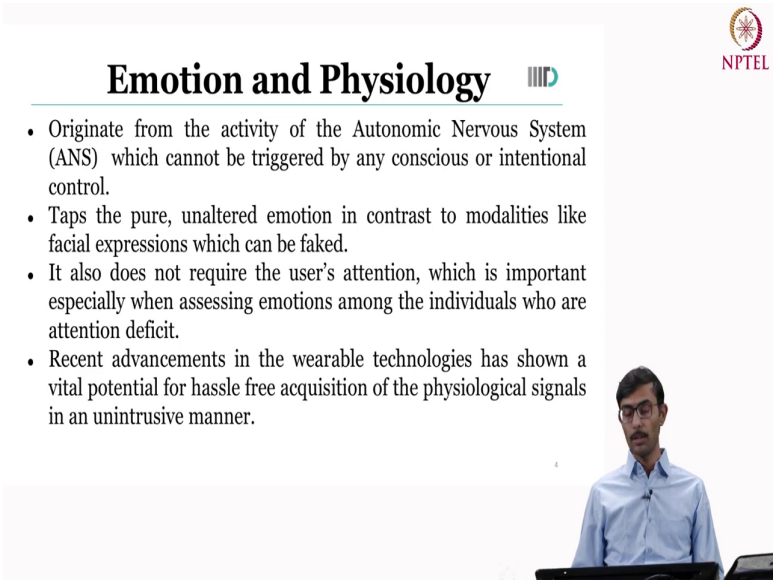

So, first thing that we have to understand that the physiological signals they originate from the activity of the autonomic nervous system and hence it cannot be triggered by any conscious or intentional control. Now, without making so many jargon, making use of so many jargon words, what essentially it means that it cannot be controlled or faked or it cannot be consciously produced. For example, the way we can do with the facial expressions and in since it cannot be consciously or intentionally controlled.

So, what it means that? You cannot fake it, I mean we cannot easily at least we cannot easily fake the emotions that are getting produced in the physiological signals. And in fact, that is what has given a rise in the popularity of the emotions in a physiological signals and it is analysis. So, other important characteristic related to the physiological signals and emotions is

that it does not really required the user to pay a lot of attention to provide the data of the emotion that is there in the physiological signals.

So, for example, if you want to get the emotions in facial expressions, you may have to ask the participant or the user to you know maybe look at in a particular direction, there should be certain standard setup. And this all will require the user to pay a bit of attention to you know how the user is sitting, how the user is looking at the camera and so on and so forth.

But in this case, nothing of this sort is required. And for the same reason, it is very very helpful even to get the emotions among the individuals those who may have some sort of attention deficiency as well. So, that was the second advantage. And more importantly, why suddenly there is another reason why it has become very very popular to analyze the emotions in physiological signals is because of the advancements in the wearable technologies.

So, from the recent advancements that we have seen over one or two decades, the it has enabled the acquisition of the physiological signals such as the ones that we are going to discuss now in an un-intrusive manner and also, I would say in relatively low cost fashion.

So, basically this low cost and un-intrusive possibility of capturing the physiological signals in a low cost using a low cost device and in an un-intrusive manner, has what also given the rise to the popularity of the emotions and its analysis in physiological signals.

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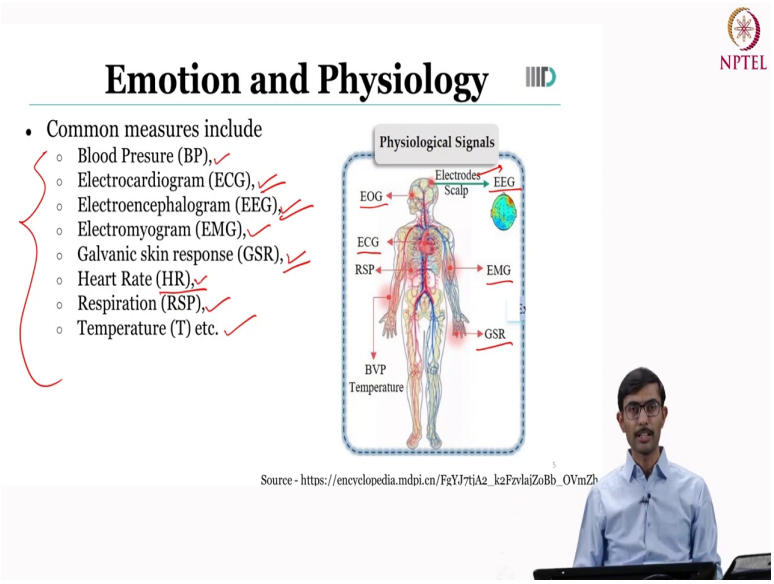

So, these are the some of the physiological signals that are commonly used when we try to understand the emotions right. So, for example, the very first one is the blood pressure. So, I believe the blood pressure is something that we all know. And of course, while it may not be very, very expressive, the emotions may not be very very expressive in the blood pressure. There has been certain studies which has looked the emotions in the blood pressure.

Of course, then the other thing is the electrocardiogram. So basically electrocardiogram, it relates to the cardiac activity of the human. So, as you can see in the right side diagram, this particular refers to the cardiac activity of the humans and from this cardiac activity, which is from the ECG using the ECG signals, we get the heart rate.

And then with the heart rate we can get the emotions that are associated that are expressed in the heart activity of the humans. Other is very, very popular method is again is the

electroencephalogram. So, basically electroencephalogram is also known as the EEG signals as you can see on the right side of the screen.

So basically, EEG as you can understand that basically to analyze the EEG, you need to we attach a cap kind of thing on the head of the humans. And then we try to with the help of certain electrodes, we try to capture the brain activity of the individual and through which we try to analyze the emotions.

So, that is the EEG signals. Other thing is the Electromyogram. So, basically electromyogram, it basically refers to as you can see here. So, this is the what is referring to the electromyogram. So, basically electromyogram, it refers to the activity of the muscles right.

So basically again, it involves attachment of some electrodes to the body to the muscles and through which we try to get a certain expression of the body posture through which we can in turn get the understanding of the emotions. Not so, popular method when it comes to the emotion analysis, but nevertheless this is another option. Another very popular method is the Galvanic skin response.

So, basically galvanic skin response as you can see here in the right side of the image. Galvanic skin response, it refers to the skin conductance. It is also known as the skin conductance or the electrode thermal activity. It refers to the skin conductance or the conductance of the skin as the name implies of the human body through which we can understand certain components of the emotion such as arousal and so on and so forth.

So, again we will look at it in a bit more detail and nevertheless of course the other component is the respiration. Respiration is of course is the respiratory activity of the humans. So, we all have seen that you know the respiration itself may change depending upon the type of the emotions that we are experiencing to certain to do a good extent and hence it has also been used in research, in literature to analyze and understand the emotions.

Nevertheless, again last, but not the least is the temperature of the human body. So, the temperature of the human body, it has also been found to be correlated with certain expression of the certain types of emotions. So nevertheless, I mean this is by no means this is an exhaustive list, apart from this for example you can also look at the EOG signals which is the activity of the human eyes.

Similarly for example, you can also look at the gaze patterns by looking by making use of the eye tracking devices and so on so forth. But nevertheless, for the sake of this course, mostly we will try to stick to the ECG signals. We will look at the EEG signals, we will look at the GSR and of course by the virtue of the ECG, we will also look at the heart rate right. So, these are the few signals that we are going to analyze and more or less many of the findings can be extended to the other signals as well; perfect.

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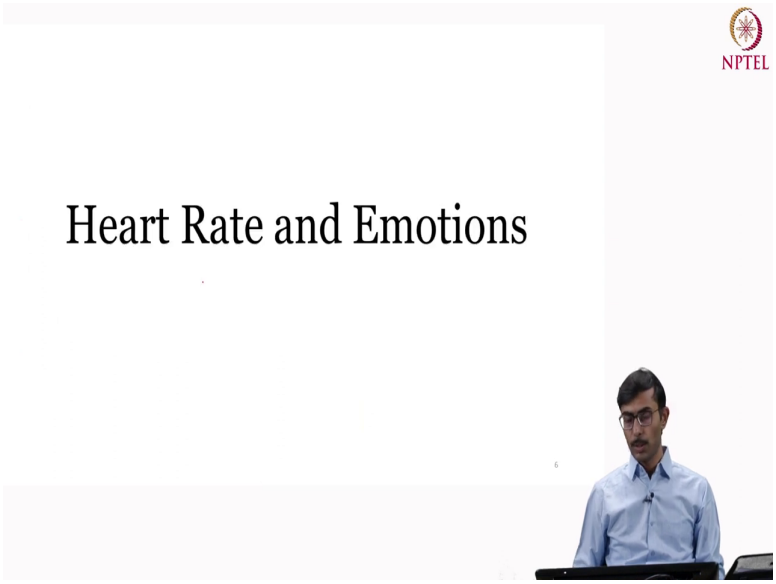

So, with that, let us try to look at the emotions and how it is being expressed and how that can help us in the analysis of the emotions in the heart rate; perfect.

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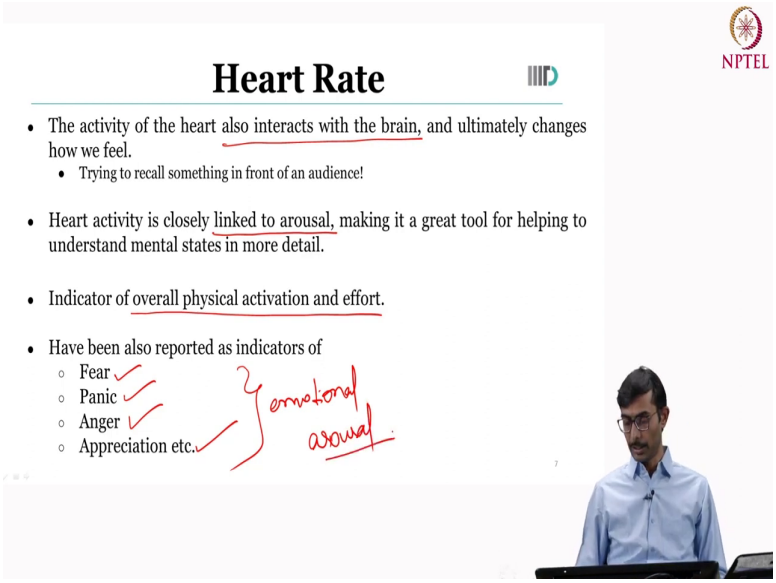

So, about the heart rate, we all the reason of course the heart has been shown to be metaphorically correlated with the emotions in so many ways, in poems, in literature, in arts, in movies.

But, the physiology says that it does not only relate to the emotions in a metaphorical way, but definitely it relates to in a physiological manner and the reason that it relates, and one of the reasons that it relates to the emotions is that the activity of the heart. It also interacts with the brain and ultimately it impacts how we experience an emotion.

And one of the best example of this particular is that imagine that you are giving a presentation or for example, you are doing a lecture such as myself now and you are trying to recall something that you have to present during the presentation in front of an audience or for example, even in an online setting.

So, and if you are notable to recall that, then imagine what happens? Imagine it is a big audience; it is a very important presentation. So, what happens that suddenly you start feeling anxious, you start feeling aroused and then you know you start feeling sweaty actually.

You know the is like that there is a proverb that you know like you start feeling sweaty here, sweatiness, lots of sweatiness and that is how you know. So, in this particular activity, if you try to analyse it, then using your brain, your while your brain is trying to recall some stat, some facts.

At the same time, your heart is getting the signal from the brain that, ok, maybe it is not able to recall and then since it knows the importance and the brain also communicates the importance of the presentation for you. So accordingly it tries to it emulates the experience that we are having as of now in front of the audience and hence, we start feeling sweatiness or even our heart rate starts increasing, right.

So, that is one very good example of how the activity of the heart, it also correlates with the activity of the brain and how overall it impacts the emotions that we experience. Specifically, the heart rate usually has been shown to have a very good correlation with the arousal.

If you recall, when we were looking at the arousal and the valence and the dominance model, VAD or the PAD model, which is the dimensional model of the emotions, then arousal was the component which was sort of giving you the energy that was there in the present in the in an emotion.

So basically, this heart rate has been shown to have a good correlation with the arousal. And hence, it can help us in so many ways in trying to understand the emotional state in a in a very

good detail. Overall, it is not hard to realize that the heart rate has been shown to be a good indicator of the overall physical activation and the effort.

So imagine, you know, if you are simply walking, your heart rate is steady and smooth, but the moment you start running, of course you can immediately notice an increase in the heart rate activity, right. And for the same reason, it is not very hard to understand how it is can be an indicator of the overall physical activation and the effort.

Nevertheless, it has when it comes to the emotional activity, it has also been found to be correlated with the fear, panic, anger, appreciation, etcetera right. So, these are some of the feelings and mostly while trying to analyze this thing, we try to look at the emotional arousal from the using the heart rate.

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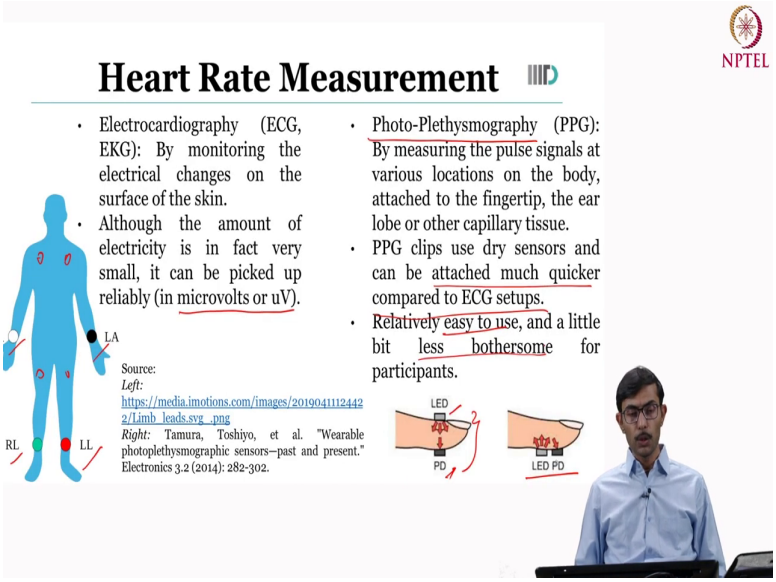

Now, having understood that how heart rate can help us in analysing different emotional states, particularly emotional arousal.

Let us try to understand how can we measure, how the heart rate is measured so many of you have, we have seen the use of the ECG. For example, the electrocardiography, electrocardiogram for measurement of the heart rate, so basically ECG you may have seen that it is the way ECG measures the heart rate is it monitors the electrical changes on the surface of the skin.

And many cases, what happens that there are multiple electrodes, usually 4 electrodes, which are placed on the four different parts of the human body. And for example, one particular scenario where it is placed on the palm, such as if you can see in the image. So for example, here one electrode on the right arm, one electrode on the left arm, one electrode on the right leg, similarly another electrode on the left leg.

So, this is what a four electrode configuration is, that is commonly used, similarly other configuration that can be used. For example, one electrode here, one electrode here, one electrode here, one electrode here and this kind of configuration is also used to get, to monitor the electrical changes that is there on the surface of the screen through which we try to observe the heart rate.

We try to get the heart rate. Now of course, the question the next question that you would like to ask, that the amount of the electricity that we observe on the human skin is it too much and of course it is not too much. We are not a walking electrical transformer right. So, the even though the electrical current is very very small, is in microvolts.

But the electrodes that we use in the electrocardiography are designed in such a way that it can pick this even the small changes in this electrical, small electrical changes on the skin in a reliable fashion and that is how we measure the heart rate of the human body. Another very popular method is the use of the PPG signals, which is also known as the photo plethysmography.

So, in the photo plethysmography or the PPG signal, what we do? We measure the pulse signals at the various locations on the body. And usually for example, it is very common to attach a PPG clip on the lobe, on the fingertip or for example even on the ear lobe or for example on either capillary tissue such as you know on the legs as well.

So, if you look at this diagram on the right hand side, the way a PPG clip is attached. What it does? It makes use of the tri sensors, which usually consists of some LEDs, some IR LEDs and some photo diodes. So, basically what happens that the IR LEDs, it emits the it emits light

And then of course, depending upon whether the blood is actually flowing through the veins at that appropriate time or not, the amount of lights they get absorbed by it. And then accordingly, whatever is the remaining light that is collected by the photo diode that is beneath this PPG clip.

Now of course, depending upon how much light it has emitted and how much light was collected, it could really analyse that ok, whether the blood was flowing or not. And of course, when the of course, when whether the blood was flowing or not. What it means? that of course, when your heart pumps the blood, I mean it has to go at certain point, then of course then it stops for a very few amount of time, then of course, it pumps and then there is a rise in the blood flow right.

So basically, this is how these are the two configurations in which this IR LED and the photo diodes are placed in the PPG clip and that is how it measures the flow blood flow and accordingly tries to estimate the heart rate of the human body. And this is the same kind of PPG clip you may have seen, which has been very, very popularly used for example, in the oximeters as well.

So, you may have seen the oximeters and then you simply place the oximeter in one of your fingers, fingertips and then you get the heart rate from there. So, this is again and as you can

see that this is of course the attachment is much quicker than in comparison to the ECG setups. In the ECG setup, you need to use this 4 electrode system, it is kind of very intrusive.

And of course, in comparison this PPG clips, they are relatively easy to use and they are of course less bothersome or cumbersome for the participants and hence they are a bit more popular for the analysis of the heart rate signals then in comparison to the ECG. But we will talk down the line that of course, it compromises the efficiency of the how effectively is calculating the and the precision of the heart rate essentially. So, but nevertheless, it is a popular choice for the analysis of the heart rates.

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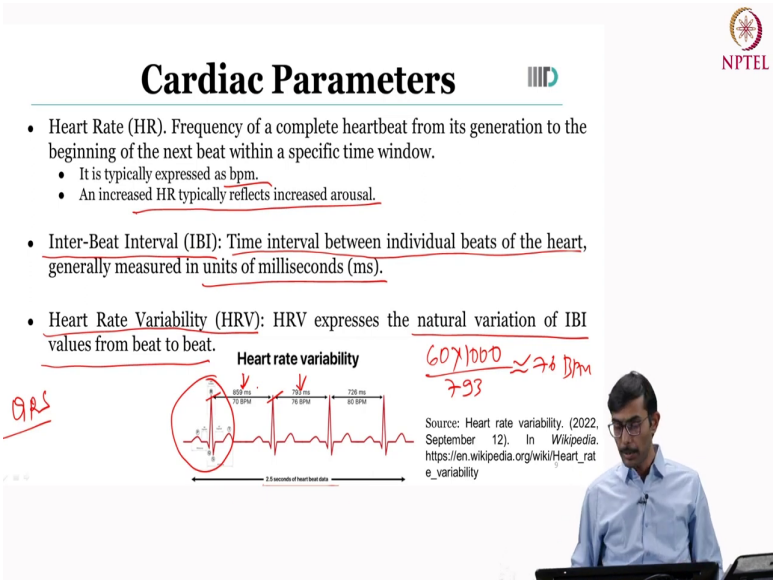

So, these are the two popular methods through which we observe the heart rate in the physiological experiments and then of course, now once we have observed and obtain the

heart rate then there are certain parameters that we can use to analyse the effects of the heart rate right. And of course, one simple parameter that we can talk about is the heart rate itself.

So, basically the heart rate, it is typically expressed as the beats per minute and as we already understand by heart rate what we simply mean, we simply mean the frequency of the complete heart beat from its generation to the beginning of the next within a particular time window right.

And then we have already seen that an increased heart rate for example, it typically reflects increased arousal. So, as I was giving the example, if you are giving an presentation in front of an audience and you are not able to recall certain very important fact or some stats that you want to present and immediately you will feel aroused and you will feel aroused and accordingly you will feel that there is an increase in the heart rate; sorry, other and of course this is the raw data that you have. Other way commonly used data is the inter beat interval.

So, basically the inter beat interval as the name itself suggest, rather than looking at the how frequently the heart beat is occurring, what it simply looks is at the time interval between the individual beats of the heart rate. So, for example, one beat another beat. So, what is the time interval between these two beats? And usually, this time interval is measured in units of milliseconds. Just one sec [FL].

So, usually it is measured in units of milliseconds as opposed to the frequency that as we see in the heart rate. But these 2, as you can see this is the raw data itself and the raw data itself many times it does not give you a lot of information. Hence, there is another very popularly used parameter which is the heart rate variability.

Which and the heart rate variability basically as the name itself suggest, it expresses the natural variation of the inter-beat values from the beat to beat. What it simply means as you can see in the diagram that is given below. So, for example, this is giving you the, this particular diagram is giving you the data of the 2 and a half seconds of the heart rate, heartbeat data right.

So, if you can see this is the one particular heartbeat, I mean it is so basically this is a this is a typical ECG signal, how the typical ECG signal looks like. So, in the typical ECG signal apart from the P and the T waves, so you have this QRS wave which is the central and most visually obvious part of tracing the ECG signals.

So, basically in the QRS signal what you have that it represents the depolarization of the right and the left ventricles of the heart and at the same time it represents the contraction of the large ventricular muscles. So, basically this is the most important part of the ECG signal that we use to analyse the ECG abnormality and so on so forth.

So, now, ok and together this QRS signal it occurs together as an event and hence it is referred to a single QRS waveform. So, in the Q so basically one heartbeat you can represent it as a single QRS waveform. So now, the this one single now the intermediate interval essentially what it represents, it represents the distance between the 1 R interval from the 1 R, of the 1 waveform and from the another R of the next waveform right.

So, basically the inter beat interval is represented as let us say 859 milliseconds here and then 70, of course it can be translated to the beats per minute which is of course, you simply have to divide the if the inter beat interval is the 793 milliseconds, then how much is going to be the beats per minute.

And then for example if you take the example of the 793 that if the inter beat interval is the 793 milliseconds then what is going to be the beats per minute. So, it simply has a matter of time, you know so you can simply take that ok 1 second is equal to 1000 milliseconds and then there are 60 seconds per minute. So, basically if you divide 60 into 1000 divide by 793 here then you will get something around 76 BPMs around 76 beats per minute and that is how you calculate how much is the beats per minute right.

So, basically this heart rate variability what it essentially gives you it gives the variation that is there between the inter beat values from beat to beat or from 1 R wave to another 1 R peak to the another R peak. So, for example, you if you can see that while the first one was 859

milliseconds the inter beat point interval for the second it was the 793 milliseconds and for the third its 720 milliseconds.

So, there is a variation between these between the times at which these beats are occurring right and it turns out that the heart rate variability is a very important parameter when it comes to the analysis of the emotional arousal as well as the emotional regulation.

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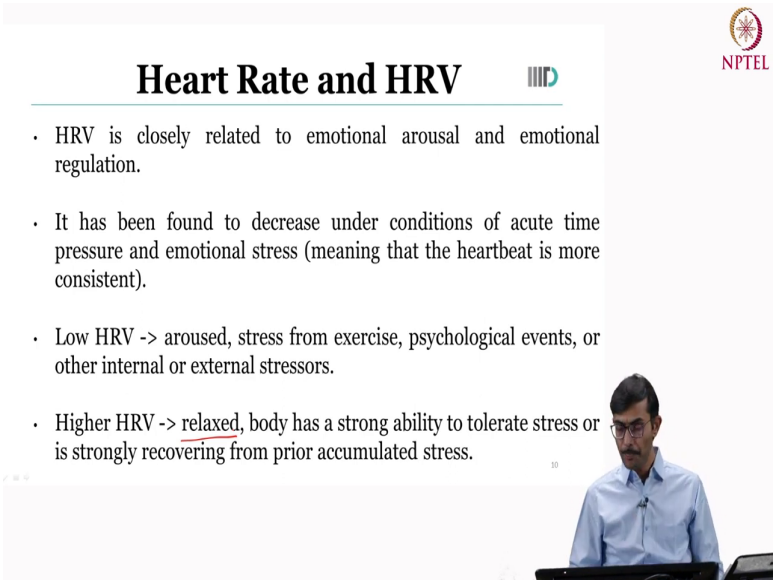

So, for example, it has been found to that heart rate variability to decrease under the conditions of the acute time pressure and the emotional interest stress. What it means that the heart beat is heart beat is more consistent when we are under a lot of stress.

Now, that may sound a bit unnatural, but what it simply means that you know whenever you are having a low heart rate variability, then it simply means that you are not able to cope up

with the stress, because in order to cope up with the stress or in order to cope up with some physically arousing event that is happening around you need.

For example, you need to have more supply of the blood from your heart and accordingly the heart rate should pump at a faster rate right. Accordingly for example, let us say if you are relaxed it should be pumping at a lower rate. So, there should be a good variations in the heart rate at which the heart rates are coming, but when there is no variation low heart rate variability means there is no variation or there is very less variation in the heartbeat.

And accordingly, what it means that you remain stressed you remain aroused and you are not able to cope up with the conditions that are happening around you. Similarly, in contrast if you have the higher heart rate variability. So, not the higher heart rate, but the higher the heart rate variability.

So, higher heart rate variability has shown to be correlated with the relaxed position what it simply means that your body has a strong ability to tolerate stress or is already recovering from a prior accumulated stress. So, and it has been found you can see you will see n number of studies you can come across, n number of studies which has consistently shown that higher heart rate variability is of course, desirable.

Now, I think you have understood that, but more importantly if you have the more healthier you are at least the more healthier your heart is the more healthier you are at the emotional level the higher the heart rate variability you will have not the higher heart rate, but the higher heart rate variability you will have.

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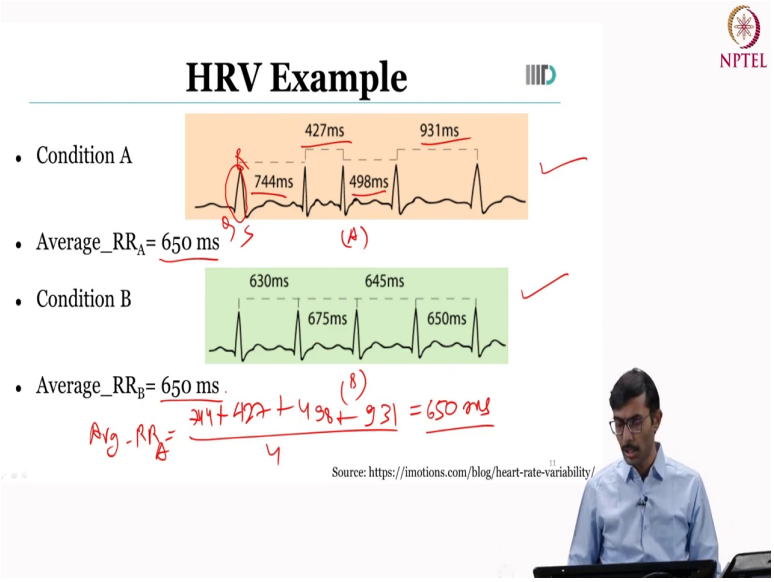

And it has it is such powerful source of information when it comes to the analysis of the emotions in not only the emotional arousal, but the emotional regulations. So, we will see a very beautiful example here. So, for example, imagine that there are two conditions one is the condition A, we will call it this is the condition A and then we will call there is another condition B.

Now, of course, the waveform that we are seeing here what it is giving you, it is giving you let us say the ECG data for certain condition A for a certain period of time and for the same period of time more or less the this B is representing the ECG data for the condition B. Of course, you can see now that this is the this is what this is nothing but this is the QRS wave right. So, you can see that this is the Q this is the R this is the S.

So, basically for the analysis purpose as we say we simply look at the and the R to R interval the distance between the R to R beats and accordingly we try to analyze the beats per minute perfect. So, now let us say these are the two conditions A and B and from the look at from looking at the heart rate we are notable to make much sense out of it. But of course, since we have this intermediate interval what we can do we can calculate the average R, R distance for the condition A and as well as for the condition B.

Now, I hope that this is not hard to understand that how did we calculate. So, for example, if you have to calculate the average for the condition A, then you can simply do it as a for example the average R R A will be represented as 744 plus 427, so 744 plus 427 plus 498 plus 931 right. So basically, all together if you look at this and then if you were to divide this by 4, then this is how you are going to come across 650 milliseconds and similarly you can calculate it for the B condition as well.

And now one interesting thing to observe when we are calculating the average let us say R, R for a condition A condition B that for both the conditions we are getting the similar values 650 milliseconds for condition A, 650 milliseconds for the condition B. So, in this case we are not able to make much make we are not able to make much information out of it.

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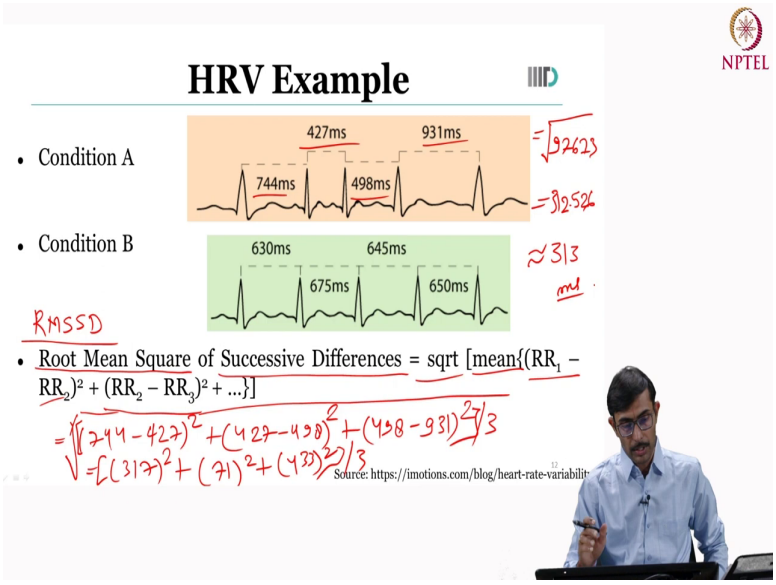

Now, let us try to look at another interesting characteristic which is using the heart rate variability, which is known as the RMSSD so, basically R so ok so this is represented as RMSSD. So, basically RMSSD as the name itself says it means the root mean square of the successive differences and the way it is calculated that you simply calculate the square of the sum of the square of all the RR intervals.

So, for example, you calculate RR1 minus RR2 square similarly RR2 minus RR3 square so on so forth you take a mean of it and then you simply take a square root of it right. So, that is how it becomes root mean square of the successive differences. And then it turns out that the RMSSD has been found to be more informative then let us say the average RR interval.

So, in order to get the root mean square of this thing let us try to calculate. So, the way for example, we will calculate the RMSSD let us try to calculate the RMSSD for the condition A.

So, if you try to calculate the RMSSD for the condition A this is this will be equal to we will have to do 744 this is 744 again minus 427 the whole square plus 427 minus 498.

Of course, since we are taking the whole square, so it does not matter whether we are subtracting the smaller from the bigger or the bigger from the smaller plus 498 minus 931 the whole square and of course you will have to take the first you will have to take the mean of the entire thing.

So, mean is going to become the you will have to take the mean and then you will have to take the square root of the square root of the entire thing. So, let me try to do the complete formula right. So, this is how more or less it is going to look like. So, if you were to if you were to let us say I will try to just you know summarize it here. So, if you were to take the square root and the average of this thing then what is going to be turn out to be?

So, for example, if you look at the 744 minus 427 square, so this will turn out to be 317 the square plus 427 minus 498 it will become 71 square, similarly 498 minus 931 it will become 433 the whole square right and of course, all you will have to take the average of everything.

So, basically this will be the average by 3, so all together it turns out that it is going to become if you take the average if you take the sum it up and take the average then it is going to it will be it will become equal to the square root of 97673 and then it is going to become equal to around 312.526 which you can roughly say that it is become it is equal to the 313 milliseconds perfect.

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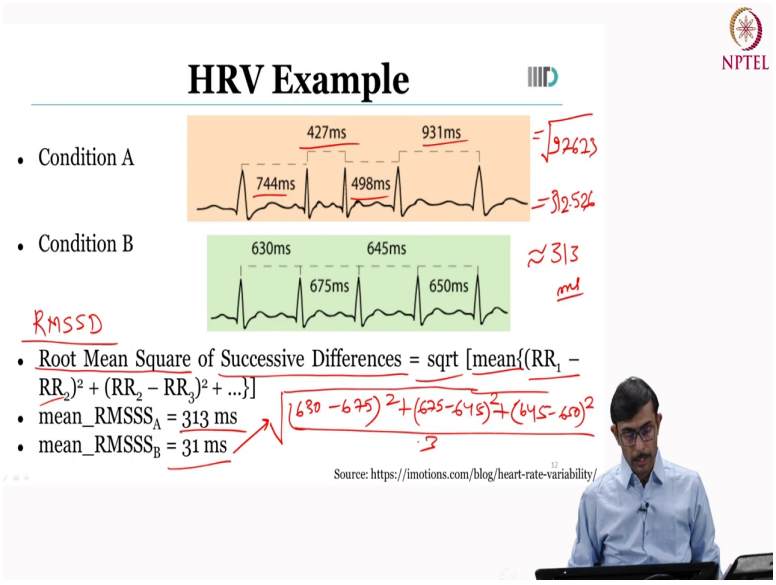

So, this is how you calculate the RMSSD for the condition A. Similarly, you can calculate the RMSSD for the condition B ok. So, let me just try to rub it again, so that you can very clearly look at it. I hope that you can understand now that how to calculate it right.

So, then what you have that you have the similarly you calculated the RMSSD RMSSD or RMSSA for A and in the same way you can calculate the RMSSD for the B. So, for the B what you will have to do again you will have to I will just write it down for you and then rest of the things you can calculate easily.

So, it will become 630 minus 675 the square please pay attention that this is I am calculating for the B and plus 675 minus 655 the square plus and of course this divide by 3 right. So, if

you were to calculate this thing this is going to come out as 31 milliseconds. So, now we have some interesting results here for the RMSSD1 and 2.

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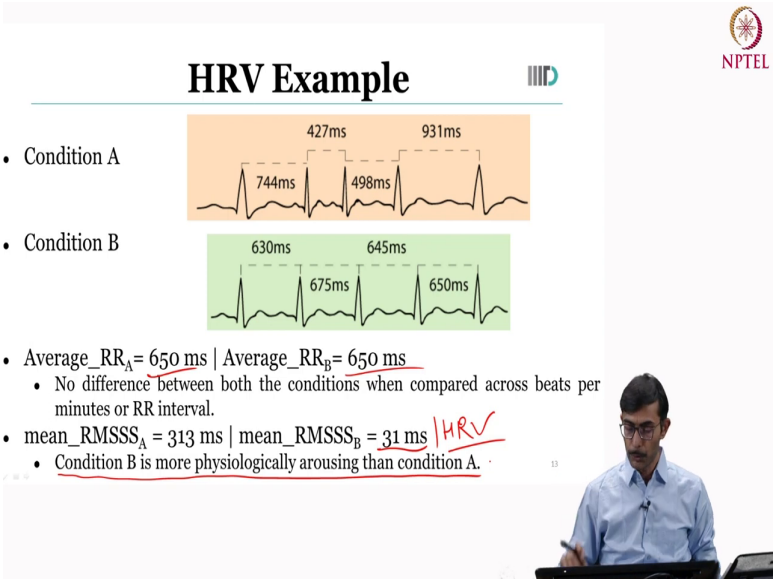

So, again to highlight we have condition A condition B, when we calculated the average RR values for both the conditions, we got exactly the same values even though the conditions are different. But when we calculated the RMSSD, so the RMSSD for A it came out to be 313 and similarly RMSSD for B it came out to be 31.

So, definitely now we can observe a clear difference between the condition A and the condition B. Now, what can we say from the difference between the condition A and the condition B. So, since the condition B is representing the lower heart rate variability, please pay attention to this thing condition B is represent this is what this is representing the heart rate variability right.

So, the condition B is representing the lower heart rate variability and we already know that the lower heart rate variability is associated with the more arousing condition right. So, for the same reason we can conclude that the condition B in this case is physiologically more arousing than condition A. Of course, assuming that this both were observed in the standard conditions and from the same participant right.

So, for example, this is very nice example of how where the heart rate simple heart rate cannot distinguish or discriminate between two conditions, the heart rate variability can easily do so.

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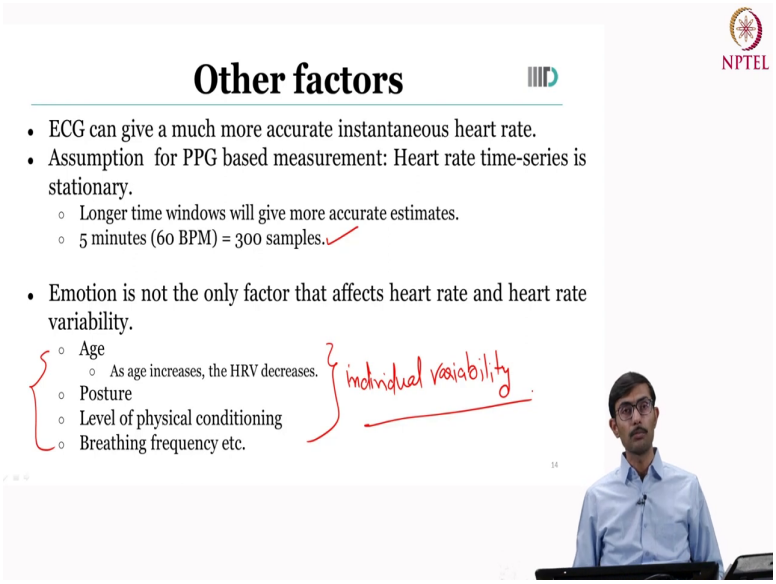

Now, let us try to look at some of the factors that we left before, that we already know that there are 2 ways in which we can capture the heart rate we can capture the heart rate either

using a ECG or we can capture the heart rate using the PPG. Now, we already talked about that how the ECG is bit more accurate measurement of the heart rate than from the PPG.

But of course, we already saw that it is a bit intrusive and it is not very comfortable for the participant. So, for the same reason the PPG based measurements have been used very commonly and it has been shown that if we can take the longer time windows for the analysis of the heart rate for the PPG signals. As derived from the PPG signals then it can give some accurate estimates of the heart rate.

So, for example, one common rule of thumb here is that if you can take the data of at least 5 minutes that is roughly corresponding to 300 samples if we take 60 bits per minute, then roughly 5 minutes of if you take if you do the analysis of the heart rate over a period of 5 minutes as collected from the PPG signals; then roughly it gives you the same accuracy as given by the ECG signals.

So, that is what is one thing that you want to keep in mind, when you are using the PPG over the PPG based heart rate measurement over the ECG based heart rate measurement ok. But and then ok so this was about the measurement one thing that one other important thing that we have to keep in mind that emotion is not the only factor that affects the heart rate and hence the heart rate variability.

So, there are several factors including for example the age, posture, level of physical conditioning, breathing frequency etcetera. And many times, you know so what so we can call it that most many of these factors we often refer to as the individual variability. You may also have observed this term while we were talking about the emotions in the week 2 I believe.

So, the individual very so for example, like with the age as the age increases the heart rate variability it has shown to be decreasing. And this is also one of the reason when why you will see that the elderly people they become anxious more anxious or they become very easily anxious in comparison to the younger adults right.

So that is for example one of the reason and then similarly, the posture of course what particular if you are not sitting in a comfortable posture itself, of course you will have to put more effort your body will have to put more effort in order to stabilize you and for the same reason maybe the heart rate itself will be a will be it will impact the heart rate according and so on so forth.

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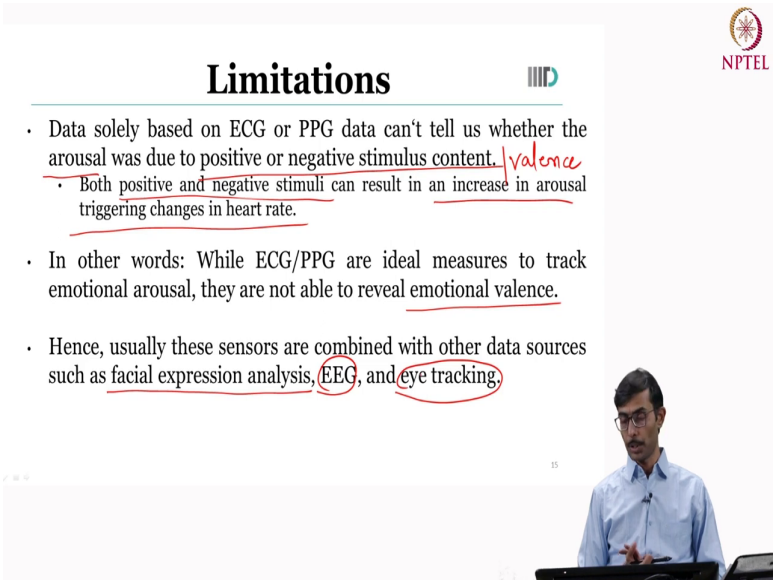

So, you have to keep this in mind while doing the analysis of the heart rate while doing the analysis of the emotions in the heart rate. Nevertheless, once you have overcome this thing then heart rate can give you a good heart rate, can give you a good estimate of the emotional state particularly with respect to the arousal.

But now there is a catch while if you only look at the heart rate it can tell us that ok whether there is an arousal or not, but it will not be able to tell you whether the arousal was because of

the positive or the negative stimulus content or alternatively while it can tell you about the arousal it cannot tell you about the valence, that is the direction of the emotion.

It does not have a lot to say about the direction of the valence and why? Simply because the both the positive and the negative stimuli they have been shown to result in an increase in the arousal triggering changes in the heart rate, hence triggering changes in the heart rate. So, now of course, both heart triggering changes in the heart rate.

And hence they are impacting the arousal, but you do not have a way to discriminate whether the arousal was because of the negative or the positive stimuli or alternatively what was the valence associated with the arousal that I am observing. And hence heart rate has been shown to be closely related to the arousal and then it is used essentially for the analysis of the arousal only.

So, as I said that it you may not want to use the heart rate or the ECG or the PPG measurements for the analysis of the valence, when it come to the when it comes to the analysis of the emotions. Now, the question is what can you do then?

Of course, in this case, you know usually what we do when we try to make use of the physiological signals or in general any other sensor as well, we try to make use of a multi-model data. In this case for example, the heart rate can be simply combined with certain other analysis which is the facial expression analysis that you have already seen.

It can also be analysis with combined with some other physiological signals, such as the EEG or for example, it can also be combined with the eye tracking modalities. In order to understand a bit more about the direction of the emotion rather than just trying to understand the emotional arousal content that is there in the emotion.

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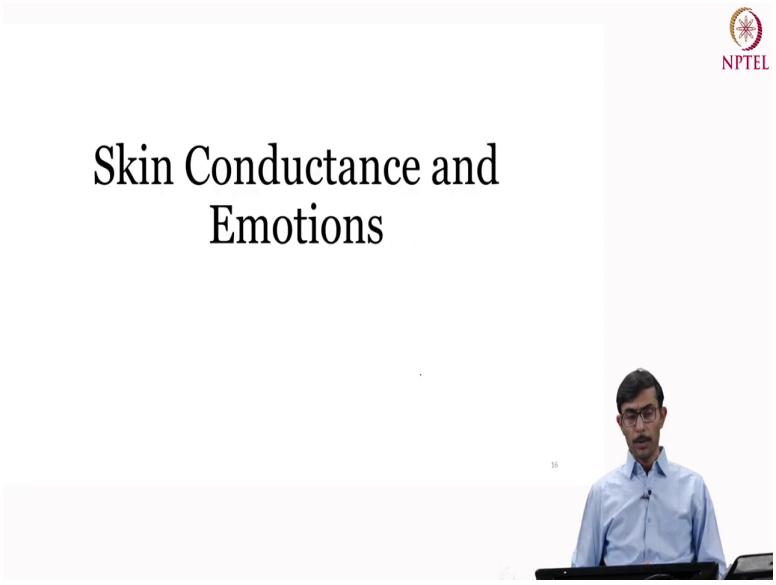

Perfect. So, with that we finish the part with the heart rate. Now, next we are going to talk about the skin conductance and the emotions.