Noise Exposures in America

Presenter: Rick Neitzel, PhD

- [Christy] It's my pleasure to welcome Dr. Rick Neitzel. He's from the University of Michigan School of Public Health. If you'd like to learn more about Dr. Neitzel and all that he's into, you can read about his bio on the course registration page, and at this time I'll hand the mic over to you.

- Great, thank you so much, Christy, and it's a pleasure to be chatting with everyone today. I look forward to spending the next hour with you talking about noise exposures in America. This is an update to a talk I gave a number of years ago and includes some updated information since our learnings about noise have increased in that time. So I will just begin with a couple of disclosures. I am an employee of the University of Michigan. I'm also funded by Apple to support my work on the Apple Hearing Study, which I'll talk about a bit later in our time together today. I don't have any non-financial relationships to disclose, and you can see my other content and sponsored disclosures.

So with those formalities out of the way, let me begin by talking about what I'm hoping you get out of our time together today. So after our one hour interplay here, and again, I will encourage folks to include questions in the Q and A, so I can address those as we go. But by the end of this hour, I hope that you'll have enough confidence to identify trends in noise exposures, but also the health impacts associated with those exposures in America. You'll be comfortable identifying some of the major sources of exposure to noise in America, and you'll also be able to discuss how and what resources are available that you can utilize to promote better understanding of the noise that faces us in this country and indeed around the world.

So we're gonna begin today with a relatively high level discussion of just what it is when I use the term noise and all that entails. We'll shift then into talking about some of the health effects associated with noise, some of which you are undoubtedly aware of, but some of which may be new to you. We'll talk about how we consider and quantify

noise exposure. So in other words, how we assess it to try to understand the exposures that people have. We'll talk about some of the limits and recommendations that are out there to keep people healthy when they're exposed to noise. And we'll also talk a bit about some of the estimates that we have for how many people in the United States might have hazardous noise exposures.

And then lastly, and perhaps most importantly, we'll spend the latter part of our session today talking about some of the options that are available to us to actually reduce noise exposure in America. Of course, as a researcher, part of what I've spent my career doing is documenting exposures, excessive exposures to noise where they occur, which is important, but it's not the end of the story. It's very unsatisfying to just identify that there's a problem we always wanna, in public health, keep an eye on how do we actually solve that problem and mitigate this issue. Just by way of a little more introduction about myself. So I am a professor of environmental health sciences as you heard Christy say earlier, I'm also an industrial hygienist by training.

And so a lot of the work that I've done as an industrial hygienist has focused on keeping workers healthy in the workplace. And I've had the great privilege basically to do that work, protecting occupational health, but also community health in many places around the world. So just to give you a little bit of insight into my background, I've been involved in a study that's gone on for more than a decade, looking at workers who work in aluminum smelters, like the work that you see here. This work is quite noisy, very physically intensive as you might imagine. And we have focused a number of our research efforts on trying to understand the risks to hearing in this workforce, but also critically to understand the impacts of so-called hearing conservation programs that this particular employer implements at their work sites.

Hearing conservation programs being programs that are intended to better understand the risks of exposure to noise in the workplace and actually implement, again, control

measures as well as medical surveillance. On the other side of the Pacific, I've been involved for almost 10 years now in a study looking at informal electronic waste recyclers. So all of you at this point are watching this webinar on kind of electronic device, a phone, a computer, a tablet, whatever that device has a finite lifespan. Of course, we hope, and I would very strongly encourage you to recycle that device at the end of the day so we can get the recoverable materials out of there instead of having to go and mine new minerals and metals.

Unfortunately, oftentimes your device, once you dispose of it, may end up in another country, Thailand, for instance, where I've done my work, getting recycled by informal workers who don't have, let's say, the strongest workplace protection. So we've been trying to understand the impacts to the health of these workers, including their hearing health from recycling electronics, which of course is a green and very necessary activity. I've spent over a decade looking at noise exposures and the risk of things like cardiovascular disease in a cohort of Swedish workers who work in the pulp and paper industry. And so in this case, we've had the opportunity to track thousands and thousands of workers over time and see how their health has been impacted by this work.

I've also done some work in Western Africa and Ghana, specifically looking at informal and artisanal gold miners. And so you might think gold mining is a dangerous industry, indeed it is, but they work with metals, for instance, like mercury, which are known or at least suspected ototoxic. And so in this case, we've looked at what is the risk of hearing loss among these workers from the noise that they have at their work, but also is that risk modified by the fact that they're working with potentially ototoxic chemicals like mercury. I've done some work with emergency responders, firefighters in this case, looking at their risk of exposure to noise, hearing loss, but also injuries associated with noise at a training facility in Illinois.

And then finally, and I'm actually coming to you from the Cupertino campus of Apple as we speak, I'm the principal investigator of the Apple Hearing Study, which is a longitudinal cohort study now in its fourth year where we're tracking almost 200,000 volunteers who are sharing with us information about their exposure to noise from the environment, but also exposure to music from headphones for instance, and how that's impacting their hearing and other aspects of their health. So enough about me, let's talk about the topic du jour here, which is noise broadly. And so, it may come as no surprise to any of you who are here on the webinar, that noise is ubiquitous. It is literally all around us.

It's almost inescapable in many parts of the country. It's quite common both in community settings but also very prevalent in workplaces. And this is not an issue that's restricted only to high income countries like the US, I can confirm from my own travels and own research that noise is just as important, if not a more important threat in low and middle income countries. Now, many of you will be aware that we have environmental regulations in the United States that are designed to protect us from things like pollutants in the air or contaminants in our water or food. Those are very important pollutants and appropriately regulated. Noise is a pollutant as well, we should absolutely recognize that.

But unlike these other air and water and food contaminants in the US, noise in the workplace is not especially emphasized by our federal regulatory agency, OSHA, the Occupational Safety and Health Administration, and community noise is even less of a focus. Unfortunately, it's been essentially neglected by the federal government since the 1980s and essentially relegated to state and local governments to deal with since that time. We'll talk about this more as we go on. So I thought I would just begin by recognizing that noise is something that all of you have undoubtedly experienced in your life. And in fact, when we do surveys of communities to ask what are the common

irritants in your community, which could be things like crime or light pollution or air pollution, noise is almost always right up at the top of that list.

In fact, there's four major sources of noise that are the quintessential irritants for Americans in their community. The first is noise from aircraft. Of course, passenger airliners are the main source there, but there's things like air shows like this photo. Noise from construction sites. So that's temporary transient noise. But if you're near a large site like this, that construction noise may last for a period of years. Noise from roadways, and this is actually a shot from Bangkok, which is one of the most congested cities I've ever traveled to. And then noise from railroads. And I will say, this is my bicycle handlebars were looking over and I sometimes am interrupted on my commute in Ann Arbor by a freight train that comes through.

So those are kind of conventional or traditional issues and sources of noise that Americans have been complaining about for decades. I will say there's a new source of noise that has only come on the scene in the last couple of decades, and I'm gonna try to play this audio. I hope this is reproduced on your end. So I'll encourage you to think what might that noise source be. You can sense it's very cyclical and I'll just note here that I've often asked people this and they'll say, oh, it sounds like maybe a washing machine or a dryer going with that cycle or maybe other machinery. In fact, that's the sound of a wind turbine right at the base of the turbine.

So wind turbines, of course, a green sustainable renewable source of energy, a very important part of our decarbonization approach in the United States. But if you live right near a wind turbine, there's actually noise impacts there. And in fact, the noise you just heard is a vanishingly small amount of the sound that a wind turbine actually puts out. Most of the sound from a wind turbine is infrasound, as you probably well know, that's frequencies that are too low for the human ear to detect, but could still potentially be harmful for us. So we have the traditional threats of aircraft noise,

construction, road noise, railway noise but then we have these emerging threats like wind turbine noise.

And I apologize, it doesn't sound like that audio played your end. Imagine sort of like a sound of a washer or dryer unit. So let's do a quick calibration here just to make sure we're all on the same page in terms of how much noise we're talking about. And so this is a graph from the Federal Aviation Administration. You can find lots of these noise thermometers as I'll call them online. I like this one because it presents some relatively familiar sources of noise, both outdoors on the left, but also indoors on the right. And so I'll highlight at the bottom of the graph here, we have zero decibels, which actually on the decibel scale is the quietest sound that a normal hearing human can perceive at a thousand hertz.

Of course, down here in the green, we have lower level sounds that are not concerning for us, they're sound levels that we've evolved with. When we start getting up into the yellow and orange range here, is where we start to get concerned, at least, in terms of a risk of hearing loss. And so for instance, a vacuum cleaner at 10 feet might be 70 or 75 decibels. That's a number that we'll talk about later in the presentation. A garbage disposal at three feet might be closer to 85 decibels, another very important level to consider. And a blender at three feet might be more like 90 decibels. Now, I'll caution you these noise thermometers are very easy to find online. Some of them are quite inflammatory or just downright incorrect.

So a rock band could certainly hit 110 decibels. On some of these thermometers, you'll see a rock band at 130 or 140 that's inflammatory and not really a supported claim. So I would take these with somewhat of a grain of salt, but I will endorse this one from the FAA as being very empirically based. All right, so let's talk about some of the health impacts of noise. Now, I presumably all of you are working in the area or at least, adjacent to the area of audiology. So I'm gonna go out on a limb and say you're all well

aware that noise is associated with noise-induced hearing loss. that's sort of a duh moment. We're still gonna talk about that a little bit because while we know a lot about noise-induced hearing loss, we don't know everything by far.

You may or may not be aware that noise has other so-called non-auditory impacts. So it can be harmful for other systems in our body beyond just the hearing mechanism. And so the two that I'm gonna focus on today are cardiovascular disease, one of the top killers of Americans and indeed people worldwide and also occupational injury. And so we'll focus on both of those and I'll sort of unpack those assertions a little bit more. Now, we have a relatively short time together, although after an hour you may feel like it's been longer. In fact, I had one of my students tell me, "Gosh, Professor Neitzel, if I knew I only had one hour to live, I'd wanna spend that hour in your class 'cause one hour feels like infinity.

" Anyway, my students are a little saucy sometimes. But I do just wanna highlight that there are many other non-auditory impacts of noise that we won't have a chance to talk about. So noise is increasingly being linked to mental health impacts, things like depression and for example, diagnosis and receipt of prescriptions for antipsychotic drugs. It's maybe associated with endocrine disruption. So the disruption of your hormonal system, it's been linked at least in some studies to things like preterm birth and low birth weight. It's absolutely linked to cognitive impacts, learning deficits in children, maybe dementia in older folks. Certainly it's linked to sleep disruption, it's linked to stress. So lots of additional impacts of noise that we unfortunately won't have time to talk about today, but I at least wanna get on your radar.

So when it comes to noise-induced hearing loss, this again, I'm assuming is something that everybody on the call is probably more than passingly familiar with. So you probably know that chronic exposures to sufficient levels of noise cause metabolic changes in the hair cells, the sensory organs within the cochlea. And that those

metabolic changes over time can lead to cell death, and that ultimately that leads to noise-induced hearing loss. So that's the mechanism for the vast majority of hearing loss we see from noise. But you are also undoubtedly aware that there's an alternative mechanism for damage called acoustic trauma, where if you have extreme exposure to very intense levels of sound, even for the briefest of periods, you can get mechanical damage essentially shearing off of those cochlear hair cells and resulting again, permanent irreversible hearing loss.

I'm assuming everybody is aware that we test hearing and determine the threshold at which you can hear a sound using audiometry. And I will just highlight here the key feature that we look for to define and identify noise-induced hearing loss is the so-called audiometric notch, somewhere between four and 6,000 hertz. Those just turn out to be the region of the cochlea that is most susceptible to sound, basically at the first turn of the cochlea. And then, I'll also acknowledge that tinnitus as well as hyperacusis or extreme sensitivity to sound are not caused by noise-induced hearing loss, but they often co-occur. And so the phenomenon of having either transient or even worse, permanent ringing or whistling or buzzing or roaring in your ears, tinnitus is something that, in fact, a lot of the workers I deal with in my research are much more concerned about than the hearing loss itself.

So I wanna take just a moment and talk not just about the health burden of noise-induced hearing loss, which I think as any practicing audiologist could attest is substantial, but also the economic impacts. And so it turns out that there's an estimated about 13% of the US working population that has a hearing loss. And so one of the studies that we published a number of years ago was trying to figure out, well, what are the costs of that hearing loss in the working population to the economy? In other words, what's the economic burden of noise-induced hearing loss? And so as many of you are likely aware, it turns out that if you have a hearing loss, you are likely

to make about 25% less than a worker of your same age, et cetera, who has normal hearing.

So workers with a hearing loss tend to have lower wages and they're also 2 1/2 times more likely to be unemployed. And so it turns out if the about 20% of the burden of hearing loss in the US that's directly attributable to noise were prevented, then those wage gaps and employment differences would be essentially erased. And we have demonstrated, or at least estimated that we might have an annual economic benefit, sort of north of a hundred billion dollars per year. So money that would be back in the economy if it weren't for this hearing loss that people have accrued. And I will say this estimate, while it's a huge number, is actually conservative 'cause it doesn't consider some of the other costs that you are well aware are associated with hearing loss, things like healthcare being fitted with hearing aids, being tested repeatedly and longitudinally for your hearing, special education for maybe younger workers who are still also in their educational portion of their life.

Okay, so noise is bad, hearing loss from noise is bad. Let's take a moment and talk about some of these non-auditory impacts of noise. And some of you may quite reasonably be asking, well, okay, it's pretty apparent to me that noise comes in the ear and the ear is directly damaged, so I don't need much convincing that that's a direct impact from noise. But what about these non-auditory impacts? And so if we think about a person who is exposed to noise, we'll just use this circle in the center of the figure here to represent a person so that person's gonna have some noise exposure. All of us exist within physical and social environments, we all have different lifestyle factors.

As we're exposed to that noise, some of us might appraise the exposure as being noise, others of us, so for instance, if I'm blaring music in my home at a really high volume, I perceive that as sound, desirable sound, presumably I like the music I'm

playing, but my neighbor next door almost certainly perceives that as noise, so there's a perceptual element here. Regardless of how I perceive it, I'm gonna have so-called vegetative responses. My nervous system is gonna respond to that signal. And then of course, all of us are beautiful and unique snowflakes. We all have genetic differences, we also have acquired characteristics. We're gonna have different sensitivities to noise, different attitudes, different abilities to cope with noise exposure.

And so depending on those personal attributes, that noise is gonna be more or less disturbing to our sleep. It might disturb the activities we do. It might disrupt our performance through cognitive impacts or our concentration. Regardless of whether those impacts occur or not, it can also separately annoy us. And then as we become annoyed and as our nervous system responds, we can start to have so-called somatic responses. So our blood pressure might change, our hormone levels might change, the lipids in our blood may alter in their levels. And those things are pretty strongly linked to issues like cardiovascular disease, but also to psychiatric disorders. So you can see it's not a especially simple picture here, but the idea is all of us are vulnerable to noise and depending on attributes of the noise, but also characteristics of ourselves, some of us are gonna be more or less at risk of some of these non-auditory health impacts.

So let's talk about cardiovascular disease in particular and its linkage to environmental noise. So noise in communities. So what we're looking at here is a graph that was published actually almost 10 years ago now, but hasn't really been replaced with anything better yet. So what we're looking at on the x-axis here are average noise levels over the course of a day. And what we're looking at on the y-axis is the relative risk. So a relative risk of one means there's no increase of cardiovascular disease, and the higher that number goes, the greater the risk of disease. So a relative risk of 1.3 or 1.30 indicates that a person with that relative risk is 30% more likely to suffer this particular health outcome.

Now we've got different colored and different types of lines on this graph. The red lines here represent the relationship between aircraft noise and cardiovascular disease. And the blue lines are between road traffic noise and cardiovascular disease. And so I'll highlight a couple things here. One, the slopes of these different lines are different, which you could take as the impacts of aircraft noise on my blood pressure, hypertension, my risk of heart attack or myocardial infarction or my mixture of stroke. So aircraft noise is gonna have a different risk for me than road traffic noise does. The other thing is, I mentioned that we start to get concerned up at levels around say, 70 or 75 decibels in terms of a risk of hearing loss.

But you can see these lines are intersecting the x-axis at much lower levels, maybe potentially even down into the average of 40 decibel range. Meaning that it's possible that even if our ears are safe from sound, we may still be experiencing a risk of these cardiovascular diseases, even at again, levels of noise which are not sufficient to put our ears at risk, so that's concerning. I think you'll agree. So lest you think it's just me who's pushing this narrative of noise as a cardiovascular disease risk factor, it's not just me. In fact, the World Health Organization has kind of firmly embraced this risk as well. And so the WHO, the World Health Organization, estimates that there's more than a million years of healthy life that are lost every year just due to environmental noise, and that's just in Europe.

So if we extrapolate that out to the world, it would be many, many more years of healthy life lost. And so we can look at how those impacts occur, that's what the graph on the right is. So you can see here that sleep disturbance accounts for the vast majority of that. So trying to sleep in noise, which probably all of us have had to do at some point in our lives, makes for disturbed sleep. And sleep is a very strong, or I should say disturbed sleep is a very strong risk factor for cardiovascular disease. But we've also got issues around annoyance, ischemic heart disease or stroke. We can

think about the impacts of cognitive impairments from trying to learn in noise or having dementia from hearing loss that you got from noise.

And of course, the impacts from tinnitus as well. And I'll just highlight these numbers that you see here are just considering environmental noise. If you have a noisy job as well, that's only gonna increase the burden on public health from noise. In a similar fashion to how I presented the estimates of the economic burden from hearing loss, we published a similar paper looking at the economic impacts of cardiovascular disease. And so this is an analysis where we said, well, how many people do we estimate are exposed at levels of noise that are sufficient to cause cardiovascular disease? We looked at the population at risk, and then we considered, gosh, what would happen if we just reduced our noise exposures by five decibels as a country?

And when we started to add this up, we figured out that if we could prevent, or I should say the fraction of coronary heart disease and hypertension that we could prevent by making the country five decibels lower, that would give us essentially a $3.9 billion boost in our economy. Or looked at another way, a $3.9 billion reduction in the direct economic impacts of cardiovascular disease from noise. So we're talking, again, pretty big numbers here. Now, as an industrial hygienist, my primary focus for much of my career has been noise in the workplace. And so what we're looking at in this graph is a comparison of the risk, again, the relative risk of cardiovascular disease. In this case, acute heart attack in workers in the province of British Columbia, Canada.

So again, a risk of one here, we're not concerned, that basically says that there's no increased risk of acute myocardial infarction from noise. And then the higher these numbers go, the greater the risk. Now as with any type of plot that you look at, where we've got whiskers here, these whiskers indicate the confidence in our estimate. And if the whiskers include one, that means we can't say with statistical significance that the risk is increased. And so what I'd like to highlight here is actually that in this particular

study, they looked at a cohort of folks who were essentially employed in industries in British Columbia, but couldn't really say for sure whether they were using hearing protection or not.

But when we looked at or when the researchers looked at a group of folks who almost certainly were not using hearing protection, then we start to see, oops, apologies. We start to see essentially statistically significant increases in risks. So the folks that we believe had the highest exposure weren't using hearing protection, had statistically significantly increased risk of having a heart attack. And so, if you take very few things away from the talk today, one should be that we don't put too much emphasis on any one epidemiological study because all studies are flawed and have weaknesses. But I hope you'll trust me when I say, there are now many studies that have confirmed and support these findings where people, especially workers who have increased exposure to noise, also have increased risk of these cardiovascular outcomes.

And another way of thinking about that is, gosh, if we could make workplaces quieter, not only would we prevent hearing loss, but we might also cut down on cardiovascular disease. So that's a win-win, I think in anybody's book. So shifting away from cardiovascular disease and now thinking about noise and injuries, which I mentioned earlier, I just wanna highlight here, you might think, well, how is noise in the workplace gonna lead to workers being injured? Well, I'm glad you asked, that's a great question. So we have kind of a conceptual model here that says that workers who are exposed to noise are also a greater risk of hearing loss. So once their hearing is lost, they're no longer possessing the same situational awareness of their workplace.

Noise can also cause communication difficulties, so perhaps workers can't hear warning sounds or shouts from their coworkers. And anytime your situational awareness and communication are degraded in the workplace that places we think at increased risk of injury in the workplace. And I will say there's lots of other factors that

tie into your risk of getting hurt at work. So things like your age, how experienced you are, the company that you work for, whether or not you have tinnitus, whether you're using hearing protection, the stress that you have at work, things like how fatigued you are. So all of those things play a role. In fact, it turns out noise can modify many of those things and place you at increased risk according to our conceptual model here.

So I'll just give you some examples of studies that have evaluated the risk of an occupational injury for workers who are exposed to noise. And so this is a fairly busy table here. We're not gonna look at the whole thing. I'm gonna essentially highlight a few aspects of the table for you here. So this left hand cluster of columns here are workers who suffered acute injuries. In other words, this is not a back strain or something that we wouldn't expect to be related to noise, but rather, someone getting hit by an object or falling, that sort of thing. And then there's serious acute injuries on the right. So these are injuries that are highly significant, more catastrophic injuries.

And so I'll highlight here that if we look at workers stratified by how much noise they're exposed to, our lowest category group here of workers who have an eight hour average of less than 82 decibels have a relative risk of one, they're are comparison group. And so I'll just highlight here that as the noise levels increase for these workers, so does the, excuse me, relative risk, and it becomes statistically significant at the level of 85 decibels as an eight hour average. We also see it's statistically significant when we look at serious acute injuries here. And so we see a similar relationship with hearing loss where workers with normal hearing are less than 10 decibel average hearing thresholds are our comparison group.

And workers with hearing worse than that are at statistically significant increased risk of injury again in the workplace. So that's one example of a study. Here's another one that considered not only hearing loss and injuries, but also tinnitus. So our question, and I was one of the authors on this study was does having tinnitus or not influence or

change that risk of injury? And so we see a very similar situation here where workers who experienced any injuries have increasing risk with increasing noise level on the job. That's true for all injuries, also true for serious injuries. Again, we see the same thing that workers in this case with truly normal hearing of less than 25 decibels as a four frequency average have a lower injury risk than workers with hearing impairment.

And then, I think most interesting thing on this table, if we go down to these bottom four rows, so we can look at the risk of workers who have no tinnitus and have normal hearing, that's our reference or comparison group, or no tinnitus and some hearing loss, or tinnitus and no hearing loss, or tinnitus and hearing loss. And so this last group here, so these are workers who have tinnitus and also have hearing that's greater than 25 decibel average hearing level, you can see they have a statistically, significantly elevated risk of injury. That's true for all injuries. It's also true for serious injuries. So reframing this or repeating it a little bit, if you're a worker and you have a noisy workplace, of course, you're at risk for hearing loss.

You're also at increased risk of injuries. And if you have a hearing loss and tinnitus, you risk of injuries goes up even more. So again, thinking about prevention here, if we can make workplaces quieter, not only can we prevent hearing loss, but we might reduce the number of injuries that workers have too. Again, that's kind of a win-win scenario, which I'm always striving to identify. All right, so let's take a few minutes here and we'll talk about how we actually assess noise in the environment around us. And so most everybody, in fact, I would say everybody in the world at this point has a variable noise level over the day. So sometimes you're commuting to work or you're working out and your spin class and noise levels are very high, other times you're sleeping at home and they are much, much lower.

So all of us have time varying noise exposures, and that's a difficulty for those of us who assess exposures. Historically, we focused more on what is your average

exposure over some period of time, maybe the eight hours that you're at work or the 24 hours in a day. And the way we've summarized that, so again, we have a noise profile that's gonna change over time. The way we summarize that is taking an average, and we call that the equivalent continuous average noise exposure level. It's quite a mouthful, we just call it the LEQ. And so this is basically the foundation of how we assess noise exposures. So the LEQ, when we use it essentially assumes that all periods of time that you're exposed are contributing equally to your risk of hearing loss or cardiovascular disease or whatever.

So the LEQ is basically what we strive to use in the workplace. However, when we're thinking about community settings, it's important to consider that not all times of the day are equal, right? So assuming you're a worker who works day shift like I am, then the daytime hours when you're awake are maybe a little less sensitive to you than the nighttime hours when you're trying to sleep. And so to account for that, many decades ago, the day-night noise leveler LDN was developed. And so this is basically in an average an LEQ over the course of the day, but there's this 10 decibel penalty that's added to the nighttime hours of 10:00 pm to 7:00 am, basically making those hours seem noisier than they are in reality, according to the device that's making the measurement.

And so this essentially just penalizes noise during those traditional sleep hours, recognizing that people are more vulnerable when they're trying to sleep than when they're awake during the day. So again, those are the two common metrics that you'll hear referred to in noise, the LEQ, just a straight average, and then the day-night noise level, which treats night levels as being more sensitive than daytime time. So I wanna just pause for a moment and recognize it, really, if you remember nothing else from this webinar, and I hope that's not the case, but if it is, there's really just one critical concept I'd like you to understand about noise. And that is that actually for noise and every other type of environmental exposure you might have, whether it's a pollutant in

your air or a contaminant in your water or a pesticide on your apples, there's three things that are equally important for us to understand your exposure.

One of them is how often that exposure occurs, that's the frequency of exposure. The second is how long does that exposure last when you have it, that's the duration. And the third is the intensity or the level of the exposure. So if I were to paraphrase those, the three critical things we need to know is how often are you exposed for how long and how much exposure do you get when that happens? So I bring this up because without information about all three of those attributes of exposure, we really can't make an accurate estimate of how much noise a person is happening or how much exposure to particulate matter in the air they have or how much exposure to radon in your drinking water from your well at home.

So how often, how much, and how long are the key things we need to know. And if we don't know a couple of those things, we can't possibly make an accurate estimate as to how much exposure a person has, and then we can definitely not hope to make an informed estimate of how at risk they might be of some health impacts. So let's talk a little bit about limits that are out there for noise. When we think about noise in the workplace or occupational noise, I've already alluded to the Occupational Safety and Health Administration or OSHA. And OSHA has what's called a permissible exposure limit for noise. So this is a legally enforceable regulation, so OSHA can come in and cite and find an employer if they break this rule.

And OSHA's PEL is a 90 decibel average over an eight-hour work shift. So that's about as loud as pushing a gas powered lawnmower around at three feet for eight straight hours. Now interestingly, even OSHA will confess that this limit, this legally enforceable limit is not sufficiently protective of workers hearing. And so if you're exposed right at that allowable limit that OSHA says, is the safe level, one in four workers, excuse me, are gonna have a substantial permanent irreversible hearing loss after a working

lifetime of 40 years. So lemme just repeat that. 25% of workers exposed at this allowable limit will end their career with a hearing loss. Now, if you think about other chemicals that we're exposed to, so the EPA starts to get concerned if it's one in a million people exposed who are getting cancer from a carcinogenic chemical, one in a million seems reasonable to me.

One out of four workers being permanently irreversibly harmed by noise at work, that's our safe limit, it's absolutely outrageous. And so virtually every other country on the planet has abandoned this OSHA permissible exposure limit and adopted a more protective limit but this is and remains the law in the United States. Now, if we look at environmental noise on the flip side, the Noise Control Act of 1972 that was passed by Congress gave the EPA, the Environmental Protection Agency, the power to regulate noise in communities. So Congress said, hey, EPA, if you find a problem, you can regulate noise in construction equipment or noise from transportation equipment or anything that has a motor or an engine or any electrical or electronic equipment.

So it's a quite broad and powerful mandate from Congress to the EPA to deal with noise in America. Now, EPA responded to Congress by establishing what was called the Office of Noise Abatement and Control or ONAC. And between 1972 and 1981, ONAC actually created limits that are still in effect today that limit how loud a garbage truck can be, how loud medium and heavy trucks can be on the road, how loud motorcycles can be, for instance. This office essentially put the US on the map in terms of being the leader around the world in assessing noise and also controlling it. Now unfortunately, when the Reagan administration came into office in 1981, they looked at this particular office and said, this is a great example of government overreach, who's the government to tell us how loud a lawnmower can be, for instance.

And so the Reagan administration, one of their first acts in office, was to defund this office within the Environmental Protection Agency, and it has never been refunded

since. Which essentially means we've still got all these laws on the books. The EPA is still legally obligated to assess and control noise in America, but they haven't done that since 1981. So we have this regulatory void where the agency that's supposed to be protecting us, the EPA is doing exactly nothing on noise. It's problematic. I think you'll agree. Now, during the time that that office was active at the EPA, they established some recommended limits. And so the EPA identified a level, an average daily level over a 24-hour period of 70 decibels or less as being completely protective against any hearing loss, even in the most sensitive individual.

So we can treat that as a truly safe level. It's very unlike the OSHA regulatory limit that says, sure, if you aim for this, only 25% of the workers exposed are gonna get a hearing loss. Here, the EPA has said, there will be zero hearing loss from noise if we keep everybody's daily average below 70 decibels. So that's a limit around hearing loss. The EPA and the World Health Organization also have other recommendations for not preventing hearing loss, but reducing annoyance, promoting healing in hospital settings, establishing good learning conditions in classrooms. And those limits are much lower, somewhere between say 30 and 55 dBA is an average. So let's talk a little bit now about how many people are actually exposed to noise in America.

It may come as no surprise, just given what I've said so far that our estimates of the workforce that's noise exposed are woefully out of date. In fact, the last national scale measurements we made of workplace noise in the US were from the early 1980s. Perhaps you're young or if you've forgotten what the 1980s looked like, it was a very different time. You can see from this photo, it was a very dark time from a fashion perspective. I'm shuttering involuntarily looking at this picture. So our workplace noise estimates are way outta date. And it's true also for our community noise estimates. Really those have not been updated since the 1980s, back when the population of the US was about 200 million people.

Now, as you may be aware, we're more like 340 million people in the United States. So when it comes to workplace noise, specifically the current estimate that our National Institute for Occupational Safety and Health or NIOSH, which is a federal health and safety research agency, the current estimate from them is somewhere between 20 and 25 million US workers are exposed regularly to hazardous noise. It probably comes as no surprise that there's some industries that are pretty well understood to be noisy industries like being in the armed services, being in the transportation industry, manufacturing, construction, mining, agriculture, and increasingly the service industry. So the next time you stop at a coffee shop, take a look at what the baristas are doing in there, and you might be shocked at how much noise exposure they have from grinders and blenders, et cetera.

As much as we understand about the workplace, we understand much less about community noise exposures unfortunately. Now here, the University of Michigan and in fact my particular laboratory that I direct, we grew dissatisfied with the circumstance and we developed a tool that's now publicly available that you could use to better understand noise in any particular workplace or industry. So we developed what's called the Job Exposure Matrix for noise in the US or Canada. For obvious reasons, we just called that the noise JEM for short. And so this, again, is an online tool. You can see the link at the bottom that's publicly available free of charge where we've compiled over 1.2 million noise measurements that we got from OSHA, from the Mine Safety and Health Administration, from researchers, from labor unions, from the published literature.

And we compiled into a data set. And so now really for the first time, we can start to evaluate how are noise levels changing in this country over time. And so you can see if we go back to 1983 and fast forward to today, in fact, there has been a reduction in sound since OSHA first passed, what's called the Hearing Conservation Amendment in 1983. And MSHA, the Mind Safety and Health Administration, tightened up their noise

limit in the year 2000. And so again, this is good news where we can see compared to 1983, the country is quieter than today. But certainly, we still have many jobs that are well exposed or I should say exposed well above the allowable limits.

So that's kind of the workplace trends that we're looking at, in terms of the community, as I said, it's much less certain. What I've done in this graphic is essentially adapted the EPAs 1981 estimates of how many people were exposed above 65 decibels as a day-night noise level from different sources, from industry, from construction, from railroads, from airplanes, and from road traffic. So the blue lines, or excuse me, the blue bars here represent EPAs 1981 limits. The red bars are just those limits updated to reflect our much larger US population today. And so you'll note that with one exception, we think that noise levels have gone up, or I should say exposures have gone up in America, in terms of the number of people exposed, comparing today to 1981.

The one success story that we've had is air transportation, where you can see, we estimate that there is a much smaller number of people exposed to high levels of air traffic noise today than there were in 1981. And I'll talk about that more in a moment. One of the takeaway messages from this slide though is that there's about 104 million Americans or more who we think are at risk of noise-induced hearing loss just from noise in their communities. So that's one out of three Americans maybe at risk of hearing loss, again, just from noise around them in their community. Now, I mentioned air traffic as our, well, I won't even say rare, it's really our only success that we've had over the past 50 years, which is pretty disappointing.

So it turns out noise exposures from aircraft of a level greater than 65 decibels is a day-night noise level have fallen 90% since 1981. And so that's huge. It's gone from about 4% of the US population in 1981 to much less than 1% or much less than .01% in 2007. And that's despite the fact that we're flying way more, there's been a sixfold

increase in the number of person miles that we're flying today compared to 1981. Now why is that? Well, in fact, this is a one example where the government stepped in. In the '60s and '70s, there was a transition happening from old prop jet airline, or excuse me, prop airliners, propeller airliners to turbo jets and finally turbo fan engines.

And so as planes got louder when jet engines were added, people in communities around the airports started to get angry and annoyed, started to complain to their policy makers, and those policy makers turned to the Federal Aviation Administration and said, my people are angry at how noisy airplanes have become, you need to fix this. And the FAA, then turned to Boeing and Airbus and other airplane manufacturers and said, you're gonna make your airplanes quieter if you wanna keep your airplanes flying in America. And so the FAA said, I don't care how you do it, but you will make your airplanes quieter by the early 1980s if you wanna fly them, and if not, they won't be allowed to fly in the US anymore.

And the industries, the manufacturer said, oh, my God, you're gonna put us out of business. This is technically infeasible, it just can't be done. And they turned around and did it. And so we moved from old turbojet type engines, which were much, much noisier to new turbo fan type engines. You can see this is me, thankfully not about to get sucked into that engine. So they figured out a technological fix that the government mandated and it made our country much quieter. So I think this is a great example of where regulation can make all of us healthier. Speaking of transportation noise. So here's another tool that's available to you publicly. This is what's called the National Transportation Noise Map from the US Department of Transportation.

And so the yellow spidery network of webbing that you see on here is estimates of noise from the US road system. You can also see around major cities, there's a little bright red or even purple cluster that tends to be major airports, which are even larger sources of noise. And so this is now as of about six years ago when it was launched,

our first national map linking community noise sources like railroads, airplanes, and road traffic to actual exposures in the community. So this is a big leap forward for our country. And again, you've got the link to the map in the bottom of the slide there. So maps can be helpful, but they don't tell us everything.

A map can tell us what an exposure might be for a person who lives in a certain area, but it doesn't tell us anything about that person's job or their hobbies or other things that might influence their exposure. And so here I just wanna introduce for a moment the Apple Hearing Study. So this is a study that we're running at the University of Michigan, launched in November, 2019. And in this study we are tracking almost 200,000 people over time and assessing their noise exposures and the impacts that they have from hearing. And so our goals here in this study are to understand what's the relationship between listening to, for instance, music on headphones and your hearing health that we get via volunteers sharing this information from their iPhones.

And the second thing is if they have an Apple Watch, the watch can measure the environment around them and we can see how their environmental noise is linked to their hearing health. And so this is a totally virtual study. Participants in the US can download the Research App from the App Store, and then that's the way that they interact with our study team. They end up getting randomized to one of two arms of the study. The first one being like any iPhone user, these participants can look at their phone and review, well, how loud are my headphones? How loud is my environmental sound? And if they are in our second arm, they actually get prompted to look at that information.

And they're also prompted to take tests to look for temporary threshold shifts in their hearing after loud exposures. And so the only way they interact with the study is through this app, which can be downloaded. Again, we're still recruiting into this study, can be downloaded from the App Store. So this is a study where everybody who's

participating chooses exactly what kind of data they wanna share or not share with us. Only we at the University of Michigan have identifiable data, Apple doesn't have access to that. We're administering to the folks in the survey, or excuse me, in the study regular surveys, so they can tell us a bit about themselves. We're giving them hearing tests through their app on their phones.

We're doing pure-tone audiometry, Speech-in-Noise, we have a novel tinnitus matching task. They're also sharing their sound exposures from the environment if they have the watch and from their headphones through their phone. And we're also getting measures of heart rate and heart rate variability, so we can start to look at cardiovascular impacts. Just to give you a sense here of some of the results from our study. This was an update that we published earlier this year where we're now able to estimate across the 50 states and US territories, what fraction of our participants and what estimate of the population of the states are exposed to hazardous noise. We can start to do things that we've never been able to do before, like rank the states and territories in order of noisiest to quietest.

Again, all this is available at the website there at the bottom. We can start to look at things like demographic factors. And in fact, our analyses so far suggests that Black and Hispanic Americans actually have higher exposures than other racial groups. So this starts to suggest perhaps an environmental justice issue. I see we have a question here about the noise app from Apple. So it is actually called the Research App. So if you go to the Apple App Store, you can just type in Research App and if you download that app, it will give you access to one of several different studies that you can read about and then choose to join or not. So thanks for that question.

Using our data, we've also been able to figure out that there are differences by age groups. So our oldest participants of 60 years or more are much quieter than our loudest group, which I thought would be the youngest group, but actually turns out to

be the 35 to 44-year-old age group. And then we've seen very similar exposures between males and females. So all information that really is unprecedented at this national scale. We have been able to look at environmental sound exposures over time. And so this is going all the way back to the study launch in November, 2019 and then forward to today. And you'll see in March and April, 2020, we had this substantial decline in exposures from the environment.

That of course was the pandemic lockdown. So we actually observed, not intentionally, but just because the study was going on, that there were major changes reductions in sound in the environment during the pandemic lockdowns. And that the exposures over time differ between age groups. We actually saw the exact same thing among headphone users. Surprisingly, it took longer for headphone exposures to come back to the pre-pandemic levels than it did for environmental exposures. So moving along here, I wanna wrap up by talking about options for reducing noise in America. So I'll present to you three different possibilities that we have here. One is direct regulation where we actually dictate how much noise a particular source can emit.

The second is information that we can provide to the public to educate them. And the third is altering the built environment that we live in. So that first option, direct regulation would be the government setting a maximum noise level for different noise sources, just like they did with the aircraft manufacturing industry. I will argue this is the only intervention that has a long-term guaranteed success because it requires reductions. This is well within the power of the Environmental Protection Agency. The states can also move in this direction, but they're limited in fact, by the fact, that EPA technically has jurisdiction here. Now of course, local municipalities can establish noise ordinances to say, during what hours of the day can businesses produce what levels of noise.

Those certainly exist, they can be very effective, but they're also pretty hard to establish and enforce. But an example of one over here from the City of Yonkers in New York is essentially a ban on gas powered leaf blowers that basically says these are noisy, you can do the job other ways. You can't use these during certain months of the year. So the second option here is altering the informational environment. And so this would be things like product disclosures. Imagine a label on the devices you buy that tells you how loud they are. Of course, they're useless if the consumer, you and I, the customer can't actually understand them, so they need to be simple and straightforward.

But we've seen this be very effective with tobacco. Some of these very blatant in your face warnings on the bottom of tobacco labels. And of course, anytime we have product disclosures and labeling, we're gonna need some education so the public can make sense of the information they're being given. We can also think about doing things like noise mapping so we can understand what is the spatial variation of noise. We looked at a national map from the Department of Transportation. Here's a local map from the city and county of San Francisco trying to understand the impacts of street noise throughout the city and identify, well, what areas might have homes that we really should try to reduce the sound levels of through intervention.

So creating a map like this, you can start to estimate, well, how many people are actually at risk of hearing loss or heart disease or whatever, and where are the areas that we need to target our interventions. Here's a snapshot of a great website. So I encourage you to visit the site at the bottom of the slide here. This is an interactive tool where you can look at Los Angeles International Airport, LAX, and it will actually track in real time the airplanes taking off, the airplanes landing into LAX. And you can see this network of sensors here that actually update in real time with how loud the noise levels are in these neighborhoods. So this is an educational tool that the public can access.

It's also a compliance tool, so the airport can use this to find airplanes that come in and violate the noise ordinance around LAX. So I think this is a great example, it's a fun site to spend some time on. Now, our third noise control option is altering the built environment. So this would be redesigning the way we build our buildings, accounting for acoustics in a much more thoughtful way. Many of you will probably be aware of the LEED certification for buildings, so Leadership in Energy and Environmental Design. LEED does not account for sound in any way. So wouldn't it be cool if when you were building a green building, you also got held to account for how much sound is getting into the occupants of that building?

And of course, we can think about how we design our environment. We can put up barriers to keep the noise on the expressway instead of in the neighborhood next door. We can think about putting in better insulation or better windows on nearby homes. We can design roads that have specifically tailor made quiet pavement. Lots of different options available to us there. So in terms of public health ramifications, just wrapping up here, I'm gonna argue that we need a very holistic approach to noise to truly protect public health. We've documented, but still need maybe more data on the fact that exposures to noise are quite substantial and they're widespread in the US and indeed around the world.

We know that your risk of health outcomes from noise is cumulative. So it's not as though your ears say, oh, that noise is from your headphones, it's not harmful in any way. We have to consider your voluntary headphone noise, your involuntary noise from the community, et cetera. And we have to consider that noise is cumulative over your lifetime. And so all of these things are complicated, but they're all things that we have to account for. I see we've got a question here about which statement is true regarding how many Americans have noise exposure. So I mentioned earlier there was a slide

that focused on the number of Americans today compared to 1981 that are exposed to excessive levels of sound.

So you wanna scroll back to that slide when you get an opportunity. Hopefully it's become apparent that understanding exposures to noise is actually surprisingly challenging. We wanna know what sources are out there exposing people, but we also wanna know, well, what's happening to individuals? Again, considering the fact that some people shoot guns, some people have other noisy hobbies, some people have very noisy jobs, each of which is an independent risk factor for health impacts. And obviously we need interventions. I mean, we have definitely enough information at this point to know that there is too much noise in this country and we should be taking steps to reduce those noise levels. So as promised, we are now done here.

I'd love to take additional questions if there are some, I can take them live right now, of course, or if you wanna send me an email offline, I'd be happy to answer that. I'll encourage you, if you're interested at all in this topic, you can visit our laboratories website where we have free publications available and other information. And I've got a few other websites on here that have information that's relevant to workplace noise exposures and then information from the CDC on more public noise exposures. So I think with that, I will stop talking for a moment here and keep an eye on the Q and A box. I do wanna thank you though before I turn it over to you for questions.

Thank you for your time and attention this afternoon. I hope this has been helpful and I certainly also welcome any feedback that you have. So thanks, everybody.

- [Christy] Thanks so much, Dr. Neitzel. We'll go ahead and open the floor. There's no questions or comments just yet, but we'd like to thank you for your time and your expertise. This has been a great update. I know it's been at least four or five years

since your last talk on audiology online, so a lot has changed and I'm so glad that you were the one that could give us the update.

- My pleasure. Thank you, Christy.

- [Christy] We don't have a question, but Margaret, one of the participants in the live class said, she just wants to say thanks, great talk. Thanks for your comment, Margaret.

- Yeah, thank you very much.

- [Christy] All right, thank you so much, Dr. Neitzel. We'll go ahead and close the classroom. Again, if you're having any issues with exam, please reach out to us and we'll be happy to coordinate that with you through customer service. Have a great day everyone.

- Thank you.