Multimodal Interaction
Technische Universitat Berlin
Lecture 1.2.3
Hearing Perception

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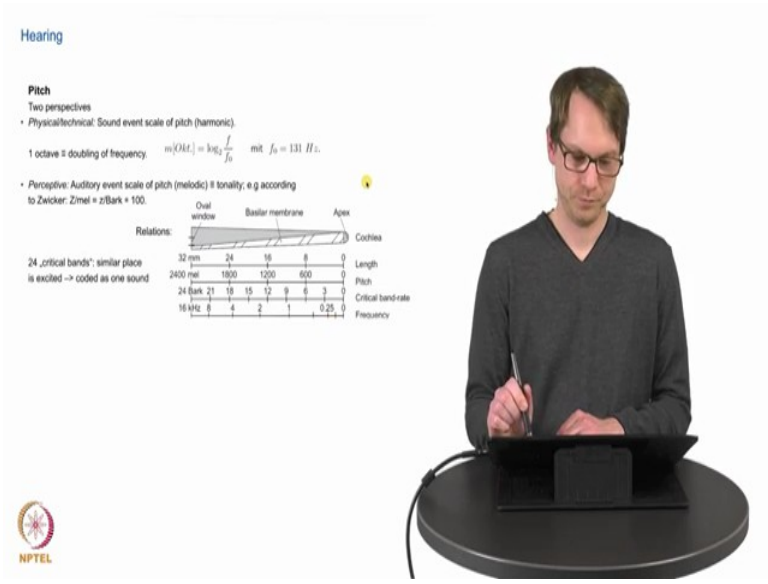

Now I will explain how pitch and loudness perception works. So, for pitch perception, there are actually two perspectives. One is the technical one, we can just measure pitch but of course we can also have a look how we humans perceive pitch, and with pitch I mean the fundamental frequency of our voice or some musical instruments. So pitch is usually measured as the fundamental frequency if we have some complex sound or just the frequency of the sine or cosine sound that is measured by the number of oscillations given a certain time.

For example, per second, but the pitch perception is not linear, this means what you know may be from musical instruments, a doubling of the pitch is usually related to the half of the wavelengths. So this is called as octave. So, we have a logarithmic relation between frequencies and our pitch perception. According to the basilar membrane, we have a relation between the place of the basilar membrane and the perception of pitch. If you have a look here this is the scheme of the length of the basilar membrane from the oval window to the apex and here we have the length in millimetres and according to that two kinds of scales related to pitch perception and here we have the actual physical or technical scale the frequency. So, just because our basilar membrane has a certain shape we do not have a linear pitch perception.

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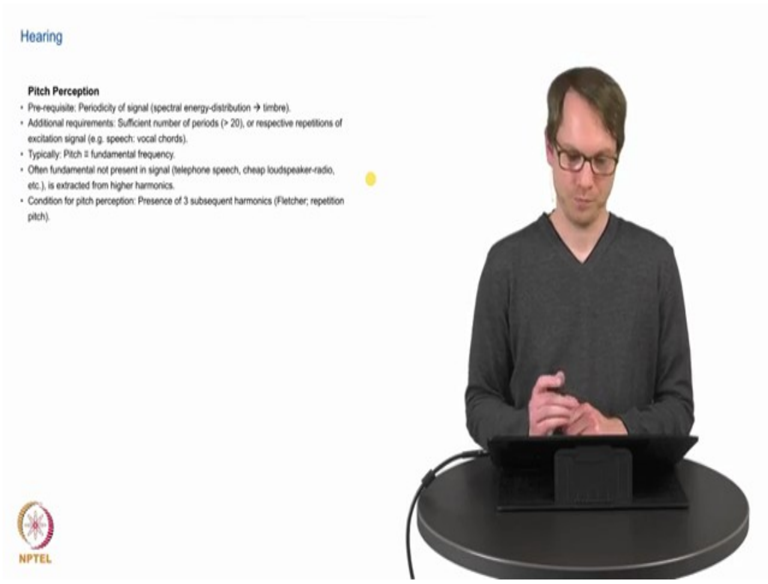

In order to perceive pitch, we need actually need some oscillations to estimate the pitch that a certain sound, maybe human speech or an instrument has. That does not mean that we have to perceive the whole pitch. Imagine for example the telephone speech which is highly filtered and the actual pitch of for example the male speaker is not present anymore because it is actually filtered, but we can still estimate the pitch of this person if we have three subsequent harmonics.

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So how is the relation between the measured frequency and the perceived pitch? You can see this here. We have two mechanisms going on here which are mixed in a certain way so the dotted line is the logarithmic relationship between the frequency of a sound and the pitch perception and this line is a linear relationship between the frequency and the perceived pitch. The solid line is now what we actually perceive and this means that we have a rather linear perception until let us say 500-600 Hertz and then what we have is the mix of two mechanisms and then we have a algorithmic pitch perception. And this is just related to the shape of the basilar membrane at least dominantly so.

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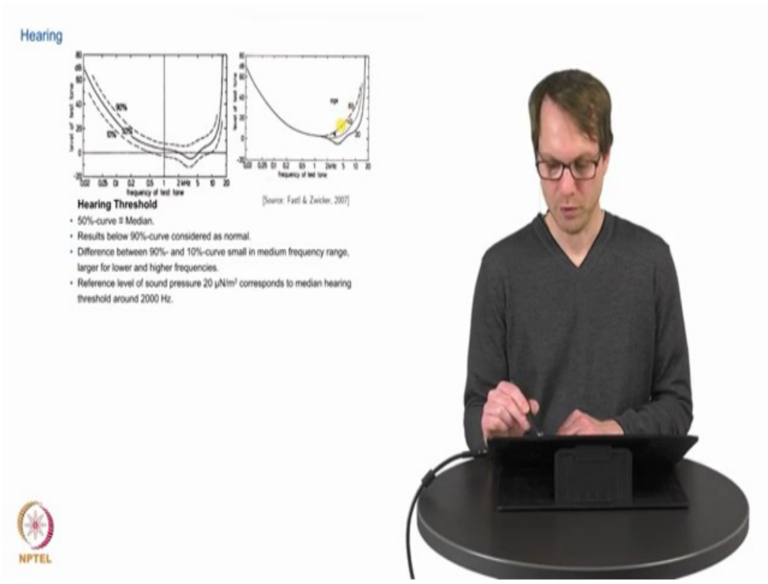

But there is an interesting relationship between pitch perception and loudness perception. Because depending on the frequency of a sound we may perceive it as better or worse and as I said already at the beginning that our capabilities are limited to 16 kilohertz or even 20 kilohertz, if you are really healthy adults. This is the so called hearing threshold and it means with the solid line a line of similar when we actually start to perceive pitch at all. So when we start having auditory event.

So, this is the frequency axis and this is the intensity in decibels. And it shows that we have some kind of standardization according to 2 kilohertz and relating to that we have a worse perception of loudness depending on the frequency region, which means the higher and the lower the frequency gets, the more intensity we need in order to perceive this frequency part at all.

And here is a small bubble and you remember maybe the numbers of this frequency region is about 3 to 4 KHz and again this sensitivity in the hearing threshold is directly related to the length of the ear canal. And I said earlier as well, with age we lose our capability in the higher frequency region which is related to the strong intensity and all the frequencies that are passing as a travelling wave of the beginning of the basilar membrane of the oval window. This is also nicely shown here that people with younger age have a much more lower, a lower, hearing threshold than older people on average.

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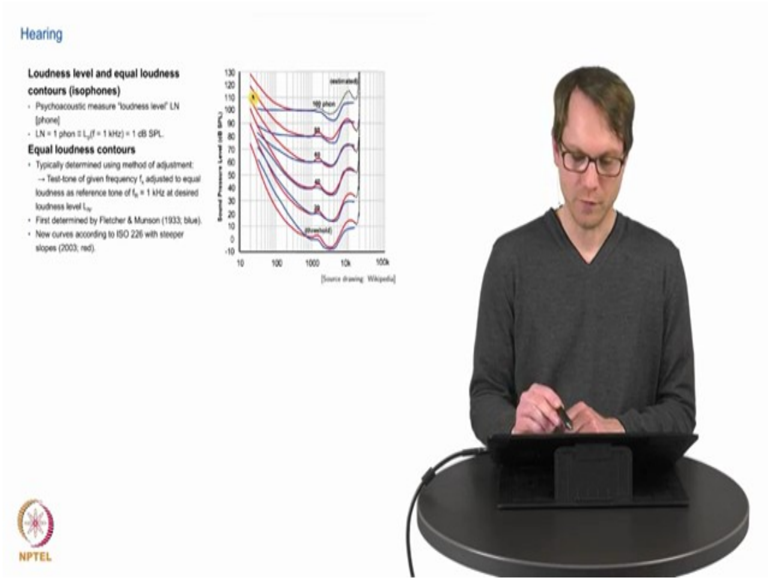

But the hearing threshold is also, only, one of the lines of equal loudness perception. There are other lines called as isophones and then they just tell us from perceptual experiments which intensity we need on different frequency tones in order to perceive the different frequency stimuli the different tones, at the same amount of loudness. So, this one consider the red ones because they are the newer ones, this is the hearing threshold again but also for rather low tones and here for really loud tones and intensive tones, we have this kind of isophones. These are just assessed by asking people please take this tone of 100 Hz and make it as loud and as low that it fits the kind of reference tone for example a 2 kilohertz.

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So, these isophones are a nice way to find out how hearing especially loudness hearing related to pitch is working, but it does not constitute any scale. So we don’t know whether the 20 decibels or the 40 decibels sounds are related in a certain fashion to each other. And therefore we have different methods to find a scale of loudness. There are two methods to do that. The so called magnitude estimation works that we present actually tones with a different intensity and we let people describe how much they differ.

For example, on a given scale it would be a six of seven, or they could say it is double the loudness of reference tone and the same works vice versa. We have the magnitude production, where we give two, for example, two different tones, a reference tone and another one and we ask people to adjust the intensity of the loudness of the other tone so that it fits a given statement concerning the reference tone, for example double the loudness.

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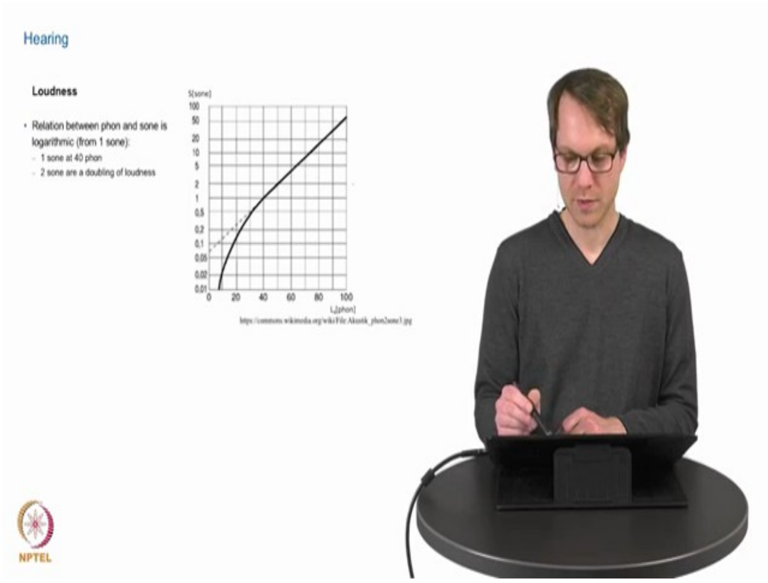

Here is a plot of the relationship between the intensity in phon so this would be for example at a given frequency, 40 dB, the dotted line and the sloid line shows the relationship to the perceived loudness. In this case the scale is called sone and remark please that this is a logarithmic scale. So again, we also have here, a kind of logarithmic scale at least in parts of the whole values that we have.

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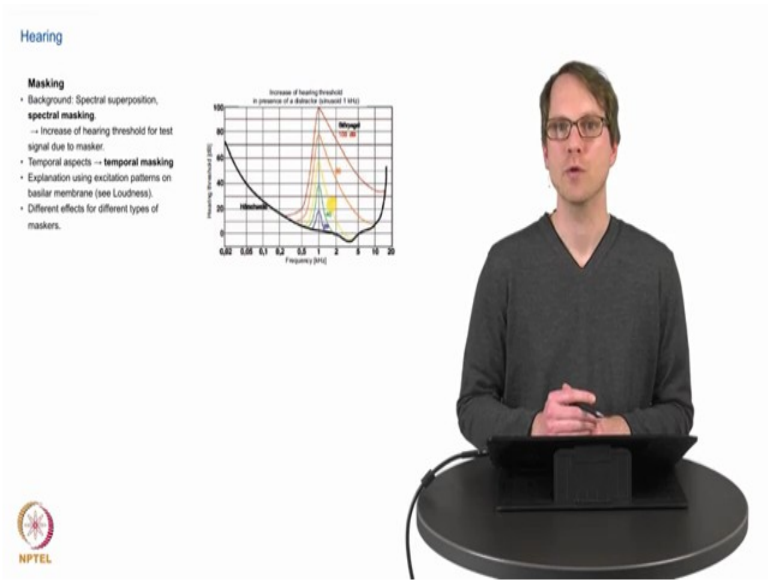

Now in sound perception there is some masking effects going on and they are related to pitch and intensity or loudness perception of a sound. If we come back to the hearing threshold again, masking occurs if we have a so called masker and under this curve if we have a second sound in the same frequency which is related to the frequency of the masker, the masker here always has 1 kilohertz, this secondary tone, will not be perceived if it falls by intensity and frequency under this certain area. And as you can see, the louder the masker gets, the broader in frequency and intensity the masking effect occurs, and this masking, this spectral masking, is directly related to the basilar membrane because the certain cells, the location that are stimulated, are evaluated together so they send they trigger, and fire information through the brain, and if there is a strong movement going on, a strong excitation of the basilar membrane, a related sound with lower frequency to the so called masker will not be perceived anymore as a tone of its own, this will not be heard then.

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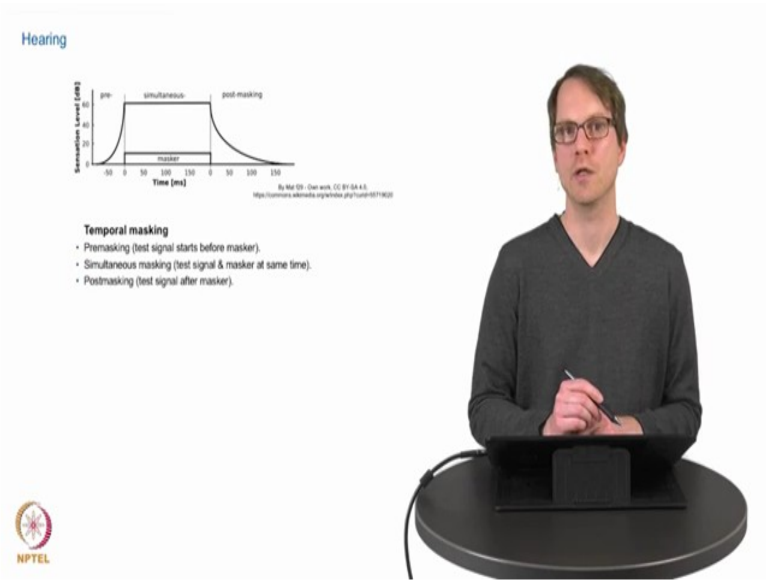

We also have temporal masking. So this means that this spectral masking occurs not only when the two sounds, the masking and the other tone, are at the same time. But if you consider the masking sound as this block, there are will also be masking of a secondary tone, if the secondary tone is after the masking tone has stopped, or even before. So, this might be puzzling, but this is the direct consequence of the processing of this information in the basilar membrane and over the auditory nerve and auditory cortex.

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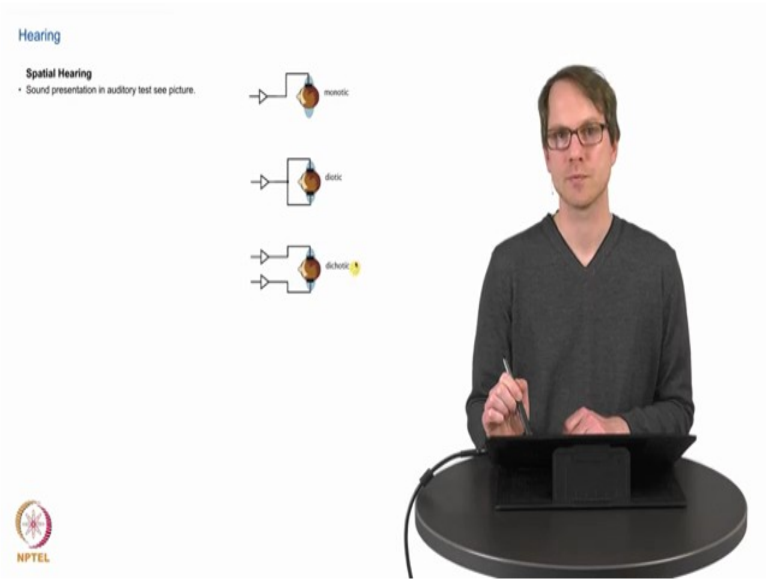

So, if you want to analyse of study how auditory perception actually works, we have three basic designs. We have the monotic presentation of sound, so one sound to one ear; we have the diotic presentation the same sound to both ears and we have the so called dichotic presentation in which we have two different sounds to the two ears.

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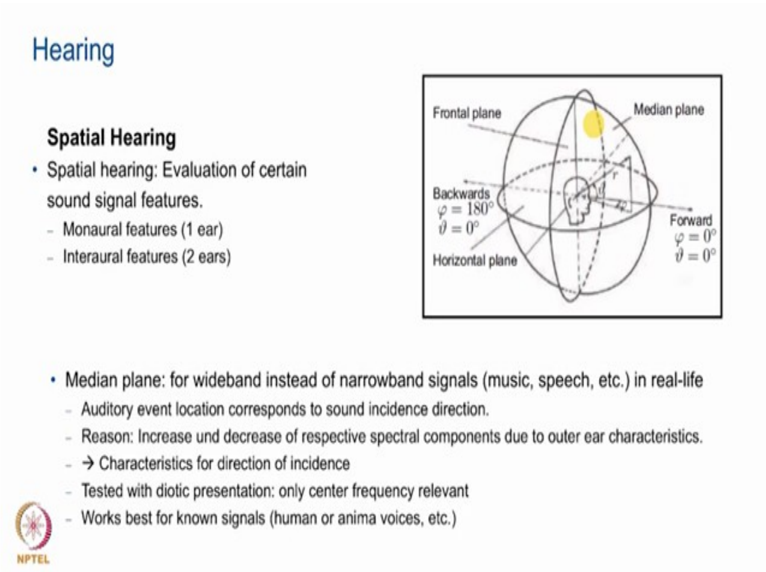

In spatial hearing, as I talked before, the outer ear is really important. But of course we have two ears, not only one. So if we for example look at the median plane, so whether this is above or below the original sound source, how does it work that we actually perceive from where the sound comes from? This is related to the special characteristics of the pinna the outer ear and its directional filtering. So, it really makes a difference whether a sound is coming from above or from the front concerning the filtering mechanism at the pinna.

So, this is the characteristics of a single ear, but if both ears work together, then we have the so called inter aural features. This just means that we perceive and compare the information which are received by the two ears. So, if we have for example, a slight intensity difference, this would indicate that if the right ear is receiving a little bit more of intensity, a little bit louder tone, that the sound source should be located a little bit closer to the right ear. The same holds for temporal differences. If the sound occurs first on one ear as this is usually a strong sign of the signal, that this ear is closer to the sound source. These inter aural features, are the ones that also help us to locate on the so called horizontal plane where the sound source is located.

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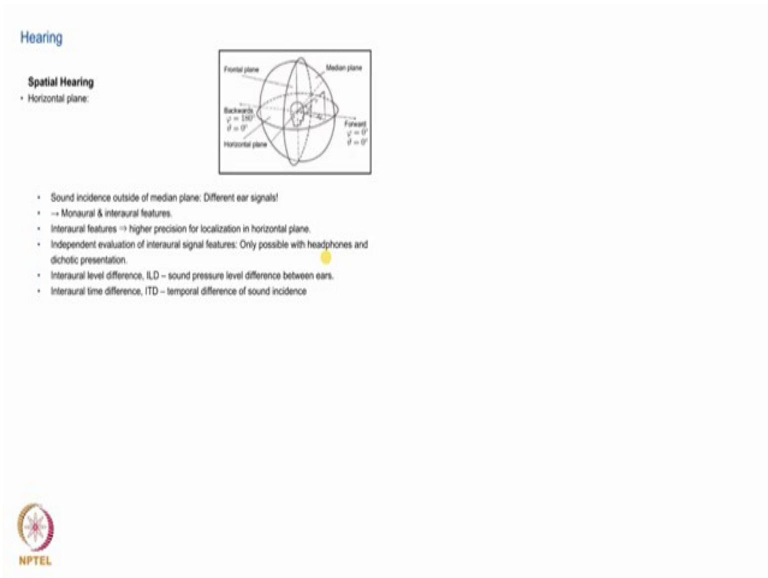

Here you have again the summary of what I have just said. It is important to notice that if we want to study and analyse these inter aural features of the two ears, we have to work with the so called dichotic paradigm that we present simulated or synthesized sounds which are little bit different on the two ears.

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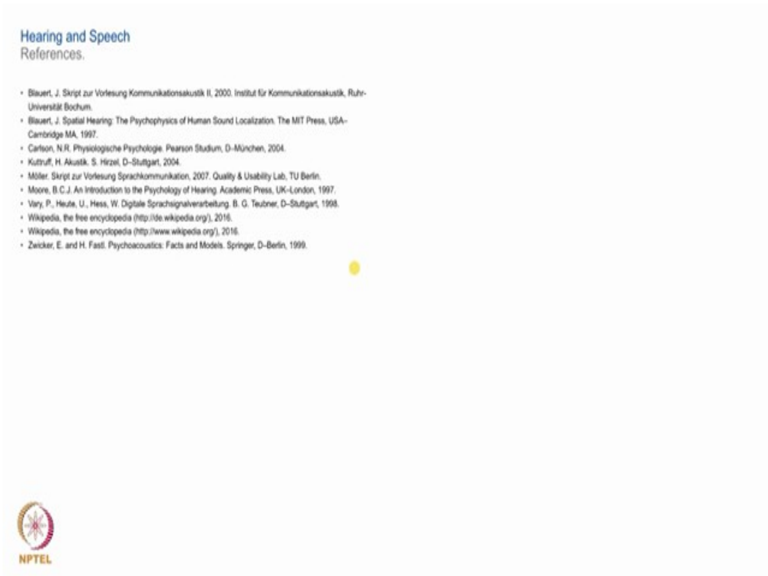

Here’s a list of references. Next week will be about the Vision.