Safety Limits for Aided Music Listening
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- [Moderator] It is my pleasure to introduce our guest speaker, who will be presenting safety elements for aided music listening. Dr. John Boley is a research, a senior research assistant at GN Hearing where he designed psychoacoustic experiments to push the limits of hearing aids. His research involves sensory analysis, experimental design, psychoacoustic and neural modeling, electro acoustics and signal processing. Thank you, Dr. Boley for being with us today. And at this time, I hand the mic over to you.

- All right, thank you. Thanks, everyone, for joining. This will be an interesting topic. Just a few notes here, let me see if I can figure out how to fix the slide, there would be a few learning outcomes. One of the things that I hope we get out of this is you'll be able to describe some of the relationships between hearing loss and vulnerability to further noise induced hearing loss. Also, you should be able to estimate the safety of some specific gain settings based on an individual person's hearing loss. And you should be able to describe some of the limitations of using some of these computer models to actually predict the outcomes.

So with that, let me start with a short introduction to this topic. First of all, I should actually thank Earl Johnson for triggering some of these thoughts. We wrote a paper together for the Audio Engineering Society, presented at a conference last summer. It was a conference specifically organized to discuss music induced hearing disorders. So if you're interested in any of the details, that I don't have to get to today, feel free to check out that paper. Basically presenting the same content that I presented at that conference. In general, the motivation is to figure out how to provide safe music amplification. The idea is for music listeners with a hearing loss, we may want them to be able to turn up the volume, for example, with hearing aids. But it's really not clear how much amplification is too much for listening to music. And we certainly want to avoid any additional hearing loss that might resolve from too much amplification.

So let's start by considering an 85dB exposure limit. So lots of organizations around the world have established an exposure limit of 85dB, saying that that is safe. And that generally assumes that you're listening for eight hours a day, and then they consider the effects of if you're exposed to that sound level every day for number of years, what the resulting hearing loss might be. They tried to determine limits based on that. So this 85dB exposure limit, based on eight hours actually corresponds to different limits depending on if you're listening for different amounts of time. So for example here, 85dB, again, A-Weighted limits the amount, the risk of permanent hearing loss, but that is essentially the same, at least in terms of these protocols, same as listening to 88dB for four hours. And this is called an exchange rate. So for every doubling or halving of the time, you get a doubling or halving of the energy or 3dB. And they call that an exchange rate. So again, eight hours at 85 is equivalent to four hours at 88, which is equivalent to two hours and 91dB, or one hour at 94. And the general idea with trying to define these limits is that after 40 years of getting exposed to this daily, you want to limit the excess risk. And so that's the risk of getting a substantial hearing loss as a result of that noise exposure.

And these limits were defined based on an excess risk of 8%. So they said they didn't want more than 8% of the population to get a resulting hearing loss from this noise exposure. So that means the other 92%, any additional hearing loss is minimal. And only 8% of the population gets a noise induced hearing loss. But what about those with pre existing hearing loss? This all assumes that most of the people start out with relatively normal hearing thresholds. Of course, over the course of time, we do expect some age related hearing loss, and so we're looking at additional hearing losses as a result of the noise exposure. But what if the user starts out with some amount of hearing loss to start out with, it's not really clear what the exposure limit should be. John Macrae in the early 90s did some research looking at hearing loss due to over amplification. And in general, he found that for people with less than 60 decibels of hearing loss, they were generally saved with, safe with the prescribed amount of gain.

For those with 60 to 100dB hearing loss, they were expected to experience some temporary hearing loss. Again, as a result of the prescribed amplification. And for those with more than 100dB of hearing loss, they might actually expect some permanent hearing loss as caused by the amplification. But this is actually all based on sound field levels of 61dB, which is roughly equivalent to soft speech. So if we're thinking about safe exposure to music, we may actually need to consider higher levels than this. And therefore, the risk of over amplification may actually be greater.

So again, our goal here is to figure out what safe levels might actually be for amplified music, and to define some safe exposure limits. I should mention here that long term average level is known to not actually predict music induced hearing loss. In fact, if you look at some of these studies, you see that music tends to actually result in less temporary threshold shifts than noise. So, noise is more damaging than music, in general. So if we actually consider some of these computer models that I'll skip discussing, that are based on noise induced hearing loss, then we're actually providing a conservative estimate for music induced hearing loss.

So the first model that we're going to look at is something that's been standardized by the International Standards Organization, ISO 1999. And this predicts population hearing thresholds has a combination of two things. First, the hearing threshold levels due to age, and then on top of that, some noise induced permanent threshold shift. The other model that will be looking at is this modified power law from Humes and Jesteadt. And this model predicts some temporary and permanent threshold shifts, and it's based on repeated exposures to steady state noise. And just to some background, this is really just based on the additivity of those noise exposures based on Stevens' power law.

So, with this first experiment, we're using this, the ISO 1999 model, again, looking at population. And here we're going to be modeling hearing loss as a function of previous noise exposure. So if you look at the output of this computer model, you see that as your total noise exposure increases, well, let's see, your total exposure as the number of years increases, we expect more, and more you're hearing loss. So the blue curve, the lowest curve here, you see, as you increase, it actually starts with five years of disclosure going up to 40. The median hearing loss barely increases. And this slight blue curve, or just call it the blue curve represents an exposure of 85dB, eight hours a day for that duration of 40 years. So pretty small expected hearing loss. And again, that actually corresponds to the median shown on this curve, and 8% of the population will actually experience meaningful hearing loss according to their definitions of what is meaningful. But you can see as we increase the noise level to say 95 with the red curve, or 105 or 115dB, we see that the hearing loss does accumulated with time.

Now if we plot this a little bit different, and plot this, instead of total exposure as a function of just the previous exposure, we can look at how much additional hearing loss you're getting compared to what you had say the previous year. And you could see that the additional hearing loss that you get relative to your previous hearing loss is actually decreasing over time. That is an important point. We'll dig into a little bit here.

So now let's plot it in a slightly different way. So instead of additional hearing loss as a function of time, let's actually plot it as a function of your previous hearing loss. You can see that as your previous hearing loss increases, the expected amount of additional hearing loss decreases. And so what I'm plotting here is actually say, how much additional hearing loss you can expect from an additional 10 years of exposure at a given level. So for example, if we look at an exposure to 105dB, the yellow curve, for somebody that had previously a 40dB hearing loss, we would expect an additional 10 years exposure would roughly correspond to maybe 3dB more hearing loss. And again, this is just for the median of a population. So in general, we see that with the previous hearing loss, the additional amount of hearing loss is reduced.

Now let's consider an example of hearing loss. If we model a pre existing threshold as a noise induced hearing loss, in this case, I modeled a 20 year exposure at 100dB every day for eight hours a day, and this is the resulting hearing loss you'd expect from that. The dark black curve represents the median and the gray region shows a distribution around that from the 10th to the 90th percentile. Now if we start with this amount of hearing loss, and we add on top of that some additional noise exposure, we want to see what additional threshold shift we would expect to see from that. So let me orient you to this plot here. So this is showing the cumulative distribution expected for different threshold levels. And so this is showing, I believe this is actually shown at a specific frequency, but you can see on the vertical axis is the quantile, so basically zero 200% of the population. And on the horizontal axis, you see the average threshold level in dB hearing level. So if you look at the curve, to the lowest in the left, the blue dash curve, we see for this person, this person is actually 60 years old. This is, well, let me actually specify this is not for a specific person, but this is actually for population of 60 year olds, this is the expected hearing loss. The blue dash curve. So if we consider a hearing threshold of 25dB to be the line between say normal and some mild hearing loss, then we would expect slightly more than 20% of this population to have some hearing loss.

Now if we expand that to say some reference exposure, and so in this case, we're taking a reference exposure to indicate our 85dB limit. So again, 85dB for eight hours a day, and we would expect to see that some people would get an additional hearing loss as a function of that noise exposure. And this is now the red dashed curve. Let's see if I can use my pointer on the screen here. Let's see. So now we see that at 25dB hearing loss, we expect an additional 8% of the population to have some hearing loss as a result of that noise exposure in addition to whatever hearing loss they had as a result of age. So now, let's take instead of starting point, just based on 60 year old, 60 years of age, let's take some starting point defined by some previous noise exposure in addition to maybe some age. In this case, we're modeling it as that 20 years of exposure to 100dB.

So if you look at this equation over on the left, we start with some initial 20 year exposure at 100dB, let's add 40 years of additional exposure to essentially come up with some total 60 year exposure. And let's increase the level of that exposure until we get to some point that causes an additional hearing loss. So what I did there is if you look at this yellow curve, this is the prior exposure. And the distribution here is of course greater, now that we start out with some hearing loss. If we had considered additional 85dB exposure, that you would see that there's no additional hearing loss on top of the yellow line. But now we increase that from 85 to 86dB to 87, and I kept increasing that to plot 97 here. So the purple line represents 97dB exposure. Again for 40 years on top of that initial exposure, and we see that that's actually pretty close to the yellow line. But if I increased it by one more dB to 98dB exposure, you would see that it actually jumps up a little bit.

And so what I did was I defined a target risk. So what I wanted to do was match the 8% that we saw, let's see if I can move this pointer again, the 8% that we saw here, based on the reference exposure, so let's match that target risk for our exposure. And say let's not induce any more noise exposed hearing... Noise induced hearing loss above that point. And so when I saw that 98dB exposure would see that line, I said okay, we'll set the limit at 97.

So in this case, for somebody with the hearing loss we saw on the previous screen, with this sort of audiogram, then the recommended noise exposure limit anyway would be 97dB. So it at least gets us to a starting point where we can start to think about okay, what is an acceptable exposure limit for somebody with a pre existing hearing loss. In this case, we saw that the exposure limit could be safely increased from 85dB to 97. I should mention that this is a conservative estimate, because it actually assumes that the original hearing loss occur due to a 97dB exposure rather than 100db. So in this case, this little plot here represents the exposure over years, where we originally thought to model 100dB over 20 years as the initial hearing loss. And then we compare that to 60 db, sorry, 60 years at 97dB. So our estimate is slightly more conservative.

Okay, let's point here for now. So, the issue is that with this ISO model, it's really not straightforward to model a specific hearing loss. And it's not really straightforward to add amplification, and it's not straightforward to change the exposure level. So to answer some of those questions, we used this other model, this modified power law model. And again, this is a situation in which we can model specific hearing loss profiles. And this is based on the model of Larry Humes and Walt Jesteadt.

So, what we did is we took a bunch of different audiograms, and this is based on a paper by Nicholas Buskerud and Associates, which they proposed a wide variety of audiograms. So we have seven audiograms with flat and moderately sloping hearing losses. So these are referred to as N1 through N7, plotted here in solid, little, solid lines. And then three audiograms with the steep sloping hearing losses. So the dash lines referred to as S1 through S3. And so what we wanted to do was look at what the resulting noise, noise induced hearing loss would be for people that started out with these various audiograms. And then from there, we wanted to apply some amplification.

And then for this study, we just use linear amplification as a simplification. And we'll come back to what this means for compression later on. But it certainly simplifies things a little bit if you can just think about the linear amplification as a simplification here. So in this case, we might look at an N3 audiogram, this mild to moderate sloping hearing loss, and then look at what the resulting in this case we're looking at NAL RP prescriptions. We look at what the resulting gain would be from that. So we looked at all these different audiograms and all the resulting, well first, looked at what the resulting hearing loss would be for different noise exposures with and without amplification. So if we calculate what the maximum sound field would be, for some of these people with different hearing loss profiles, you can calculate what the recommended exposure limit would be. And so these numbers here are based on free field, unaided, and you can see that as the amount of hearing loss increases, also the recommended exposure increases.

So for example, if we look for a normal audiogram, as expected, the recommended exposure limit is 85dB. And then if we look at, say, for example, the N3 audiogram, the recommended exposure limit is 98dB. And again, this is assuming eight hours of exposure in a day. And so the way that we arrived at these limits is to just limit any additional hearing loss to less than a dB, specifically focusing on frequencies from one to four kilohertz. So if the exposure would result in any more than 1dB hearing loss, then we say all right, let's draw the limit there. Now, what happens if we give the user amplification? So again, for normal hearing, we don't expect any prescribed amplification. So again, the recommended exposure limit is 85dB. But now, if we look at some of these audiograms, the recommended exposure limit with amplification is actually quite a bit lower. So for example, again, with the N3 hearing loss without amplification, limit was 98dB, but with the linear prescription, the limit would actually be only 76dB. So something to be aware of there.

So then we said okay, well, instead of looking at the prescribed gain, what would actually be an appropriate gain for each of these people? So calculated, again, limiting the amount of additional hearing loss to just 1dB, we calculated out the maximum gain at each frequency for each audiogram. So again, if we just use the N3 audiogram as an example, we can see that at low frequencies, the acceptable gain to prevent hearing loss is 0dB, going up to 17dB of gain high frequencies. So a little less than the prescribed gain, but certainly some gains seem to be okay, if we're concerned about avoiding any sort of permanent threshold shifts. And again, these gains here are limits, so we don't want to have any more gain than these numbers here. And this represents the difference from the normal, well, let me just put it this way, if you're being exposed to a sound field at the limit, say 85dB for eight hours, this is the maximum appropriate gain for that situation. And of course, we would need to account if the sound field is a different level, or if you're being exposed to a different time, these values may change accordingly.

So what we've seen here is for listeners with hearing loss, the models seem to suggest a higher exposure limit for people with hearing loss. But also that we should be careful to avoid over amplification. So again, these values shown in this table indicate some reference exposure levels that seemed to work well for different amounts of hearing loss. And then we just need to consider for an individual person based on their audiogram, and their exposure level and exposure time, what would be an appropriate limit.

So again, for example, let's consider the N3 hearing loss. In this case, the exposure limit is 98dB. Again, this is for a free field sound, and assuming eight hours of exposure. Now, based on that 3dB exchange rate, we can say 98dB for eight hours is the maximum. But if you're considering 16 hours, then that should be lowered to 95dB. Or if you're considering going from eight to four hours, that would change from 98dB, up to 101dB for four hours. So, hopefully that is clear.

Now, of course, most people aren't getting linear gain, but they're actually getting some sort of wide dynamic range compression. So when we consider the implications for compression, we really want to consider the long term average. So we could consider the actual exposure level and time. So that's where we would take that table indicating the recommended exposure limits, or we could actually look at the gains relative to the normal exposure limits. Of course, there we'd have to consider representative input levels.

So again, just as an example, let's take that N3 hearing loss and say, we have calculated out what the maximum gain should be as a function of frequency for linear gain. But now for compression, we just need to consider the long term average. So in this case, we should be considering the long term average insertion gain. And in this case, say for six kilohertz, the long term average gain should be no more than 17dB. Equivalently, we could look at the... The exposure limit. And here the exposure limit is 98dB. Here we're averaging over frequency. So this is an a A-Weighted signal. So you don't get the resolution but certainly simple to look at a single number. And so you just have to consider what is the average sound level that this person would be exposed to assuming the representative compression.

So for example, if the compression results in an average of let's say, 15dB gain at six kilohertz, that should be okay. But if the long term average gain is 20dB, at six kilohertz, you may be getting into some dangerous situation there. And I should also emphasize that this is really, really concerned about the real ear exposure. So when you're looking at the gain limits, you should be thinking about real ear insertion gain. And then we're looking at the free field limits, this is based on just an average ear canal. And so of course, we do know that there's some variability from person to person in terms of their real ear gain. So that would need to also be taken into consideration.

What is that individual person's real ear gain relative to some average ear? So we looked at two different computers models. The computer models are actually pretty different in the way they function, but we tended to see that they predicted pretty similar exposure limits. So for example, in that first experiment, we looked at what the predicted hearing loss would be. Remember, from 20 years at 100dB, for eight hours a day, the resulting exposure limit was 97dB. Now, if we actually took the hearing loss model from the modified power law, and model the exact same hearing loss, that would predict an exposure limit of 94dB, in the median case. But then when we actually looked at some of the distribution of what the hearing loss would result in, we see that actually, we get plus or minus three in terms of the predicted limit. So pretty similar in terms of the recommended exposure limits there. When we looked at the vulnerability to further hearing loss, we can look at some of the previous research, we see that there are few studies that found reduced vulnerability with pre existing hearing loss.

We also saw that with this ISO model of noise induced permanent threshold shifts. We also saw reduced vulnerability as a function of years of exposure indicating that people with more hearing loss are likely to get less hearing loss as a function of the same noise exposure. But there's one study that seems like it might conflict with that. Let me just mention. So here's what we saw from the ISO model, again, emphasizing that the additional hearing loss decreases as a function of previous exposure. But there is a study in 2012 which at first glance looks like it might actually provide some conflicting evidence, but I think if we dig into it a little bit more, it's actually not so conflicting. In that 2012 study, they saw, let me just quote, they said, we also saw evidence that those with higher hearing threshold baseline suffered a larger noise related decline. And I've seen in some publications, that has been interpreted as saying that, oh, maybe there's actually a likelihood that people with hearing loss are actually more susceptible to hearing loss than those with normal hearing. But I'm not sure that that's the right way to interpret that.

In fact, if you dig into the discussion in that paper, they thought that that could be actually attributed to some individual differences. So if you think about individual differences and vulnerability to sound induced hearing loss, there's been a few studies that show that some people are actually more vulnerable to noise induced, or just general sound induced hearing loss than other people. And so if you think about that, if some people are more vulnerable than others, then we expect a correlation between people with early hearing loss, and people with late hearing loss, essentially. So there should be some correlation between people who start out with hearing loss, and people who end up with even more hearing loss as a function of noise exposure. So I think this study indicates not necessarily conflicting evidence with what we saw here with reduced vulnerability. But actually, just that there are some individual differences that we have to consider. There are a few limitations that we should think about when we're thinking about these. These are computer models, and these are based on lots of epidemiological population studies. Actually, I should mention, before I dig into this, that there was actually a paper that I just discovered, published by the Acoustical Society of America last week, indicating the author was arguing that this ISO model may actually be underestimating the amount of risk for hearing loss.

So there is some apparently some active discussion happening in the literature about some of these computer models right now. But in general, these computer models are intended to predict the risk of a population. So they can't really predict the risk for an individual user, but just tell us what the likelihood is of a hearing loss or a population. Also, we have to consider the excess risk that we're modeling. And here, we matched the 8% as excess risk of some of the existing limits that are out there indicating that we really don't want to allow additional hearing loss in more than 8% of the population. So this is saving essentially 92% of the population, but it is allowing some hearing loss in a small portion of that population. So something to keep in mind. Also, there's a few opportunities for some future work here. And also, this ties in with some of the limitations, here, we only consider frequencies from one to four kilohertz.

So certainly something that I've been thinking about is how we might extend this to a higher bandwidth, consider frequencies both lower and higher than this range. And also, we know that real ear insertion gains often vary, and we've seen measurements indicating by 10dB or more. And so, if we can't do a real ear verification in every person for every insertion, then actually it might make sense to define some more conservative limits than really just based on the median insertion gain, but maybe actually account for some of the variability that we see, and try to define some more conservative limits based on that. I should also mention that this was all based on permanent hearing loss. But the modified power law model also lets us look at temporary hearing loss.

So if we were to look at what the maximum gain would be to prevent temporary hearing loss, we can also generate a similar table. And it would look a little something like this. So to avoid any sort of temporary threshold shift, these indicate the maximum gains. So again, if we look at say the N3 audiogram, the maximum gain to avoid any sort of temporary hearing loss is very, very low, zero to be low frequencies, maybe 4dB of gain at high frequencies. So this tells us that if we want to avoid temporary hearing loss, we probably don't want to apply much gain at all relative to the existing exposure limits. And that starts to get into things like hidden hearing loss.

There's been some suggestion that every time somebody has a temporary hearing loss, there may actually be some related hidden hearing loss associated with that, even if they're temporary thresholds come back to their pre-exposure threshold, there may be some resulting damage that can't be measured by an audiogram. So if we want to avoid that sort of noise induced damage, maybe we should be considering the traditional exposure limits rather than any modification of those exposure limits. Something to keep in mind there. I think with that, that's actually, I kind of rushed through that a little bit. And, but I think, is there any questions? We have... We have some time to dig into some questions there.

So with that, I see that we have at least one question in the chat. Feel free to post any other questions there. I see that Christy asked, did the studies indicate what genre of music and are there differences between types of music hearing aid users listen to? If I remember correctly, there was some correlation between the genre of music that the users tended to listen to, and the amount of hearing loss that resulted. So for example, somebody who tended to like listening to rock music tended to get less threshold shift than users who did not like to listen to rock music. So there seemed to be some correlation based on the types of music that people liked. So there may actually be some kind of cognitive effect going on. Maybe some sort of top down thing where, if you, if you enjoy the music, there's less likelihood of damage. And I would assume that most people don't like listening to noise for long periods of time and so that actually may be one of the more damaging. I think this is definitely an area ripe for more research. It's kind of hard to really draw conclusions from just the two or three studies that seem to be out there. But that does seem to be the general trend in that research so far.

- [Moderator] Thank you, Dr. Boley. This is Christy. We're going to leave the classroom open for just for a few more minutes. So what are you working on next in this area of music and musicians?

- All right, I think, yeah, apologies for rushing through that a little bit quicker than I intended to. Certainly, have some time left for questions. Feel free to. So for me, I think one of the next areas that I'm particularly interested in looking at is for specific hearing aids, what are the actual exposure, yeah, the exposure levels? And try to calculate out some of these things.

- [Moderator] I find it fascinating that it was found that the person with normal threshold can actually stay longer than someone with a moderate hearing loss if they are sitting right to each other. I find that really fascinating, don't you?

- Typical fittings, and try to better understand some of those situations and see if there are ways that we can make sure that we're not exposing people to dangerous levels.

- [Moderator] And Dr. Boley, did they... Did they find how much longer could someone with normal thresholds can stay longer without experiencing an effect or loss?

- Yeah, so if neither of them are wearing hearing aids, the person with the hearing loss could actually stay longer. But with, we definitely saw with the linear amplification there was a danger of wearing those hearing aids in that noisy environment, so. Well, let's actually look back at that, that data real quick. Let's see if I can find that slide. Well, we can use the lower right, of this slide. So the recommended exposure limit for somebody with normal hearing was 85dB. And just for simplicity, let's look at the N1 hearing loss. So the limit there was 89dB. So 85dB for eight hours, for normal hearing, or 89 for eight hours with the N1 one hearing loss. Now if we consider the N1 one hearing loss, instead of eight hours, let's consider 16 hours, that limit go down to 86. And let's see, I guess we can't do 32 hours a day, so we can't go down further than that. But if we go the opposite direction, consider, let's think about the N1 hearing loss 89, relative to normal at 85. Now the normal, the person with normal thresholds instead of 85dB for eight hours, let's consider, let me think about that, am I going in the right direction? Oh, I'm sorry, I had that backwards. N1 hearing loss at 89dB for eight hours, instead of eight hours, let's consider four hours. Now the limit would be at 60dB. So then we'll be comparing normal at 85dB for eight hours, or, four hours for that person would be 88dB. No, I'm sorry, I hit that backwards, again. This is dangerous, you have to make sure you're keeping track of the right direction. 85dB at eight hours, or 82dB for 16, or the other direction, 88dB for 16 hours. Ah, I said that wrong again. I'm gonna have to write this down so I can keep track of with this. All right, I'm writing this down. 85 for eight hours. 88 with higher level, I mean less time so four hours. Or we can go down in level to 82dB and expose for 16 hours. So that was all for for normal hearing. Now for the user with the N1 hearing loss, the eight hour limit is 89dB. The four hour limit would be 92dB. And then the other direction, the 16 hour limit would be at 86dB. So then if we consider after four hours of exposure, somebody with normal hearing could be exposed to at 88DB.

- [Moderator] Thank you Dr. Boley. We do have a question here from Stewart. Stewart asks, what is theory of why additional gain or noise may be allowed for existing loss? And could it be that damage has already occurred at lower level and the additional exposure will not create additional loss?

- Certainly there's this, for both people, there's this 3dB exchange rate and then you just have to consider the relative time that each of them are being exposed to that. But in any case, yes.

- [Moderator] And he added, Stewart added, that is to say why is the ear that has the loss, why does that ear have a buffer for higher hiring.

- Yeah, that's the way I interpreted it is that there's already been some damage maybe to the hair cells or other anatomy or physiology in the inner ear and that in order to create more damage, you'd have to apply more energy to the ear. So yeah, I think that interpretation is the most likely one. Yeah, exactly, if you think about.

- [Moderator] Thank you Dr. Boley, we're gonna go ahead and wrap the presentation. If you wanted to leave any last comments and then I will wrap it up for today.

- Cochlea, if it's already, if the motion is already dampened by some hearing loss by some damage, in order to cause more damage, you would have to present it with a higher sound level and create even more motion to the point that it causes that damage. So that's the way I think about it.

- [Moderator] Thank you Dr. Boley, and for everyone in the classroom here, there's Dr. Boley's contact information if you had any further questions that we didn't get to today. We want to thank you for your time in New York City.

- I think some of the limitations that I mentioned are important to consider particularly that these are just computer models based on some population studies, and most of the numbers here were based on avoiding temporary hearing loss. And if you want to avoid temporary hearing loss, we probably have to do much more.

- [Moderator] Thank you so much everyone and have a great day.