

The Science of Hearing, Balance & Accelerated Learning | Huberman Lab Podcast #27

This episode I describe how our ears and nervous system decode sound waves and gravity to allow us to hear and make sense of sounds. I also describe protocols for rapid learning of sound and other types of information. I discuss sound localization, doppler effects (sound motion), pitch perception and how we isolate sounds in noisy environments. I also review the scientific findings on binaural beats and white noise and how they can improve learning. Other topics and protocols include tinnitus, sea sickness, ear movement, ear growth and the science-supported ways we can all accelerate learning using \"gap effects\".

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- Welcome to the Huberman Lab Podcast, where we discuss science and science-based tools for everyday life. I'm Andrew Huberman and I'm a professor of neurobiology and ophthalmology at Stanford School of Medicine. Today, we're going to talk all about hearing and balance and how you can use your ability to hear specific things and your balance system in order to learn anything faster. The auditory system, meaning the hearing system, and your balance system, which is called the vestibular system, interact with all the other systems of the brain and body and, used properly, can allow you to learn information more quickly, remember that information longer and with more ease and you can also improve the way you can hear. You can improve your balance. We're going to talk about tools for all of that. This is one area of science, where we understand a lot about the cells and the mechanisms in the ear and in the brain and so forth. So we're going to talk about that a little bit, and then we're going to get directly into protocols, meaning tools. We're also going to talk about ways in which the auditory and balance system suffer. We're going to talk about tinnitus, which is this ringing of the ears that, unfortunately, for people that suffer from it, they really suffer. It's very intrusive for them. We're going to talk about some treatments that can work in some circumstances and some of the more recent emerging treatments that I think many people aren't aware of. We're also going to talk about this, what seems like kind of a weird fact, which is that 70% of people, all people, make what are called otoacoustic emissions, their ears actually make noises. Chances are your ears are making noises right now, but you can't perceive them. And yet those can have an influence on other people and animals in your environment. It's a fascinating aspect of your biology. You're going to learn a lot about how your biology and brain and ears and the so-called inner ear that's associated with balance, you're going to learn a lot about how all those work, you're going to learn a lot of neuroscience. I'll even tell you what type of music to listen to. And if you listen to me, you can leverage that in order to learn faster. Before we begin talking about the science

00:02:20 Protocol: New Data for Rapid Learning

of hearing and balance and tools that leverage hearing and balance for learning faster, I

want to provide some information about another way to learn much faster. There's a paper that was published recently. This is a paper that was published in Cell Reports, an excellent journal. It's a peer-reviewed paper from a really excellent group, looking at skill-learning. Now, previously, I've talked about how, in the attempt to learn skills, the vital thing to do is to get lots of repetitions. You've heard of the 10,000 hours thing, you've heard of lots of different strategies for learning faster, 80/20 rule and all that; the bottom line is you need to generate many, many repetitions of something that you're trying to learn. And the errors that you generate are also very important for learning. It also turns out that taking rest within the learning episode is very important. I want to be really clear what I'm referring to here. In earlier episodes, I've discussed how when you're trying to learn something it's beneficial, it's been shown in scientific studies, that if you take a 20-minute shallow nap or you simply do nothing after a period of learning, that it enhances the rates of learning and the depth of learning, your ability to learn and remember that information. What I'm about to describe are new data that say that you actually should be injecting rest within the learning episode. Now I'm not talking about going to sleep while learning. This is the way that the study was done: the study involved, having people learn sequences of numbers or keys on a piano. So let's use the keys on a piano example. I'm not a musician, but I think I'll get this correct. They asked people to practice a sequence of keys, G-D-F-E-G; G-D-F-E-G; G-D-F-E-G. And they would practice that either continually for a given amount of time, or they would just do that for 10 seconds, they would play G-D-F-E-G, G-D-F-E-G, G-D-F-E-G, G-D-F-E-G for 10 seconds. And then they would take a 10-second pause or rest. They would just space take a space or a period of time where they do nothing for 10 seconds then they would go back to G-D-F-E-G, G-D-F-E-G. So the two conditions, essentially, were to have people practice continually, lots of repetitions, or to inject or insert these periods of 10 seconds idle time where they're not doing anything, they're not looking at their phone, they're not focusing on anything, they're just letting their mind drift wherever it wants to go and they are not touching the keys on the keyboard. What they found was that the rates of learning, the skill acquisition and the retention of the skill was significantly faster when they injected these short periods of rest, these 10-second rest periods. And the rates of learning were, when I say significantly faster, were much, much faster. I'll reveal what that was in just a moment, but you might ask why would this work? Why would it be that injecting these 10-second rest periods would enhance rates of learning? What they called them was micro-offline gains because they're taking their brain offline from the learning task for a

moment. Well, turns out the brain isn't going offline at all. You've probably heard of the hippocampus, the area of the brain involved in memory and the neocortex, the area of the brain that's involved in processing sensory information. Well, it turns out that during these brief periods of rest, these 10-second rest periods, the hippocampus and the cortex are active in ways such that you get a 20 times repeat of the G-D-F-E-G. It's a temporal compression, as they say. So basically, the rehearsal continues while you rest, but at 20 times the speed. So if you were normally getting just, let's just say five repetitions of G-D-F-E-G, G-D-F-E-G, G-D-F-E-G per 10 seconds. Now you multiply that times 20. In the rest periods, you've practiced it 100 times. Your brain has practiced it. We know this because they were doing brain imaging, functional imaging of these people with brain scanners while they were doing this. This is an absolutely staggering effect and it's one that, believe it or not, has been hypothesized or thought to exist for a very long time. This effect is called the spacing effect. And it was actually first proposed by Ebbington in 1885. And since then, it's been demonstrated for a huge number of different, what they call domains, in the cognitive domain. So for learning languages, in the physical domain, so for learning skills that involve a motor sequence. It's been demonstrated for a huge number of different categories of learning. If you want to learn all about the spacing effect and the categories of learning that it can impact, there's a wonderful review article. I'll provide a link to it. The title of the review article is parallels between spacing effects during behavioral and cellular learning. What that review really does is it ties the behavioral learning and the improvement of skill to the underlying changes in neurons that can explain that learning. I should mention that the paper that I'm referring to, the more recent paper that injects these 10-second little micro-offline gains, rest periods is the work of the laboratory of Leonard Cohen, not the musician, Leonard Cohen. He passed away, he was not a neuroscientist; a wonderful poet and musician, but not a neuroscientist. Again, the paper was published in Cell Reports and we will provide a link to the full paper as well. So the takeaway is if you're trying to learn something, you need to get those reps in, but one way that you can get 20 times, the number of reps in is by injecting these little 10-second periods of doing nothing. Again, during those rest periods, you really don't want to attend to anything else, as much as possible. You could close your eyes if you want, or you can just simply wait and then get right back into generating repetitions. I find these papers that Cell Reports and other journals have been publishing recently to be fascinating because they're really helping us understand what are the best protocols for learning anything. And they really leverage

the fact that the brain is willing to generate repetitions for us, provided that we give it the rest that it needs. So inject rest throughout the learning period. And if you can, based on the scientific data, you would also want to take a 20-minute nap or a 20-minute decompress period where you're not doing anything after a period of learning. I think those could both synergize in order to enhance learning even further,

00:09:10 Introduction: Hearing & Balance

although that hasn't been looked at yet. Before we begin talking about hearing and balance, I just want to mention that this podcast is separate from my teaching and research roles at Stanford. It is, however, part of my desire and effort to bring zero-cost to consumer information about science and science related tools to the general public. In keeping with that theme, I want to thank the sponsors of today's podcast and make it clear that we only work with sponsors whose products we absolutely love, and that we think you will benefit from as well. Our first sponsor is Roka. Roka makes sunglasses and eyeglasses, that, in my opinion are the very highest quality available. The company was founded by two all-American swimmers from Stanford and everything about their eyeglasses and sunglasses were created with performance in mind. These eyeglasses and sunglasses have a number of features that really make them unique. First of all, they're extremely lightweight, the optical clarity of the lenses is spectacular. And for the sunglasses, they have this really great feature, which is as you move in and out of shadows, or across the day, the amount of sunshine might change, you always experience the world as clear and bright, and that can only come from really understanding how the visual system works. The visual system has all these mechanisms for adaptation and habituation. You don't need to know how those things work, but the folks at Roka clearly do because you put these glasses on and you don't even notice that they're on. They also stay on your face even if you get sweaty. They were designed to be used while active, so running and biking, et cetera or indoors. One thing that I really like about Roka eyeglasses and sunglasses is that the aesthetic is terrific. Even though they were designed for performance, unlike a lot of sunglasses out there that were designed for performance that look kind of ridiculous, kind of space-age, Roka eyeglasses and sunglasses, you could wear anywhere. The aesthetic is really clean and they have a huge number of different styles to select from. If you'd like to try Roka eyeglasses, you can go to Roka, that's R-O-K-A, .com and enter the code

Huberman to save 20% off your first order. That's Roka, R-O-K-A, .com and enter the code Huberman at checkout. Today's podcast is also brought to us by InsideTracker. InsideTracker is a personalized nutrition platform that analyzes data from your blood and DNA to help you better understand your body and reach your health goals. I've long been a believer in getting regular blood work done for the simple reason that many of the factors that impact our immediate and long-term health can only be analyzed from a quality blood test. And now with the advent of DNA tests, we can get further insight and information into how our metabolism is working, how our brain is functioning, how our endocrine system, meaning our hormone system is functioning. One of the issues with a lot of companies and programs that involve getting blood and DNA tests, however, is that you get the information back, you don't know what to do with that information. With InsideTracker, they make all of that very easy. First of all, they can send someone to your home to take the samples, if you like or you can go to a local clinic. You get the information back and, of course, you get all the numbers and levels of hormone factors, metabolic factors, et cetera, but the dashboard at InsideTracker provides directives so that if you want to bring those numbers up or bring them down, or if you want to keep them in the same range, it points to specific regimens related to nutrition, exercise, and other lifestyle factors so you can really move around those numbers to best suit your health goals and health status. If you want to try InsideTracker, you can go to insidetracker.com/huberman, and you'll get 25% off any of InsideTracker's plans. Just use the code Huberman at checkout. Today's podcast is also brought to us by Headspace. Headspace is a meditation app that's backed by 25 published studies. And in addition to those, there are hundreds of studies showing that meditation is beneficial for our brain and for our body. One of the challenges, however, is maintaining a meditation practice. I started meditating a long time ago, but I found it very hard to keep that practice going. Then I discovered the Headspace meditation app and what I found was that because they have meditations that are very short, as well as some that are longer and some that are much longer, I could maintain my meditation practice. Sometimes I do a short five-minute meditation, sometimes I do 20-minute meditation, I try and meditate at least 20 minutes per day, but sometimes, some weeks, I only do it five times a week and I'll just meditate for longer. So with Headspace, you have the full palette of meditations to select from. If you want to try Headspace, you can go to headspace.com/specialoffer. And if you do that, you'll get a free one-month trial so no cost whatsoever, with their full library of meditations. So that's the best offer that they

have. So, again, if you want to try Headspace

00:13:53 How We Perceive Sounds

and you want to get access to all their meditations for free go to headspace.com/specialoffer. Can you hear me? Can you hear me? Okay, well, if you can hear me, that's amazing because what it means is that my voice is causing little tiny changes in the airwaves wherever you happen to be. And that your ears and whatever's contained in those ears and in your brain can take those sound waves and make sense of them. And that is an absolutely fantastic and staggering feat of biology and yet we understand a lot about how that process works. So I'm going to teach it to you now in simple terms over the next few minutes. So what we call ears have a technical name. That technical name is oracles, but more often they're called pinna, the pinnas, P-I-N-N-A, pinna. And the pinnas of your ears, this outer part that is made of cartilage and stuff is arranged such that it can capture sound in the best way for your head size. We're going to talk about ear size also, 'cause it turns out that your ears change size across the lifespan and that how big your ears are or rather how fast your ears are changing size is a pretty good indication of how fast you're aging. So we'll get to that in a few minutes, but I want to talk about these things that we call ears and some of the stuff contained within them that allow us to hear. So the shape of these ears that we have is such that it amplifies high-frequency sounds. High frequency sounds, as the name suggests, is the squeakier stuff. So low frequency sound, Costello snoring in the background that's a low frequency sound or high frequency sound, okay? So we have low frequency sounds and high frequency sounds and everything in between. Now those sound waves get captured by our ears. And those sound waves, for those of you that don't maybe fully conceptualize sound waves, are literally just fluctuations or shifts in the way that air is moving toward your ear and through space. In the same way that water can have waves, air can have waves. So it's reverberation of air. Those come in through your ears and you have what's called your eardrum. And on the inside of your eardrum, there's a little bony thing that shaped like a little hammer. So attached to that eardrum, which can move back and forth like a drum, it's a little membrane, you got this hammer attached to it. And that hammer has three parts. For those of you that want to know, those three parts are called malleus, incus and stapes. But basically, you can just think about it as a hammer. So you've got this eardrum and then a hammer. And then that hammer has to

hammer on something. And what it does is it hammers on a little coiled piece of tissue that we call the cochlea, sometimes called the cochlea, depending on where somebody lives in the country. So, typically, in the Midwest, on the East Coast, they call them cochleah. And on the West Coast, we call them caw-cochlea, same thing. So this snail-shaped structure in your inner ear is where sound gets converted into electrical signals that the brain can understand. But I want to just bring your attention to that little hammer because that little hammer is really, really cool. What it means is that sound waves come in through your ears, that's what's happening right now, that eardrum that you have, it's like the top of a drum. It's like a membrane, or it can move back and forth. It's not super rigid and it moves that little hammer. And then the hammer goes, doom-doom-doom-doom and hits this coil-shaped thing that we're calling the cochlea. Now the cochlea, at one end, is more rigid than the other. So one part can move really easily and the other part doesn't move very easily. And that turns out to be very important for decoding or separating sounds that are low frequency like Costello's snoring and sounds that are of high frequency, like a shriek or a shrill. And that's because within that little coil thing, we call the cochlea, you have all these tiny little what are called hair cells. Now they look like hairs, but they're not at all related to the hairs on your head or elsewhere on your body. They're just shaped like hair, so we call them hair cells. Those hair cells, if they move, send signals into the brain that a particular sound is in our environment. And if those hair cells don't move, it means that particular sound is not in our environment. So just to give you the mental picture of this, sound waves are coming in, because there's stuff out there, making noises like my voice; it's changing the patterns of air around you in very, very subtle ways; that information is getting funneled into your ears because your pinnas are shaped in a particular way. The eardrum then moves this little hammer and the hammer bangs on this little snail-shaped thing. And because that snail-shaped thing, at one end, is very rigid, it doesn't want to move and at the other end, it's very flexible, it can separate out high-frequency and low-frequency sounds. And the fact that this thing in your inner ear that we call the cochlea is coiled, is actually really important to understand because along its length, it varies in how rigid or flexible it is, I already mentioned that before and at the base, it's very rigid and that's where the hair cells, if they move, will make high-frequency sounds, and at the top, what's called the apex, it's very flexible and it's more like a bass drum. So basically what happens is sound waves come into your ears and then at one end of this thing that we call the cochlea, at the top, it's essentially encoding or only responding to sounds that are like, doom-doom-doom-

doom. Whereas, at the bottom, it responds to high-frequency sounds like a cymbal, [clanging]. And everywhere in between, we have other frequencies, medium frequencies. Now this should stagger your mind. If it doesn't already, it should. Because what this means is that everything that's happening around us, whether or not it's music or voices or crying or screaming or screaming of delight from small children who are excited, 'cause they're playing or 'cause they get cake; all of that is being broken down into its component parts and then your brain is making sense of what it means. These things that I've been talking about, like the pinna of your ears and this little hammer and the cochlea, that's all purely mechanical. It has no mind of its own. It's just breaking things down into high frequencies, medium frequencies and low frequencies. And if you don't understand sound frequency, it's really simple to understand, just imagine ripples on a pond. And if those ripples are very close together, that's high frequency; they occur at high frequency. If those ripples are further apart, it's low frequency. And obviously, medium frequency is in between. So just like you can have waves in water, you can have waves in air. So that's really how it works. Now we are all familiar with light and how, if you take a prism and put it in front of light, it will split that light into its different wavelengths, its different colors, red, green, blue, et cetera. So like the Pink Floyd "Dark Side of the Moon" album, I think, has a prism and it's converting white light into all the colors, all the wavelengths that are contained in white light. Your cochlea, essentially, acts as a prism. It takes all the sound in your environment and it splits up those sounds into different frequencies. So you can think of the cochlea of your ear, sort of like a prism and then the brain takes

00:21:56 Your Hearing Brain (Areas)

that information and puts it back together and makes sense of it. So those hair cells in each of your two cochlea, because you have two ears, you also have two cochlea, send little wires, what we call axons that convey their patterns of activity into the brain. And there are a number of different stations within the brain that information arrives at before it gets up to the parts of your brain, where you are consciously aware. And because some of you have asked for more names and nomenclature, I'll give that to you. If you don't want a lot of detailed names, you can just ignore what I'm about to say. But, basically, the cochlea send information to what's called the spiral ganglion. A ganglion, by the way, if you're going to learn any neuroscience, just know that anytime you hear

ganglion, a ganglion is just a clump, so it means a bunch of neurons. So a clump of cells. So the spiral ganglion is a bunch of neurons that the information then goes off to what are called the cochlear nuclei in the brainstem. Brainstem is down near your neck, then up to a structure that has a really cool name called the superior olive, because you have one on each side of your brain. And if I were to bring you to my lab and show you the superior olives in your brain or anyone else's brain, they look like little olives, even that little divot in them that to me, it looks like a pimiento, but they just call them the superior olive. And then the neurons in the superior olive, then they send information up to what's called the inferior colliculus, only called inferior because it sits below a structure called the superior colliculus. And then the information goes up to what's called the medial geniculate nucleus. And then up to your neocortex where you make sense of it all. Now you don't have to remember all that, but you should know that there are a lot of stations in which auditory information is processed before it gets up to our conscious detection.

00:23:48 Localizing Sounds

And there is a good reason for that, which is that more important than knowing what you're hearing, you need to know where it's coming from. It's vital to our survival, that if something, for instance, is falling toward us, that we know if it's coming to our right side, if it's going to hit us from behind, we have to know, for instance, if a car is coming at us from our left or from our right. And our visual system can help with that. But our auditory and our visual system collaborate to help us find and locate the position of things in space. That should come as no surprise. If you hear somebody talking off to your right, you tend to turn to your right, not to your left. If you see somebody's mouth moving in front of you, you tend to assume that the sound is going to come from right in front of you. Disruptions in this auditory hearing and visual matching are actually the basis of what's called the ventriloquism effect, which we'll talk about in a few minutes in more depth. But the ventriloquism effect can basically be described in simple terms as when you essentially think that a sound is coming from a location that it's not actually coming from. We'll talk about that in a moment but what I'd like you to realize is that one of these stations, deep in your brainstem is responsible for helping you identify where sounds are coming from through a process that's called interaural time differences. And that sounds fancy, but really, the way you know where things are coming from, what direction a car

or a boss or a person is coming from is because the sound lands in one ear before the other. And you have stations in your brain, meaning you have neurons in your brain that calculate the difference in time of arrival for those sound waves in your right versus your left ear. And if they arrive at the same time, you assume that thing is making noise right in front of you. If it's off to your right, you assume it's over on your right. And if the sound arrives first to your left ear, you assume, quite correctly, that the thing is coming toward your left ear. So it's a very simple and mechanical system at the level of sound localization. But what about up and down? If you think about it, a sound coming from above is going to land on your right ear and your left ear at the same time. A sound from below is going to land on your right ear and your left ear at the same time. So the way that we know where things are in terms of what's called elevation, where they are in the up and down plane is by the frequencies. The shape of your ears actually modifies the sound depending on whether or not it's coming straight at you, from the floor or from high above. And so already at the level of your ears, you are taking information about the outside world and determining where that information is coming from. Now, this all happens very, very fast and it's subconscious but now you know why if people really want to hear something, they make a cup around their ear. They essentially make their ear into more of a fennec fox type ear. If you've ever seen those cute little fennec fox things, they have these big spiky ears, they look like a French bulldog, although the fox version version of the French bulldog. This big, tall ears, and they have excellent sound localization. And so when people lean in with their ear, with their hand like this, if you're listening to this, I'm just cupping my hand at my ear, I'm giving myself a bigger pinna. And if I do it on the left side, I can do this side. And if I really want to hear something, I do it on both sides. So this isn't just gesturing, this actually serves a mechanical role. And actually, if you want to hear where things are coming from with a much greater degree of accuracy, this can actually help because you're capturing sound waves and funneling them better. It's really remarkable, this whole system. So you've got these two ears and because of the differences in the timing of when things arrive in those two ears, as well as these differences in the frequencies that certain things sound, or I should say the differences in the frequencies

00:28:00 Ear Movement: What It Means

that arrive at your ears, depending on whether or not the thing is above you or right in

front of you or below you, you're able to make out where things are in space pretty well. So now you're probably starting to realize that these two things on the side of our head that we call ears are there for a lot more than hanging earrings on or for other aesthetic purposes or for putting sunglasses on top of. They are very powerful devices for allowing us to capture sound waves from our environment. Now I have a question for you, which is, can you move your ears? It turns out that unlike other animals, humans are not terrifically good at moving their ears. Other animals can move their ears even independently. So Costello is pretty good at raising his ears, the two of them together, He can't really move his ear separately. Some dogs can do that really well. In fact, sighthounds and some scenthounds do that exquisitely well. Some animals like deer and other animals that really have very acute hearing will put one ear down to a very particular angle and will tilt the other one and they will actually capture information about two distant sound-making organisms, those could be hunters coming after them or other animals coming after them. They are very good at doing this. We're not so good at it. But about 60% of people, it's thought, can move their ears consciously without having to touch their ear. So can you do that? Maybe you should try it. Ask someone to look at you and see whether or not you can do it. The typical distances that people can move it is usually no more than two or three millimeters. It's subtle but can you flap your pinna with just using mental control? If you can, or if you can't, try looking all the way to your right or all the way to your left. Obviously, if you're driving a car or doing something or exercising, don't put yourself in danger right now. But if you move your eyes all the way to your left, which I'm doing now or all the way to my right, you might feel a little bit of a contraction of the muscles that control ear movement. Now I want to ask you this: can you raise one eyebrow? I'm not very good at it, I can do a little bit, but it's mostly by like cramping down my face on one side. And I certainly can't raise my right eyebrow. I can only do my left eyebrow. Trying to talk while I'm doing this, that's why it looks strange. People who can raise one eyebrow very easily, almost always, can move their ears without having to touch them. It's controlled by the same motor pathway. And there does seem to be a small, but statistically significant sex difference in the ability to move one's ears. Typically, men can do this more than women can, although plenty of women can move their ears as well. Now, if you think that is all a little strange or off topic, it's not because what we're really talking about here is a system of the brain, but also of the body of the musculature for localizing things in space. And so you might find it interesting to note that one of the things that we share very closely with other primates,

with non-human primates, like macaque monkeys and chimpanzees, if you look at their ears, their ears are remarkably similar to our ears, or rather our ears are remarkably similar to their ears. The eyes of certain monkeys like macaque monkeys are remarkably similar to human eyes. This is one of the reasons why, if you look at a baby macaque monkey, it has this unbelievably human element to it. But the ears of these primates is very similar to our ears; our ears, similar to their ears. If you're interested in ear movements and what they could mean and some of the things that ear movements correlate with in other aspects of our biology, there's a nice paper, actually, a scientific paper. The author's last name is Code, C-O-D-E, it was published in 1995. I'll give a reference to that. It's a review article that discusses some of the sex differences in ear movement control, as well as the relationship between ear movements and eye movements. And it's a pretty accessible paper. It's one that I think any of you who are interested in this topic could parse fairly easily. And there's some very interesting underlying biology and some theories as to why humans would have this so-called vestigial or ancient carry-over of a system for moving our ears. Now, if ear movement seems strange, next, I want to talk about a different feature of your hearing and ears that's even stranger, but that has some really interesting implications

00:33:00 Your Ears (Likely) Make Sounds: Role of Hormones, Sexual Orientation

for your biology. And I'm guessing that you've not heard of this. What am I about to describe are called otoacoustic emissions. And otoacoustic emissions, as the name suggests, are sounds that your ears make. Believe it or not, 70% of people make noises with their ears, but they don't actually detect them. Like I said, you've never heard of this. Okay, that's not what I mean. But what I do mean is that 70% of people's ears are making noise that's cast out of the ear. And these otoacoustic emissions, actually, can be detected by microphones. Sometimes they can be detected by other people in the room if they have very good hearing. Now, it turns out that women or, I should be technical here, females who report themselves as heterosexual, have a higher frequency, not frequency of sound, but a higher frequency of otoacoustic emissions than do men who report themselves as heterosexual. Women who report themselves as homosexual or bisexual, make fewer otoacoustic emissions than heterosexual women. These are data that come from Dennis McFadden's lab at the University of Texas, Austin. He actually discovered these, what are called sexual dimorphisms and

differences based on sexual orientation without looking for them. He was studying hearing. He's an auditory scientist and people were coming into his laboratory and they were detecting these otoacoustic emissions. And they started to notice the group differences in otoacoustic emissions. So they started asking people about their sex and about their sexual orientation. And these differences fell out of the data, as we say. And it's interesting because otoacoustic emissions are not something that we associate with sex or sexual dimorphism. But what these data really underscore is, first of all, a lot of us are making noises with our ears, some of us more than others. And that exposure to certain combinations of hormones during development are very likely shaping the way that our hearing apparatus, meaning the cochlea and the pinna and all sorts of things, how those develop and how those functions throughout the lifespan. We did do an episode on hormones and sexual development, which gets much deeper into the other effects that hormones have on the developing brain and body.

00:35:30 Binaural Beats: Do They Work?

If you want to check out that episode, we will put a link to it in the captions. So now I want to shift to talking about ways to leverage your hearing system, your auditory system so that you can learn anything, not just auditory information, but anything faster. I get a lot of questions about so-called binaural beats. Binaural beats, as their name suggests, involve playing one frequency of sound to one ear and a different frequency of sound to the other ear. So it might be doo, doo, doo, doo to your right ear, and it might be ding-ding-ding-ding-ding to the left ear. And the idea is that the brain will take those two frequencies of sound and because the pathways that bring information from the ears into the brain, eventually crossover, they actually share that information with both sides of the brain, that the brain will average that information and come up with this sort of intermediate frequency. And the rationale is that those intermediate frequencies place the brain into a state that is better for learning. And when I say better for learning, I want to be precise about what I mean. That could mean more focus for encoding or bringing the information in. As you may have heard me say before, we have to be alert and focused in order to learn. There is no passive learning unless we're little tiny infants. So can binaural beats make us more focused? Can binaural beats allow us to relax more if we're anxious? I know some people, they go to the dentist and the dentist offers binaural beats as they drill into your teeth and give root canals and things of that sort,

probably causing some anxiety just describing those things right now. But those are available in many dental practices. Binaural beats have been thought to increase creativity, or at least they have been proposed to increase creativity. So what does the scientific data say about binaural beats? There are a number of different apps out there that offer binaural beats. There are a number of different programs. I think you can also even just find these on YouTube and on the internet. But typically, it's an app and you'll program in a particular outcome that you want: more focused, more creative, fall asleep, less anxious, et cetera. So what does the scientific data say? So believe it or not, the science on binaural beats is actually quite extensive and very precise. So sound waves are measured, typically, in hertz or kilohertz. I know many of you aren't familiar with thinking about things in hertz or kilohertz. But again, just remember those waves on a pond, those ripples on a pond. If they're close together, then they are of high-frequency. And if they're far apart, then they are of low frequency. So when you hear more hertz, what you're essentially hearing is higher frequency. And so if it's many more kilohertz then it's much higher frequency than if it's fewer hertz or kilohertz. And so you may have heard of these things as delta waves or theta waves or alpha waves or beta waves, et cetera. Delta waves would be big, slow waves, so low frequency. And, indeed, there is quality evidence from peer-reviewed studies that are not sponsored by companies that make binaural beat apps that tell us that delta waves like one to four hertz, so very low frequency sounds, think Costello's snoring, can help in the transition to sleep and for staying asleep. And that theta rhythms, which are more like four to eight hertz can bring the brain into a state of subtle sleep or meditation, so deeply relaxed, but not fully asleep. And then you can sort of ascend the staircase of findings here, so to speak. And you'll find evidence that alpha waves, eight to 13 hertz can increase alertness to a moderate level. That's a great state for the brain to be in for recall of existing information. And that beta waves, 15 to 20 hertz are great for bringing the brain into focus states for sustained thought or for incorporating new information and especially gamma waves, the highest frequency, the most frequent ripples of sound, so to speak, 32 to 100 hertz for learning and problem-solving. Now, all of this matches, or I should say, maps onto what I've said before about learning really nicely, which is that you need to be in a highly alert state in order to bring new information in, in order to access a state of mind in which you can tell your brain or the brain is telling itself, okay, I need to learn this. This is why stress and unfortunate circumstances are so memorable is because our brain gets into a really high alert system. Here, we're talking about the use of binaural beats in order to

increase our level of alertness or our level of calmness. Now that's important to underscore because it's not that there's something fundamentally important about the binaural beats. They are yet another way of bringing the brain into states of deep relaxation through low frequency sound or highly alert states for focused learning with more high-frequency sound. So they are effective and I'll review a little bit of the data in detail, they're effective, but it's not that they're uniquely special for learning. It's just that they can help some people bring their brain into the state that allows them to learn better. So there are a lot of studies that allowed us to arrive, or I should say allowed the field to arrive on these parameters of slow, slow, low frequency waves are going to bring you into relaxed states, high frequency waves into more alert states. There's very good evidence for anxiety reduction from the use of binaural beats. And what's interesting is anxiety reduction seems to be most effective when the binaural beats are bringing the brain into delta, so those slow big waves like sleep, theta and alpha states. And I'll link to a couple of these studies although I will probably link more to the list that really segregates them out one by one so you can see them all next to one another. There's good evidence that binaural beats can be used to treat pain, chronic pain. There's three studies in peer-reviewed journals which I took a look at, and they seem to be of good quality, not sponsored research, as we say, not paid for by any specific company. Binaural beats have been shown to modestly improve cognition, attention, working memory and even creativity. But the real boost from binaural beats appears to be for anxiety reduction and pain reduction. Some people might find these beneficial for these oral surgeries, right? Believe it or not, there are people who would rather have the entire root canal or cavity drilled without Novocaine. And that's because they sometimes have a syringe phobia or something of that sort or they just don't like being numb from the Novocaine, or maybe there's an underlying medical reason. But I think most people do don't enjoy getting their teeth drilled even if they have Novocaine in there or a root canal. And so it seems that binaural beats can be effective in that environment. And you don't have to go into that sort of extreme environment to benefit from binaural beats. Binaural beats are a either relatively inexpensive thing to access, most of the apps are pretty inexpensive. I don't have a favorite binaural beats app to recommend to you. I confess I did use binaural beats a few years ago. I shifted over to other what I call NSDR, non-sleep deep rest protocols in favor of those, but many people like binaural beats and say that they benefit from them, especially while studying or learning. I think part of the reason for that relates to the ability to channel our focus when we have some

background noise. And this is something I also get asked about a lot. Is it better to listen to music and have background noise when studying or is it better to have complete silence? Well, there's actually a quite good literature on this as well, but not so much as it relates to binaural beats, but rather whether or not people are listening to music, so-called white noise, brown noise; believe it or not, there's white noise and there's brown noise, there's even pink noise and how that impacts brain states

00:43:54 White Noise Can Enhance Learning & Dopamine

that allow us to learn information better or not. So now I'd like to talk about white noise and I want to be very clear that white noise has been shown to really enhance brain states for learning in certain individuals, in particular, in adults. But white noise actually can have a detrimental effect on auditory learning and maybe even the development of the auditory system in very young children in particular in infants. So first I'd like to talk about the beneficial effects of white noise on learning. There are some really excellent studies on this. The first one that I'd like to just highlight is one that's entitled: Low Intensity White Noise Improves Performance in Auditory Working Memory Task, an fMRI Study. This is a study that explored whether or not learning could be enhanced by playing white noise in the background. But the strength of the study is that they looked at some of the underlying neural circuitry and the activation of the neural circuitry in these people as they did the learning task. And what it, essentially, illustrates is that white noise, provided that white noise is of low enough intensity, meaning not super loud, not imperceptible, so not so quiet that you can't hear it, but not super loud either, it actually could enhance learning to a significant degree. And this has been shown now for a huge number of different types of learning. There's a terrific article as well in a somewhat obscure journal, at least, obscure to me, which is: The Effects of Noise Exposure on Cognitive Performance and Brain Activity Patterns. That's a study involving 54 subjects. They, basically, were evaluated for mental workload and attention under different levels of noise exposure, background noise and different, essentially, loudness of noise. And the reason I like this study is that they looked at different levels of noise and types of noise, and they varied a number of different things, as opposed to just doing a two-condition, either white noise or no white noise type thing. And what they found, again, is that provided the white noise is not extremely loud, it could really enhance brain function for sake of learning any number of different kinds of information. Now that's all great, but

it really doesn't get to the deeper guts of mechanism. And as a neuroscientist, what I really want to see is not just that something has an effect. That's always nice. It's always nice to see in a nice peer-reviewed study without any kind of commercial biases that there's an effect, binaural beats can enhance learning or listening to white noise, not too loud can enhance learning. But you really want to understand mechanism because once you understand mechanism, not only does it start to make sense, but you can also imagine ways in which you could develop better tools and protocols. So I was very relieved to find, or I should say excited to find this study published in the Journal of Cognitive Neuroscience, this is a 2014 paper, White Noise Improves Learning by Modulating Activity in Dopaminergic Mid-Brain Regions and Right Superior Temporal Sulcus. Now I don't expect you to know what the right superior temporal sulcus is. I don't expect you to know what the dopamine midbrain region is, but if you're like me, you probably took highlighted notice of the word dopaminergic. Dopamine is a neuromodulator, meaning it's a chemical that's released in our brain and body, but mostly in our brain that modulates, meaning controls the likelihood that certain brain areas will be active and other brain areas won't be active. And dopamine is associated with motivation. Dopamine is associated with craving. Motivation is associated with all sorts of different things, including movement but what this study so nicely shows is that white noise can really enhance the activity of neurons in what's called the substantia nigra VTA. The substantia nigra VTA is a very rich source of dopamine and that's because it's very chockablock full of dopamine neurons. It's an area of the brain that is, perhaps, the richest source of dopamine neurons. And you actually can see this brain region under the microscope if you take a slice of brain or you look at a brain without even staining it for any proteins or dopamine or anything. It's two very dark regions at the bottom of the brain. And the reason it's called substantia nigra, nigra meaning dark is because the dopamine neurons actually make something that makes those neurons dark. And so you've got these two regions down there, that contain dopamine and can release dopamine and, essentially, activate other brain regions and activate our sense of motivation and activate our sense of desire to continue focusing and learning. But you can't just snap your fingers and make them release dopamine. You actually have to trigger dopamine release from them. Now that trigger can be caused by being very excited about something or the fact that that thing gave you a lot of pleasure in the past, or you're highly motivated by fear or desire. But what's so interesting to me is that it appears that white noise itself can raise what we call the basal, the baseline levels of

dopamine that are being released from this area, the substantia nigra. So now we're starting to get a more full picture of how particular sounds in our environment can increase learning. And that's, in part, I believe, through the release of dopamine from substantia nigra. So I'm not trying to shift you away from binaural beats, if that's your thing, but it does appear that turning on white noise at a low level, not too loud. You may say, "Well, how loud?" And I'll tell you in a moment, but not too loud can allow you to learn better because of the ways that it's modulating your brain chemistry. So how loud or how soft should that white noise be while you learn? Well, in these studies, it seemed that white noise that could be heard by the person, so it wasn't imperceptible to them, so it was loud enough that they could hear, but not so loud that they felt it was intrusive or irritating to them. So that's going to differ from person to person because people have different levels of auditory sensitivity. It's going to depend on age, going to depend on a number of different factors. So I can't tell you turn to level two on your volume controller. That's just not going to work. Also, I don't know how far you are from a given speaker in the room or if you've got earphones in your head or you've got speakers in the room or if it's coming out of your computer. I don't know those things. So what you're going to have to do is adjust that white noise to the place where it's not interfering with your ability to focus, but rather it's enhancing your ability to focus. I think a good rule of thumb is going to be to put it probably on the lower third of any kind of volume dial, as opposed to in the upper third, where it would really be blasting.

00:51:00 Headphones

And really blasting any noise, frankly, is not good, but that's especially not good, meaning it's especially bad if you have headphones in. I do want to mention something about headphones before I talk about white noise in the developmental context and why it can be dangerous there. When you put headphones in your ears, it has this incredible effect of making the sounds like they come from inside your head, not from out in the room. And now that might seem like kind of a duh, but that's actually really amazing, right? Your brain assumes that the sounds are coming from inside your head, as opposed from the environment that you're in the moment you put headphones in. So if you're listening to an audiobook or maybe you're listening to this podcast with headphones, that's very different than when you're listening to something out in the room and there are other sounds, other sound waves, especially if you use these noise-

cancellation headphones. So if you're going to use white noise to enhance studying or learning of any kind, this also could be for skill-learning, motor skill-learning while you're exercising, my suggestion would be that if you're using headphones, to keep it quite low. This is an effect on the midbrain dopamine neurons that's a background effect of raising the baseline of dopamine release. The way that dopamine neurons fire, they're always firing; yours are firing right now, so are mine, when something exciting happens, they fire a lot. And when something disappointing happens, that firing, the release of dopamine goes down below baseline. What you're talking about here is raising your overall levels of attention and motivation, which translate to better learning by just tickling those neurons a little bit, raising the baseline firing. You're not turning up the white noise to the point where you're feeling amazing. This isn't like turning on your favorite song. This is actually the opposite. This is about getting that baseline up just a bit. So I recommend turning the volume up just a bit so that you can focus entirely on the task that you're trying to do. And, of course, you've turned on white noise so your attention might drift to that for a moment. Is it too loud? Is it too soft? If you can disappear into the work, so to speak, if your attention can disappear into the work, then that's probably sufficiently quiet. And for those of you that say, well, I like really loud music and if I just blast the music, then I forget about the music. I don't suggest blasting music. And this is coming from somebody who really likes loud music. I grew up with kind of a loud fast rules mentality, and if you don't know what loud fast rules means, then I can't help you, but there's a time and a place, perhaps, to listen to music loud but, especially, with headphones, you can trigger, excuse me, hearing loss quite rapidly. And unfortunately, because these hair cells that we talked about earlier, our central nervous system neurons, they do not regenerate, they do not come back. Now along the lines of hearing loss, I should just say that the best way to blow out your hearing for good, to eliminate your hearing is to have very loud sounds super imposed on a loud environment. So loud environments can cause hearing loss over time. So if you work at a construction site, clanging really loud, or if you work the sound board in a club or something, you are headed towards hearing loss unless you protect your hearing with earplugs and headphones. Nowadays, some of the ear plugs are very low profile, meaning you can't see them. So that's kind of nice, so you're not like the, when I was younger, like you didn't want to be the dork to go to the concert with the earplugs, but it turns out those dorks were smarter than everybody else, because they're not the ones who are craning their neck to try and hear trivial things at the age of 30 or so 'cause they blew out their

hearing. So if you are working in a loud environment or you expose yourselves to a loud environment, you really want to avoid big inflections in sound above that. So loud environment plus fireworks, loud environment plus gunshot, loud environments plus very high-frequency intense sound, that's what we call the two-hit model, this is also true for concussion, that you can take a stimulus that normally would be below the threshold of injury, you add another stimulus at the same time, that would be below the threshold of injury. And then, suddenly, you killed the neurons. So I don't want to make people paranoid, but you do want to protect your hearing. It's no fun to lose your hearing. If you're going to use headphones and you feel like you want to crank it up all the way, just remember that the more that you can get out of a lower volume, meaning the longer that you can go listening to things at lower volume, the longer you'll be able to hear that music or that thing. So again, I'm not the hearing cop. That's not my job, but as somebody who's lost some of his high-frequency hearing, I can tell you it's not a pleasure. The old argument that it helps you not have to hear or listen to people that you don't want to listen to,

00:55:51 White Noise During Development: Possibly Harmful

that does it doesn't really work. They just send you text messages instead. So what about white noise and hearing loss in development? I know a lot of people with children have these noise machines like sound waves and things like that, that help the kids sleep. And look, I think kids getting good sleep and parents getting good sleep is vital to physical and mental health and family health. So I certainly sympathize with those needs. However, there are data that indicate that white noise during development can be detrimental to the auditory system. I don't want to frighten any parents if you played white noise to your kids, this doesn't mean that their auditory system or their speech patterns are going to be disrupted or that their interpretation of speech is going to be disrupted forever. But there are data published in the journal, Science, and Science being one of the three, APEX Journal, Science, Nature, Cell, the most stringent journals, data published in the journal, Science, some years ago, actually by a scientist who I know quite well, his name is Edward Chang, he's a medical doctor now, he's a neurosurgeon, he's actually the chair of neurosurgery at UCSF and he runs a laboratory where they study auditory learning, neuroplasticity, et cetera, he and his mentor at the time, Mike Merzenich published a paper showing that if young animals and this was in

animal models were exposed to white noise, so [shushing] the very type of noise that I'm saying as a older person, and when I say older, I mean, somebody who's in their late teens, early 20s and older could benefit from listening to that at a low level in the background for sake of learning, well, they exposed very young animals to this white noise, it actually disrupted the maps of the auditory world within the brain. And we haven't talked about these maps yet, but I want to take a moment and talk about them and explain this effect and what it might mean for you if you have kids or if you were exposed to a lot of white noise early on. So auditory information goes up into our cortex, into these, essentially, the outside portion of our brain that's responsible for all our higher level cognition and our planning, our decision-making, et cetera, creativity and up there, we have what are called tonotopic maps. What's a tonotopic map? Well, remember the cochlea, how it's coiled and at one end, it responds to high frequencies and the other end, it responds to low frequencies? Like a piano, the keys sound different as you extend down and up the piano keys. And it's organized in a very systematic way. It's not all intermixed high frequencies and low frequencies. It's organized in a very systematic way from one end to the other. Your visual system is in, what's called a retinotopic map. So neighboring points in space off to my right, like my two fingers off to my right are mapped to neighboring points in space in my brain. And that space right in front of me is mapped to a different location in my brain, but it's systematic, it's regular. It's not random. It's not salt and pepper. It goes from high to low or from right to center to left. In the auditory system, we have what are called tonotopic maps, where frequency, high frequency to low frequency and everything in between is organized in a very systematic way. Now our experience of life from the time we're a baby until the time that we die is not systematic. We don't hear low frequencies at one part of the room or at one part of the day and high frequencies is another part of the room and other part of the day, they're all intermixed. But if you remember, the cochlea separates them out. Just like a prism of light separates out the different wavelengths of light, the cochlea separates out the different frequencies. And the developing brain takes those separated out frequencies and learns this relationship between itself, meaning the child and the outside world. White noise, essentially contains no tonotopic information. The frequencies are all intermixed. It's just noise. Whereas when I speak, my voice has, now I'm getting technical, but it has what's called a certain envelope, meaning it has some low frequencies and some slightly higher frequency. Like I might a voice higher, although I'm not very good at that. My voice starts to crack and I can make my voice lower, although

not as low as Costello's snore. So it has an envelope, it has a container. White noise has no container. It's like all the colors of the rainbow spread out together, which is actually what you get when you get white light white noise is analogous to white light. So one of the reasons why hearing a lot of white noise during development for long periods of time can be detrimental to the development of the auditory system is that these tonotopic maps don't form normally; at least, they don't in experimental animals. Now, the reason I'm raising this is that many people I know, in particular, friends who have small children, they say, "I want to use a white noise machine while I sleep. But is it okay for my baby to use a white noise machine?" And I consulted with various people, scientists about this. And they said, "Well, the baby is also hearing the parent's voices and is hearing music and it's hearing the dog bark. So it's not the only thing they're hearing." However, every single person that I consulted with said, "But there's neuroplasticity during sleep. That's when the kid is sleeping. And I don't know that you'd want to expose a child to white noise the entire night, because it might degrade that tonotopic map." It might not destroy it. It might not eliminate it, but it could make it a little less clear, like taking the keys on the piano and taping a few of them together, right? So you still got the highs and lows in the appropriate order and everything in between. But when you take the keys together, you don't get the same fidelity. You don't get the same precision of the noise that comes out of that piano. So, again, I don't want to scare anybody, but I would say if you are in a position to make the choice of either using white noise or something similar, pink noise is just a variation. It's got a little bit more of a certain frequency, just like pink light has a little bit more of a certain wavelength than white light. If you are in a position to make choices about things, to put in a young, especially very young child's sleeping environment, white noise might be something to consider avoiding. Again, I'm not telling you what to do, but it's something to perhaps consider avoiding. I don't think most pediatricians are going to be aware of these data, but if you talk to any auditory physiologists or an audiologist or somebody who studies auditory development, I'm fairly certain that they would have opinions about that. Now, whether or not their opinions agree with mine and these folks that I consulted with or not is a separate matter. I don't know, cause I don't know them, but it's something that I felt was important enough to cue you to, especially since I've highlighted, excuse me, the opposite effect is true in adulthood. Once your auditory system has formed, once it's established these tonotopic maps, then the presence of background white noise should not be a problem at all. In fact, it shouldn't be a problem at all because you're also not attending to it. The idea is

that it's playing at a low enough volume that you forget it in the background and that it's supporting learning by bringing your brain into a heightened state of alertness and, especially, this heightened state of dopamine, dopaminergic activation of the brain,

01:03:25 Remembering Information, The Cocktail Party Effect

which will make it easier to learn faster and easier to learn the information. So now I want to talk about auditory learning and actually how you can get better at learning information that you hear, not just information that you see on a page or motor skill learning. There are a lot of reasons to want to do this. A lot of classroom teaching, whether or not it's by Zoom or in-person is auditory in nature. Not everything is necessarily written down for us. It's also good to get better at listening or so I'm told. So there's a phenomenon called the cocktail party effect. Now, even if you've never been to a cocktail party, you've experienced and participated in what's called the cocktail party effect. The cocktail party effect is where you are in an environment that's rich with sound, many sound waves coming from many different sources, many different things, so in a city, in a classroom, in a car that contains people having various conversations, you somehow need to be able to attend to specific components of those sound waves, meaning you need to hear certain people and not others. The reason it's called the cocktail party effect is that you and meaning your brain are exquisitely good at creating a cone of auditory attention, a narrow band of attention with which you can extract the information you care about and wipe away or erase all the rest. Now this takes work, it takes attention. One of the reasons why you might come home from a loud gathering, maybe a stadium, a sports event or a cocktail party, for that matter, and feel just exhausted is because if you were listening to conversations there or trying to listen to those conversations while watching the game and people moving past you and hearing all this noise, clinking of glasses, et cetera, it takes attentional effort and the brain uses up a lot of energy just at rest, but it uses up even more energy when you are paying strong attention to something, literally caloric energy burning up things like glucose, et cetera, even if you're ketogenic, it's burning up energy. So the cocktail party effect has been studied extensively in the field of neuroscience and we now know at a mechanistic level, how one accomplishes this feat of attending to certain sounds, despite the fact that we are being bombarded with all sorts of other sounds. So there are a couple ways that we do this. First of all, much as with our visual system, we can expand or contract our

visual field of view, so we can go from panoramic vision, see the entire scene that we are in by dilating our gaze, talked a lot about this on this podcast and elsewhere. We can, for instance, keep our head and eyes stationary or mostly stationary, you don't have to be rigid about it, and you can expand your field of view so you can see the walls and ceiling and floor, can see yourself in the environment, that's panoramic view. It's what you would accomplish without having to try at all if you went to a horizon, for instance, or we can contract our field of view, I can bring my focus to a particular location, what we call a vergence point, directly in front of me. Now I'm pointing at the camera directly in front of me. We can do that, we can expand and contract our visual field of view. Well, we can expand and contract our auditory field of view, so to speak, our auditory window. You can try this next time you are in an environment that's rich with noise, meaning lots of different sounds. You can just tune out all the noise to a background chatter. You try not focus on any one particular sound and you get the background chatter of noise. And you'll find that it's actually very relaxing in comparison to trying to listen to somebody at a cocktail party or shouting back and forth. Now, if you're very, very interested in that person, or getting to know them better or what they're telling you, or some combination of those things, then you'll be very motivated to do it but nonetheless, it requires energy and effort and attention. How do we do this? Well, it's actually quite simple or, at least, it's simple, in essence, although the underlying mechanisms are complex. Here, I have to credit the laboratory of a guy named Mike Wehr, W-E-H-R, up at the University of Oregon who essentially figured out that we are able to accomplish this extraction of particular sounds. We can really hear one person or a small number of people amidst a huge background of chatter because we pay attention to the onset of words, but also to the offset of words. Now, the way to visualize this is if the background noise is just like a bunch of waves of noise, it's literally just sound waves coming every frequency, low frequency, high frequency, glasses clinking together. If you've got a game, people are shouting, people are talking on their phone, there's the crack of the ball, if somebody actually manages to hit the ball, the announcer, et cetera, but whatever we were paying attention to, we set up a cone of auditory attention, a tunnel of auditory attention, where we are listening although we don't realize it, we are listening for the onset and the offset of those words. Now this is powerful for a couple of reasons. First of all, it's a call to arms, so to speak, to disengage your auditory system when you don't need to focus your attention on something particular. So if you are somebody, you're coming home from work, you've had a very long day and you're trying to make out a particular conversation

on background noise, you might consider just not having that conversation, just letting your auditory landscape be very broad, almost like panoramic vision. If you're trying to learn how to extract sound information, it could be notes of music, it could be scales of music, it could be words spoken by somebody else, maybe somebody is telling you what you need to say for a particular speech or the information that you need to learn for a particular topic, and they're telling it to you, deliberately paying attention both to the onset and to the offset of those words can be beneficial because it is exactly the way that the auditory system likes to bring in information. So one of the more common phenomenon that I think we all experience is you go to a party or you meet somebody new and you say hi, I would say, "Hi, I'm Andrew." And they'd say, "Hi, I'm Jeff," for instance. "Great to meet you." And then a minute later, I can't remember the guy's name. Now, is it because I don't care what his name is? No, somehow the presence of other auditory information interfered. It's not that my mind was necessarily someplace else. It's that the signal-to-noise as we say wasn't high enough. Somehow the way he said it or the way it landed on my ears, which is really all that matters, when it comes down to learning, is such that it just didn't achieve high enough signal-to-noise. The noise was too high or the signal was too low or some combination of those. So the next time you ask somebody's name, remember listen to the onset of what they say and the offset. So it would be paying attention to the j in Jeff and it would be paying attention to that in f in F, in Jeff, excuse me. And chances are, you'll be able to remember that name. Now, I don't know if people who are super learners of names do this naturally or not. I don't have access to their brains. I don't think they're going to give me access to their brains either. But it's a very interesting way to take the natural biology of auditory attention and learning and apply it to scenarios where you're trying to remember either people's names or specific information. Now, I do acknowledge that trying to learn every word in a sentence by paying attention to its onset and offset could actually be disruptive to the learning process. So this would be more for specific attention, like you're asking directions in a city and somebody says, okay, you say you're lost and they say, okay, you're going to go two blocks down, you're going to turn left. And then you're going to see a landmark on your right. And then you're going to go in the third door on your left. That's a lot of information, at least, for me. So the way you would want to listen to that is you're going to go down the road. See, I already forgot. You're going to go left and you're just going to program and instead of just hearing the word left, you're going to think the L at the front of left and the T. You're going to left, okay. So you're coding in specific

words. And what this does is this hijacks these naturally-occurring attention mechanisms that the auditory system likes to use. So a little bit of data that for auditory encoding, this kind of thing can be beneficial. There are a lot of data that attention for auditory coding is beneficial. There are a little bit of data showing that deliberately encoding auditory information this way, meaning trying to learn auditory information this way can be beneficial or can accelerate learning. And some of these features of what I'm describing here, map onto some of the work that of Mike Merzenich and others that have been designed to try and overcome things like stutter and to treat various forms

01:12:55 How to Learn Information You Hear

of auditory learning disorders. But more importantly, and perhaps more powerful is the work of Mike Merzenich that was done with his then graduate student, Gregg Recanzone that showed that, using the attentional system, we can actually learn much faster and we can actually activate neuroplasticity in the adult brain, something that's very challenging to do. And that the auditory system is one of the main ways in which we can access neuroplasticity more broadly. So I just want to take a couple of minutes and describe the work of Recanzone and Merzenich, because it's absolutely fantastic and fascinating. What they did is they had subjects try to learn auditory information, except that they told them to pay attention to particular frequencies. So now you know what frequencies are so, essentially, high-pitched sounds or low-pitched sounds. What they found was just passively listening to a bunch of stuff does not allow the brain to change and for that stuff to be remembered at all. That's not a surprise. We've all experienced the phenomenon of having someone talk and we see their mouth moving and we're like, yeah, this is really important, this is really important. We're listening. We're trying to listen. And then they walk away and we think I didn't get any of that. And you wonder whether or not it was them, maybe this is happening to you right now. You wonder whether or not it was you, you wonder whether or not you have trouble with learning or you have attention deficit. It could be any number of different things. But what Recanzone and Merzenich discovered was that if you instruct subjects to listen for particular cues within speech, or within sounds, that not only can you learn those things more quickly, but that you can remap these tonotopic maps in the cortex that I referred to earlier. You actually get changes in the neural architecture, the neural circuitry in the brain, and this can occur not only very rapidly, but they can occur in the adult brain,

which prior to their work was not thought to be amenable to change. It was long thought that neuroplasticity could only occur in the developing brain, but the work of Recanzone and Merzenich in the auditory system actually was some of the first that really opened up everybody's eyes and ears to the idea that the brain can change in adulthood. So here's how this sort of process would work and how you might apply it. If you are trying to learn music, or you're trying to learn information that you're going to then recite, you can decide to highlight certain words or certain frequencies of sound or certain scales or certain keys on the piano, and to only focus on those for certain learning bouts. So I'll give an example that's real time for me, meaning it's happening right now. I know generally what I want to say when I arrive here, I even know specifically certain things that I want to make sure get across to you, but I don't think about every single word that I'm going to say and the precise order in which I'm going to say those things. That would be actually very disruptive because it wouldn't match my normal patterns of speech and you'd probably think I was sounding rather robotic if I were to do that. So one way that we can remember information is as we write out, for instance, something that we want to say, we can highlight particular words, we can underline those. If we're listening to somebody and they're telling us information, we can decide just to highlight particular words that they said to us and write those down. Now, of course, we're listening to all the information, but the work of Recanzone and Merzenich and the work of others in addition to his former student or former post-doc, I don't know which, Michael Kilgard who's now got his own lab down in Texas or others have shown that the cuing of attention to particular features of speech, particular components of speech, the way in which it increases our level of attention overall allows us to capture more of the information overall. And so I don't want this to be abstract at all. What this means is when you're listening, you don't have to listen to every word. You're already listening to every word. All the information is coming in through your ears. What you're trying to extract is particular things or themes within the content. So maybe you decide if you're listening to me that you're only going to listen to the word tools, or you're only going to listen to when my voice goes above background, you get to decide what you decide to listen to or not. And what you decide to focus on isn't necessarily as important as the fact that you're focusing. So I hope that's clear. The auditory system does this all the time with the cocktail party effect. What I'm talking about is exporting certain elements of the mechanisms of the cocktail party effect, paying attention to the onset and offset of words or particular notes within music or particular scales, or you can make it even broader and

particular motifs of music or particular sentences of words or particular phrases. And in doing that, you extract more

01:18:10 Doppler

of the information overall, even though you're not paying attention to all the information at once. Now, I'd like to talk about a phenomenon that you've all experienced before, which is called Doppler. So the Doppler effect is the way that we experience sound when the thing that's making that sound is moving. The simplest way to explain this is to translate the sound into the visual world once again. So if you've ever seen a duck or a goose sitting in a pond or a lake and it's bobbing up and down, what you'll notice is that the ripples of water that extend out from that duck or goose are fairly regularly spaced in all directions. And that's because that duck or goose is stationary. It's moving up and down, but it's not moving forward or backward or to the side. Now, if that duck or goose were to swim forward by paddling its little webbed feet under the surface, you would immediately notice that the ripples of water that are close to and in front of that duck or goose would be closer together than the ones that trailed it, that were behind. And that is essentially what happens with sound as well. With the Doppler effect, we experience sounds that are closer to us at higher frequency, the ripples are closer together, and sounds that are further away at lower frequency, especially when they're moving past us. So if you've ever, for instance, heard a siren in the distance, [humming] that's essentially my rendition of a siren, I don't know what ambulance or police or what, passing you on a street, that is the Doppler effect. The Doppler effect is one of the main ways that we make out the direction that things are arriving from and their speeds and trajectories. And we get very good, from a very young age, at discerning what direction things are arriving from and the direction that they are going to pass us in. And the Doppler effect has probably saved your life many, many times. In this way, you just don't realize it because you'll step off the curb or you're driving your car and you pull to the side so that the ambulance or firetruck can go by because you heard that siren off in the distance, and then you pull away from the curb and you get back on the road in part, because you don't see it any longer, but also you don't hear any other sirens in the distance. Now, some animals such as bats are exquisitely good at navigating their environments according to sound. Now, we've all heard that bats don't see. That's actually not true. They actually have vision, but they just rely more heavily on their auditory system. And

the way that bats navigate in the dark and the way that bats navigate using sound is through Doppler. Now, they don't simply listen to whether or not things are coming at them or moving away from them and pay attention to the Doppler like the siren example I gave for you. What they do is they generate their own sounds. So a bat, as it flies around is sending out clicks, [Andrew clicks tongue] I think that's my best bat sound or maybe it's [Andrew clicks tongue] and they're clicking, they're actually propelling sound out at a particular frequency that they know. Now, whether or not they're conscious of it, I don't know. I've never asked them. And if I did ask them, I don't think they could answer. And if they could answer, they couldn't answer in a language that I could understand. But the bat is essentially flying around, sending out sound waves, pinging its environment with sound waves of a particular frequency and then depending on the frequency of sound waves that come back, they know if they're getting closer to an object or further away from it. So if they send out sounds at a frequency of, this was much slower than it would actually occur, but let's say one every half second, [whining] and it's coming back even faster [roars] then they know they're getting closer because of the Doppler effect. And if it comes back more slowly, they know that there's nothing in front of them. So the bat is essentially navigating its world by creating these auras of sound that bounce back on to them from the various objects, trees, et cetera, buildings and people, it's kind of eerie to think about.

01:22:43 Tinnitus: What Has Been Found To Help?

But yes, they see you, they experience you with their sound, they sense you and they're using Doppler to accomplish it. Now I'd like to talk about ringing in the ears. This is something that I get asked about a lot. And speaking of signal-to-noise, I don't know if I get asked about it a lot, because many people suffer from ringing in their ears, or because the people who suffer from ringing in their ears suffer so much that they are more prone to ask. So it could be a sampling bias, I don't know, but I've been asked enough times and some of the experiences of discomfort that people have expressed about having this ringing of the ears really motivated me to go deep into this literature. So the ringing of the ears that one experiences is called tinnitus, not ti-nahy-tus, but tinnitus. And tinnitus can vary in intensity and it can vary according to stress levels, it can vary across the lifespan or even time of day. So it's very subject to background effects and contextual effects. So I think we all know that we should do our best to maximize

healthy sleep. We did a number of episodes on that. Essentially, the first four episodes of the Huberman Lab Podcast were all about sleep and how to get better sleep. We all know that we should try and limit our stress. And we had an episode about stress and ways to mitigate stress as well. However, there are people, it seems, that are suffering from tinnitus, for which stress or lack of sleep just can't explain the presence of the tinnitus. Tinnitus can be caused by disruption to these hair cells that we talked about earlier or damage to the hair cells. So that's another reason why, even if you have good hearing now that you want to protect that hearing and really avoid putting yourself into these two-hit environments, environments where there's a lot of background noise, and then you add another really loud auditory stimulus. This also can happen at different times, I should mention. If you go to a concert or you listen to loud music with your headphones and then you go to a concert, or you go into a very loud work environment, the hair cells can still be vulnerable. And once those hair cells are knocked out, currently, we don't have the technology to put them back. Although many groups, including some excellent groups at Stanford and elsewhere, too, of course, are working on ways to replenish those hair cells and restore hearing. There are treatments for tinnitus that involve taking certain substances. There are medications for tinnitus. In the non-prescription landscape, which is typically what we discuss on this podcast, when we discuss taking anything, there are, essentially, four compounds for which there are quality peer-reviewed data, where there does not appear to be any overt commercial bias, meaning that nothing's reported in the papers as funding from a particular company and those are melatonin, Ginkgo bilboa, zinc and magnesium. Now I've talked about melatonin before. I'm personally not a fan of melatonin as a sleep aid, but there are four studies, first one entitled: The Effects of Melatonin on Tinnitus, tinnitus, excuse me, and Sleep. Second one, Treatment of Central and Sensory Neural Tinnitus with orally-administered melatonin. And then the title goes on much longer, but it's a randomized study. I'm not going to read out all these. Melatonin: Can it Stop The ringing? which is an interesting article, double-blinded study, and The Effects of Melatonin on Tinnitus. Each one of these studies has anywhere from 30 to more than 100 subjects, in one case 102 subjects; both genders as they list them out, typically, it's listed as sex, not gender in studies so it should say both sexes, but nonetheless; an age range anywhere from 30 years old, all the way up to 65 plus. I didn't see any studies of people younger than 30. All three focused on melatonin, not surprisingly, because of the titles, looking at a range of dosages anywhere from three milligrams per day, which is sort of typical of many

supplements for melatonin, still much higher than one would manufacture endogenously through your own pineal gland, but three milligrams in these studies for a duration of anywhere from 30 days to much longer in some cases, six months. And all four of these studies found modest yet still statistically significant effects of taking melatonin by mouth, so it's orally-administered melatonin in reducing the severity of tinnitus. So that's compelling, at least to me. It doesn't sound like a cure. And, of course, as always, I'm not a physician, I'm a scientist, so I don't prescribe anything. I only profess things, I report to you the science. You have to decide if melatonin is right for you if you have tinnitus. And certainly, I say that both to protect myself, but also protect you. You're responsible for your health and wellbeing. And I'm not telling anyone to run out and start taking melatonin for tinnitus, but it does seem that it can have some effects in reducing its symptoms. Ginkgo Boaboa is an interesting compound. It's been prescribed for or recommended for many, many things, but there are a few studies, again, double-blinded studies lasting one to six months, one that has have an impressive number of subjects, 978 subjects ranging from age 18 all the way up to 65 so on and so forth that show not huge effects of Ginkgo, but as they quote, limited evidence suggests that if tinnitus is a side effect of something else, in particular, cognitive decline, so age-related tinnitus might be helped by Ginkgo Boaboa. I won't go through all the details of the zinc studies, but it seems that zinc supplementation at higher levels than are typical of most people's intakes of 50 milligrams per day, do appear to be able to reduce subjective symptoms of tinnitus in most of the people that took the supplemented zinc. There aren't a lot of studies on that. So I could only find one double-blinded study. It lasted anywhere from one to six months, 41 subjects, both genders listed out again here, 45 to 64, and they saw a decrease in the severity of tinnitus symptoms with 50 milligrams of elemental zinc supplementation. And then last but not least is the magnesium study. Again, only a single study. It's a Phase II study looking at a fairly limited number of subjects, so only 19 subjects taking 532 milligrams of elemental magnesium. For those of you that take magnesium, there's magnesium and elemental magnesium, and it's always translated on the bottle, but it was associated with a lessening of symptoms related to tinnitus. So for you tinnitus sufferers out there, you may already be aware of this, you may already be taking these things and had no positive effects, meaning they didn't help, maybe not. I hope that you'll, at least, consider these, talk to your doctor about them. I do realize that tinnitus is extremely disruptive. I can't say I empathize because I don't, from a place of experience, that is, because I don't have tinnitus, but for those of you that don't include

myself, you can imagine that hearing sounds of things that aren't there and the ringing in one's ears can be very disruptive and I think would be very disruptive and explains why people with tinnitus reach out so often

01:30:40 Aging: How Big Are Your Ears?

with questions about how to alleviate that. And I hope this information was useful to you. I'd like to now talk about balance and our sense of balance, which is controlled by, believe it or not, our ears and things in our ears, as well as by our brain and elements of our spinal cord. But before I do that, I want to ask you another question or I would rather, I'd like to ask you to ask yourself a question and answer it, which is how big are your ears. It turns out that the ears grow our entire life. In the early stage of our life, they grow more slowly. And then as we age, they grow more quickly. You may have noticed if you have family members who are well into their 70s and 80s, and if you're fortunate, into their 90s and maybe even 100s, is that the ears of some of these individuals get very, very big, relative to their previous ear sizes. So it turns out that biological age can actually be measured according to ear size. Now you have to take a few measurements but there's, believe it or not, there is a formula in the scientific literature, if you know your ear circumference, so the distance around your ear, ears, plural, presumably you have two, most people do, in millimeters, so you're going to take the circumference of your ears in millimeters. How would you do this? How would you do this? Maybe you take a string and you put it around your ear, and then you measure the string. That's probably going to be easier than marching around your ear or somebody else's ear with a ruler and measuring in millimeters. So what's your ear circumference, on the outside, don't go in on the divot or anything. You're just going around as if you're going to trace the closest fitting oval, assuming your ears are oval, closest fitting oval that matches your ear circumference. Take that number in millimeters, subtract from it... Oh, excuse me, I should do this correctly. Do that for both ears, add them together, add those numbers together, divide by two, get the average for your two ears, get your average ear circumference, of course, your two ears. Then take that number in millimeters, subtract 88.1 and then whatever value that is, multiply it times 1.96 and that will tell you your biological age. Now why in the world would this be accurate? As we age, there are changes in number of different biological pathways. One of those pathways is the pathways related to collagen synthesis. So not only are our ears growing, but our noses

are growing too, and my nose seems to be growing a lot. But then again, I did sports where I would get my nose broken, something I don't recommend. As I always point out, you don't get a nose like mine doing yoga, but nonetheless, my nose is still growing and my ears are still growing. And I suspect as I get older, if I have the good fortune of living into my 80s and 90s, my ears are going to continue to grow. A comparison between chronological age and biological age is something that's a really deep interest these days in the work of David Sinclair at Harvard Medical School and others. So called Horvath clocks that people have developed have tapped into how the epigenome and the genome can give us some insight into our biological age and how that compares to our chronological age. Most of us know our chronological age, because we know when we were born and we know where we are relative to that now. But you can start to make a little chart, if you like, about your rates of ear growth. Your rates of ear growth actually correlate pretty well with your rates of biological progression through this thing that we call life. So it's not something that we think about too often, but just like our DNA and our epigenome, and some other markers of metabolic health and hormone health relate to our age, so does our collagen synthesis. And one of the places that shows up the most is in these two little goodies on the sides of our heads, which are our ears. So even though it's a little bit of a bizarre metric,

01:35:00 Balance: Semi-Circular Canals

it makes perfect sense in the biological context. So let's talk about balance and how to get better at balancing. The reason why we're talking about balance and how to get better at balancing in the episode about hearing is that all the goodies that are going to allow you to do that are in your ears. They're also in your brain, but they're mostly in your ears. So as you recall from the beginning of this episode, you have two cochlea, cochleas, that are one on each side of your head. And that's a little spiral snail-shaped thing that converts sound waves into electrical signals that the rest of your brain can understand. Right next to those, you have what are called semicircular canals. The semicircular canals can be best visualized as thinking about three hula hoops with marbles in them. So imagine that you have a hula hoop and it's not filled with marbles all the way around, it's just got some marbles down there at the base. So if you were to move that hula hoop around, the marbles would move around, [shushing]. You've got three of those and each one of those hula hoops has these marbles that can move

around. One of those hula hoops is positioned vertically with respect to gravity. So it's basically parallel to your nose. It sits like this, if you're watching on a video, but basically it's upright. Another one of those hula hoops is basically at a 90-degree angle to your nose. It's basically parallel to the floor if you're standing up right now, if you're seated. And the other one, it's kind of tilted about 45 degrees in between those. Now why is the system there? Well, those marbles within each one of those hula hoops can move around, but they'll only move around if your head moves in a particular way, and there are three planes or three ways that your head can move. Your head can move up and down like I'm nodding right now. So that's called pitch, it's pitching forward or pitching back. So it's a nod, up and down, or I can shake my head no, side to side. That's called a yaw. You pilots will be very familiar with this, yaw. Not yawn, yaw. And then there's roll, tilting the head from side to side, the way that a cute puppy might look at you from side to side or that if somebody doesn't really understand or believe what you're saying, they might tilt their head, very common phenomenon. I mean, nobody does that to me, but they do that to each other. So pitch, yaw and roll are the movements of the head in each of the three major planes of motion, as we say. And each one of those causes those marbles to move in one or two of the various hula hoops. So if I move my head up and down when I nod, one of those hula hoops, literally, right now, the marbles are moving back and forth. They aren't actually marbles by the way, these are little, kind of like little stones, basically, little calcium-like deposits and when they roll back and forth, they deflect little hairs, little hair cells that aren't like the hair cells that we use for measuring sound waves. They're not too different, but they are different from them, not like the hairs on our heads, but they're basically rolling past these little hair cells and causing them to deflect and when they deflect downward, the neurons, because hair cells are neurons, send information up to the brain. So if I move my head like this, there's a physical movement of these little stones in this hula hoop as I'm referring to it, but they deflect these hairs, send those hairs, which are neurons, those hair cells, send information off to the brain. If I move my head from side to side, different little stones move. If I roll my head, different stones move. This is an exquisite system that exists in all animals that have a jaw. So any fish that has a jaw has this system, a puppy has the system, any animal that has a jaw has this so-called balance system, which we call the vestibular system. One of the more important things to know about the vestibular, the balance system is that it works together with the visual system. Let's say I hear something off to my left and I swing my head over to the left to see what it is. There are two sources of

information about where my head is relative to my body and I need to know that. First of all, when I quickly move my head to the side, those little stones, as I'm referring to them, I realize they're not actually stones, but as I'm referring to them, they quickly, whoom, activate those hair cells in that one semicircular canal, and send a signal off to my brain that my head just moved to the side like this, not that it went like this and pitched back or not that it tilted, but it just moved to the side. But also visual information slid past my field of view. I didn't have to think about it, but just slid past my field of view. And when those two signals combine, my eyes then lock to a particular location. Now, if this is at all complicated, you can actually uncouple these things. It's very easy to do. You can do this right now. In fact, I'd like you to do this experiment if you're not already doing something else

01:40:35 A Vestibular Experiment

that requires your attention. And certainly, don't do this if you're driving. You're going to sit down and you're going to move your head to the left very slowly with your eyes open. So you're going to move it very, very slowly. The whole thing should take about five, six, maybe even 10 seconds to complete. Okay, I just did it. Now, I'm going to do it very quickly. I'd like you to do it very quickly as well. Now do it slowly again. What you probably noticed is that it's very uncomfortable to do it slowly, but you can do it very quickly without much discomfort at all. You just move your head to the side. The reason is when you move your head, very slowly, those little stones at the base of that hula hoop, they don't get enough momentum to move. So you're actually not generating this signal to the brain that your head is moving. And what you'll notice is that your eyes have to go, boom, boom, boom, jumping over step-by-step. Whereas if you move your head really quickly, the signal gets off to your brain and your eyes just go boom, right to the location you want to look at. So moving your body slowly is actually very disruptive to the vestibular system. And it's very disruptive to your visual system. Now, if you've ever had the misfortune of being on a boat and you're going through big oscillations on the boat, for those of you seasick, folks that get seasick, this can actually make certain people seasick just to hear about it, those big oscillations going up and down and up and down. Those are very disruptive. We'll talk about nausea in a minute and how to offset that kind of nausea. I get pretty seasick, but there are ways that you can deal with this but this is incredible because what it means is a purely physical system of these little stones rolling

around in there and directing where your eyes should go. So you can do this also just by looking up. So let's just say, you're sitting in a chair, you're going to look up towards the ceiling and your eyes will just go there. You're doing this eyes open and you look down. Now try doing it right really, really slowly. Some people even get motion sick doing this, which if you do, then just stop. Okay, so you can do this also to the side, although it works best if you're moving your head from side to side and we're nodding up and down. So what we're doing here is we're uncoupling these two mechanisms, we're pulling them apart, the visual part and the vestibular part, just to illustrate to you that, normally, these mechanisms in your inner ear tell your eyes where to go, but as well,

01:43:15 Improve Your Sense of Balance

your eyes tell your balance system, your vestibular system, how to function. So I'd like you to do a different experiment. I'm not going to do it right now, but basically stand up. If you get the opportunity, you can do this safely, wherever you are, you're going to stand up and you're going to look forward about 10, 12 feet. Pick a point on a wall or you can, anywhere that you like, if you're out in public, just do it anyway. Just tell them you're listening to Huberman Lab Podcasts, and someone's telling you to do it. Anyway, if you don't want to do it, don't do it. But, basically, do it. Stand on one leg and lift up the other leg. You can bend your knee, if you like and just look off into the distance about 10, 12 feet. If you can do that, if you can stand on one leg, now close your eyes, chances are you're going to suddenly feel what scientists call postural sway. You're going to start swaying around a lot. It is very hard to balance with your eyes closed. And if you think about that, it's like, why is that? That's crazy. Why would it be that it's hard to balance with your eyes closed? Well, information about the visual world also feeds back onto this vestibular system. So the vestibular system informs your vision and tells you where to move your eyes and your eyes and their positioning tell your balance system, your vestibular system how it should function. So there's a really cool way that you can learn to optimize balance. You're not going to try and do this by learning to balance with your eyes closed. What you can do is you can raise one leg and you can look at a short distance, maybe off to just the distance that your thumb would be if you were to reach your arm out in front of you. Although you don't necessarily have to put your thumb in front of you. So maybe just about two feet in front of you. Then while still balancing, you're going to step your vision out a further distance, and then a further distance and as

far as you can possibly see in the environment that you're in. And then you're going to march it back to you. Now, what the literature shows is that this kind of balance training where you incorporate the visual system and extending out, and then marching back in the point at which you direct your visual focus, sends robust information about the relationship between your visual world and your balance system. And, of course, the balance system includes not just these hula hoops, these semicircular canals, but they communicate with the cerebellum, the so-called mini-brain, it actually means mini-brain in the back of your brain, combines that with visual information and your map of the body surface. That pattern of training is very beneficial for enhancing your ability to balance because the ability to balance is, in part, the activation of particular postural muscles, but just as much, perhaps even moreso, it's about being able to adjust those postural muscles, excuse me, it's about the ability to adjust those postural muscles as you experience changes in your visual world. And one of the most robust ways that you can engage changes in your visual world is through your own movement. And so most people are not trying to balance in place, right? They're not just trying to stand there like a statue on one leg. Most of what we think about when we think about balance is for sake of sport or dynamic balance of being able to break ourselves, when we're lunging in one particular direction to stop ourselves, that is, and then to move in another direction or for skateboarding or surfing or cycling or any number of different things, gymnastics. So the visual system is the primary input by which you develop balance, but you can't do it just with the visual system. So what I'm recommending is if you're interested in cultivating a sense of balance, understand the relationship between the semicircular canals, understand that they are both driving eye movements and they are driven by eye movements. It's a reciprocal relationship. And then even just two or three minutes a day, or every once in a while, even three times a week, maybe five minutes, maybe 10 minutes, you pick, but if you want to enhance balance, you have to combine changes in your visual environment with a static posture, standing on one leg and shifting your visual environment or static visual view, looking at one thing and changing your body posture. So those two things, we now know from the scientific literature, combine in order to give an enhanced sense of balance. And there's a really nice paper that was published in 2015 called Effects of Balance Training on Balance Performance. This was in healthy adults. It's a systematic review and a meta analysis. A meta analysis is when you combine a lot of literature from a lot of different papers and extract the really robust and the less robust statistical effects. So it's a really nice paper as well. There are some

papers out there, for instance, comparison of static balance and the role of vision in the elite athletes. This is essentially the paper that I've extracted most of the information that I just gave you from. And that paper, and there are some others as well, but basically I distilled them down into their core components. The core components are move your vision around while staying static, still but in a balanced position like standing on one leg, could be something more complicated if you're somebody who can do more complicated movements. Unilateral movement seemed to be important, so standing on one leg as opposed to both, or trying to generate some tilt is another way to go about it or imbalance, meaning one limb asymmetrically being activated compared to the other limb.

01:48:55 Accelerating Balance

And then the other way to encourage or to cultivate and build up this vestibular system and your sense of balance actually involves movement itself, acceleration. So that's what we're going to talk about now. So up until now, I've been talking about balance only in the static sense, like standing on one leg for instance, but that's a very artificial situation. Even though you can train balance that way, most people who want to enhance their sense of balance for sport or dance, or some other endeavor, want to engage balance in a dynamic way, meaning moving through lots of different planes of movement, maybe even sometimes while squatting down low or jumping and landing or making trajectories that are different angles. For that, we need to consider that the vestibular system also cares about acceleration. So it cares about head position, it cares about eye position and where the eyes are and where you're looking, but it also cares about what direction you're moving and how fast. And one of the best things that you can do to enhance your sense of balance is to start to bring together your visual system, the semicircular canals of the inner ear and what we call linear acceleration. So if I move forward in space rigidly upright, it's a vastly different situation than if I'm leaning to the side. One of the best ways to cultivate a better sense of balance, literally, within the sense organs and the neurons and the biology of the brain is to get into modes where we are accelerating forward, typically, it's forward while also tilted with respect to gravity. Now this would be the carve on a skateboard or on a surf board or a snowboard. This would be the taking a corner on a bike while being able to lean, safely, of course, lean into the turn so that your head is actually tilted with respect to the earth. So anytime that

we are rigidly upright, we aren't really exercising the vestibular system imbalance. And this is why you see people in the gym on these, one of those bouncy balls, Bocce balls are the one that the guys roll in the park. Bouncy balls, where they're balancing back and forth, that will work the small stabilizing muscles. But what I'm talking about is getting into modes where you actually tilt the body and the head with respect to earth. What I mean is with respect to Earth's gravitational pull. Now the cerebellum is a very interesting structure because not only is it involved in balance, but it's also involved in skill-learning and in generating timing of movements. It's a fascinating structure deserving of an entire episode or several episodes all on its own, but some of the outputs of the cerebellum, meaning the neurons in the cerebellum get inputs, but they also send information out.

01:51:55 Self-Generated Forward Motion

The outputs of the cerebellum are strongly linked to areas of the brain that release neuromodulators that make us feel really good, in particular, serotonin and dopamine. And this is an early emerging sub-field within neuroscience, but a lot of what are called the non-motor outputs of the cerebellum have a profound influence, not just on our ability to learn how to balance better, but also how we feel overall. So for you exercisers out there, I do hope people are getting regular healthy amounts of exercise. We've talked about what that means in previous episodes, so at least 150 minutes a week of endurance work, some strength training, a minimum five sets per body part to maintain musculature even if you don't want to grow muscles, you want to do that in order to maintain healthy, strengthened bones, et cetera. If you're doing that but you're only doing things like curls in the gym, squats in the gym, riding the Peloton, or even if you're outside running, and you're getting forward acceleration, but you're never actually getting tilted, you're never actually getting tilted with respect to Earth's gravitational pull, you're not really exercising and getting the most out of your nervous system. Activation of the cerebellum in this way of being tilted or the head being tilted and the body being tilted while in acceleration, typically forward acceleration, but sometimes side to side has a profound and positive effect on our sense of mood and wellbeing. And as I talked about in previous episode, it can also enhance our ability to learn information in the period after generating those tilts. And the acceleration. And that's because the cerebellum has these outputs to these areas of the brain that release these neuromodulators, like

serotonin and dopamine. And they make us feel really good. I think this is one of the reasons why, growing up, I had some friends, some of whom might've been the world heavyweight champions of laziness for essentially everything, except they would wake up at 4:30 in the morning to go surf. They would drive, they would get up so early to go surf. It's not just surfers and some surfers, by the way, I should point out are not lazy humans. They do a lot of other things. But I knew people that couldn't be motivated to do anything, but they were highly driven to get into these experiences of forward acceleration while tilted with respect to gravity, likewise, with snowboarding or skiing or cycling. Those modes of exercise seem to have an outsized effect both on our wellbeing and our ability to translate the vestibular balance that we achieve in those endeavors to our ability to balance while doing other things, and I don't mean psychological balance necessarily. I mean physical balance. So for those of you that don't think of yourselves as very coordinated or with very good balance, getting into these modes of acceleration forward movement or lateral movement while getting tilted, even if you have to do it slowly, could be beneficial, I do believe, and the scientific literature points to the fact that it will be beneficial for cultivating better sense of physical balance. It can really build up the circuits of this vestibular system. And then, of course, the feel-good components of acceleration while tilted or while getting the head into different orientations relative to gravity, well, that's the explanation for roller-coasters. Some people hate roller-coasters. They make them feel nauseous. Many people love roller-coasters and one of the reasons they love roller-coasters is because of the way that when you get the body, even if you're not generating the movement, you get the body into forward acceleration and you're going upside down and tilted to the side as the tracks go from side to side and tilt, et cetera, you're getting activation of these deeper brain nuclei that trigger the release of neuromodulators that just make us feel really, really good. In fact, some people get a long arc, a long duration buzz from having gone through those experiences. Some people who hate roller-coasters are probably getting nauseous, just hearing about that. So I encourage people to get into modes of acceleration while tilted every once in a while, provided you can do it safely. It's an immensely powerful way to build up your skills in the realm of balance. And it's also, for most people, very, very pleasing. It feels really good because of the chemical relationship

01:56:25 Dizzy versus Light-Headed

between forward acceleration and head tilt and body tilt. Now, speaking of feeling nauseous, some people suffer from vertigo. Some people feel dizzy, some people get lightheaded. An important question to ask yourself, always, if you're feeling quote-unquote dizzy or lightheaded, is are you dizzy or are you lightheaded? Now, we're not going to diagnose anything here because there's just no way we can do that. This is essentially me shouting into a tunnel. So we don't know what's going on with each and every one of you but if ever you feel that your world is spinning, but that you can focus on your thumb, for instance, but the rest of the world is spinning and your thumb is stationary, that's called being dizzy. Now, if you feel like you're falling or that you feel like you need to get down onto the ground because you feel light-headed, that's being light-headed. And, oftentimes, with language we don't distinguish between being dizzy and being lightheaded. Now there are a lot of ways that dizziness and lightheadedness can occur. And I don't even want to begin to guess at the number of different things and ways that it could happen for those of you that suffer from it because it could be any number of them. But, oftentimes, if people are lightheaded, yes, it could be low blood sugar. It could also be that you're dehydrated. It could also be that you are low in electrolytes. We talked about this in a previous episode, but we will talk about it more in a future episode. Many people have too little sodium in their system, salt, and that's why they feel lightheaded. I have family members who, for years, thought they had disrupted blood sugar. They would get shaky, jittery, lightheaded, feel like they were nauseous, et cetera. And simply the addition of little sea salt to their water remedied the problem entirely. I don't think it's going to remedy every issue of lightheadedness out there by any stretch, but just the addition of salt, in this particular case, helped the person. And they are not alone. Many people who think that they have low blood sugar, actually are lightheaded because of low electrolytes and because of the way that salt carries water into the system and creates changes in blood volume, et cetera. Low sodium can often be a source of lightheadedness as can low blood sugar and, of course, other things as well.

01:58:38 Motion Sickness Solution

Now for dizziness or seasickness, we were all taught that you need to pick a point on the horizon and focus on it. But actually, that's not correct. It is true that if you are down in the cabin of a boat or you're on the lower deck and all you can see are things up close to

you, that getting sloshed around, like so or the boat going up and down, like so, I think I'm getting a little seasick, even as I do this and I describe it, focusing on things close to you can be problematic. And in that case, the advice to go up on deck and get fresh air and to look off into the horizon, that part is correct. But focusing your eyes on a particular location on the horizon is effectively like trying to move very slowly as I had you do before, where you're trying to move your head very slowly while fixating on one location. Your eyes and your balance system were designed to move together. So really, what you want to do is allow your visual system to track with your vestibular system. This is why sitting in the back of an Uber or a taxi and being on your phone can make you suddenly feel very nauseous. Sometimes the cabs, particularly in New York City, they have a lot of occluders, they have a lot of stuff blocking your field of view. There's usually a little portal where you can see out to the front of the front windshield, but there's all this stuff now, televisions in the back seat and you're watching that television and the cab is moving. You're in linear acceleration, and sometimes you're taking corners, you're braking so then your vestibular system has to adjust to that. If you're looking at your phone or a book, or even if you're talking to somebody, actually, I'm starting to feel a little nauseous just talking about it. I promise I'm not going to finish this episode by vomiting at the end, at least not here, but what can happen is that you're uncoupling the visual information from your motion, from your vestibular information. You want those to be coupled. This is why a lot of people have to drive, they can't be in the passenger seat. Because when you drive, you also get what's called proprioceptive feedback. Your body is sending signals also to the vestibular system about where you are in space. When you're the passenger, you're just getting jolted around as the person is driving. And if you're looking at your phone, it's even worse. And if you're looking at the occluder between you and the two front seats, that's even worse. So this is why staring out the front windshield is great but you don't want to fixate. So, hopefully, I spared a few people and, hopefully, a few cab drivers of having people get sick in their cars or Ubers. Let your visual system and your vestibular system work together. If appropriate, get into linear acceleration, and you'll improve your sense of balance.

02:01:23 Synthesis

Once again, we've covered a tremendous amount of information. Now, you know how you hear, how you make sense of the sounds in your environment, how those come into

your ears and how your brain processes them. In addition, we talked about things like low level white noise and even binaural beats, which can be used to enhance certain brain states, certain rhythms within the brain, and even dopamine release in ways that allow you to learn better. And we talked about the balance system and this incredible relationship between your vestibular apparatus, meaning the portions of your inner ear that are responsible for balance and your visual system and gravity. And you can use those to enhance your learning as well, as well as just to enhance your sense of balance. If you're learning from this podcast, please subscribe on YouTube, that really helps us. In addition, please leave us any comments or feedback or suggestions for future episode content on YouTube in the comment section. If you haven't already subscribed on Apple and Spotify, please do that as well. And on Apple, you have the opportunity to leave us up to a five-star review. At Apple, you can also leave us comments and feedback. During this episode, I mentioned some supplements. We partnered with Thorne because Thorne has the very highest levels of stringency with respect to the quality of their ingredients and accuracy about the amounts of those ingredients contained within their products. If you'd like to see the products that I take from Thorne, you can go to T-H-O-R-N-E dot com, slash the letter U slash Huberman. So that's thorne.com/u/huberman to see all the supplements that I take. And if you do that, you can get 20% off any of those supplements or 20% off any of the supplements that Thorne makes. For those of you that might want to support us in other ways, we have a Patreon account. It's patreon.com/andrewhuberman, and there you can support our podcast at any level that you like. In addition, if you'd like to support the podcast, please check out our sponsors mentioned at the beginning of the episode. That is absolutely the best way to support us. Last but not least, I'd like to thank you for your time and attention and desire and willingness to learn about vision and balance. And, of course, thank you for your interest in science. [tranquil music]