Welcome to the Huberman Lab podcast where we discuss science and science-based tools for everyday life. My name is Andrew Huberman and I'm a professor of neurobiology and ophthalmology at Stanford School of Medicine. This podcast is separate from my teaching and research roles at Stanford. It is, however, part of my desire and effort to bring you zero cost to consumer information about science and science-related tools. Today, we're going to talk about how to change your nervous system for the better. As you recall, your nervous system includes your brain and your spinal cord, but also all the connections that your brain and spinal cord make with the organs of your body, and all the connections that the organs of your body make with your brain and spinal cord. This thing that we call the nervous system is responsible for everything we know, all our behavior, all our emotions, everything we feel about ourselves and the outside world, everything we think and believe it's really at the center of our entire experience of life and who we are. Fortunately, in humans, unlike in other species, we can change our nervous system by taking some very specific and deliberate actions. Today, we're really going to focus on the actions, the motor commands and the aspects of movement and balance that allow us to change our nervous system. It turns out that movement and balance actually provide windows or portals into our ability to change our nervous system the way we want, even if those changes are not about learning new movements or learning how to balance. And soon you'll understand why. So today, we're going to talk a lot about the basic science of neuroplasticity. I promise to not use excessive nomenclature. There'll be a little bit, but I'll try and make it as clear as possible. And we're also going to talk a lot about protocols and tools that the scientific literature points to and supports for changing our nervous system, again, not just for sake of learning new motor movements or how to balance better, but for how to feel differently about particular experiences, both past, present, and future, as well as how to learn faster. We're not going to discuss hacks or word I love. We're not going to discuss gimmicks. We're going to discuss mechanism and scientific data and the tools that those mechanisms and scientific data point to so that you can tailor your practices around learning to your specific needs and goals. So let's begin by just examining the big picture question, which is, does the brain control behavior? And my hope is that everyone is immediately thinking, yes, the brain and nervous system, we really should say, because the brain is just one component of the nervous system, controls our behavior. How does it do that? Well, there are a couple different levels that it does that. First of all, if we're talking about movement behavior generally means movement, if we're talking about movement, we have two categories of neurons that are very important to think about in the context of neuroplasticity. First of all, we have what are called lower motor neurons. These are motor neurons that live in our spinal cord. If for the aficionados out there for those of you that might be head to medical school or just want to learn more about the anatomy, they live in the ventral horn of the spinal cord. That doesn't matter. If you don't want to know that, just know that you have these things called lower motor neurons. These are neurons that are in the spinal cord, but they extend a wire that we call an axon out into the peripheral nervous system into the body. And those neurons connect with muscle. They send electrical potentials out there that allow our muscles to twitch and to contract. As a little point of fact, actually, we don't have muscle memory. There's no such thing as muscle memory. Muscles are dumb. They don't know anything. They don't have a history. They don't have a memory. They don't know anything. It is the neurons that control those muscles and their firing patterns in which all the information for motor patterns are stored. So your ability to walk is not muscle memory. It's neural memory. Now the lower motor neurons, while smarter than the muscle, so to speak, are not the most brilliant of the motor neurons. They are generally involved in doing what they are told. And they are told what to do from two sources. We have circuits in our brain stem. So this would be kind of around your neck deep in the brain that are called central pattern generators. These are sometimes called CPGs. Central pattern generators are what allow us to generate repetitive patterns of movement. So inhaling and exhaling and exhaling and exhaling subconsciously is controlled by a central pattern generator. That just means a collection of neurons. If you really want to know, they're called the pre-bought singer neurons discovered by Jack Feldman and colleagues at UCLA. These neurons in the brain stem send information down the phrenic nerve and control the diaphragm. So it goes inhale, exhale, inhale, exhale. You don't have to think about that. You could think about it and you could change the durations of inhales and exhales and change that up. But the motor neurons that control that are just responding to what the brain is telling it to do. The other central pattern generators include things like walking, the right limb left limb, right limb left limb pattern that we normally associate with walking was learned during childhood. And these central pattern generators sometimes called CPGs tell our lower motor neurons fire. Now you fire. Now you fire. So they are literally saying right left right left. They are the marching orders from the brain stem to the lower motor neurons. So these lower motor neurons do what they are told. They are obedient little soldiers and they do what they are told. And their job is to make the muscles contract at specific times. Okay, that's all simple. But then there are the upper motor neurons. The upper motor neurons actually reside in our motor cortex way up on top of the brain. And they are involved in sending signals for deliberate action. Okay, so they send signals to the lower motor neurons, which are the effectors, the ones that actually control the muscles. But the upper motor neurons are the ones that send very specific signals. For instance, the signals that would allow you to make a cup of coffee in the morning or to deliberately engage in any kind of behavior. Now you can probably make a cup of coffee in the morning without having to think about it too much. It's almost reflexive for you now, which means that a lot of the information about how to perform that particular movement has been passed off to circuitry that's now more or less in the brain stem and below the motor cortex. Now, why am I giving you all this detail? Well, if you want to change motor patterns, you have to know where in the circuitry changes are possible and you have ought to know where the changes are most likely to occur. You also need to know how do you signal to the brain that a nervous system that a change is necessary. So let's just pause there, return to the initial question that we started with, which is, does the brain control behavior? And the answer is yes, and now you know how it's upper motor neurons, lower motor neurons. You've got these things called central pattern generators and some connection with the muscles. So there you go. You just got basically what was the equivalent of the introduction to a college lecture on motor control in the nervous system. But the point today is all about plasticity. How can that be leveraged in order to open up this magical thing that we call plasticity in order to access changes to our emotional experience or to our belief system or to our ability to remember and use specific kinds of information for say math or language, etc. Well, what I'm not going to tell you is that you need to go running or you need to go biking or that simply going through motor patterns is going to open up plasticity because I hate to tell you this, but as beneficial as exercise is, it does not open plasticity unless you do certain things. And I will tell you exactly what those certain things are today to be clear, I think exercise is wonderful and healthy can improve cardiovascular function, maintain strength, bone density, all that good stuff. But just working out or doing your exercise of various kinds will not change your nervous system. It will maintain it and it can certainly improve other health metrics, but it is not going to open up the window for plasticity. The question we need to ask is can behavior change the brain? We already agreed that the brain can change behavior, but can behavior change the brain? And the answer is yes, provided that behavior is different enough in specific ways from the behaviors that you already know how to perform. Let me repeat that. Can behavior change the brain? And the answer is yes, provided that behavior is different enough from the sorts of behaviors that you already know how to perform. And I should have added the word well because you can't obviously perform a behavior that you don't know how to perform because you don't know how to do it yet. But there's a key element to accessing neuroplasticity that frankly, I don't see out there in the general discussion about neuroplasticity and about learning. I hear all these gimmicks about using different ways to remember lots of people's names and arranging things into their first letters and mnemonics and all this kind of stuff, which frankly to me feels really gimmicky. And I think that if you look at super learners, they tend to be people that have a process of, say, extreme memory. But people who have extreme memory generally, the literature shows us are pretty poor at other things. So I don't think most of us are interested in walking around knowing how to remember everything. In fact, there are some interesting studies looking at humans who over-remember and they suffer tremendously because they remember all sorts of things like the number at the top of the receipt at the bodega that they bought a Coca-Cola 10 years ago. This is useless information for most people. They don't do well in life, really. So the goal isn't to remember everything. The goal is to be selective about your brain changes. And when we talk about brain changes, I want to highlight adaptive changes. There's a whole category of things that we're going to discuss when we talk about traumatic brain injury and dementia, a topic for a future episode, about all the things that happen when you have damaged your nervous system or your missing neurons. But today, I really want to talk about something that I think is very near and dear to many of your hearts, which is what are the behaviors that you can engage in to access neuroplasticity so that then you can apply that plasticity to the specific things that you want to learn or unlearn. This is very important because I don't want people to get the impression that we're really talking about learning a bunch of motor movements. You may be an athlete, you might not be an athlete, you might want to learn how to dance, you might not. You might want to learn how to dance and get better at remembering and learning languages, for instance, or at unlearning some difficult emotional experience, meaning you want to remove the emotional load from a particular memory of an experience. What we're talking about today is using behavior as a gate to enter states of mind and body that allow you to access plasticity. So let's talk about the different kinds of plasticity that are available to us because those will point directly towards the type of protocols that we should engage in to change ourselves for the better, this so-called adaptive plasticity. There is something called representational plasticity. Representational plasticity is just your internal representation of the outside world. So you have a map of auditory space, believe it or not, meaning you have neurons. They respond when something over on my right happens, like I'm snapping my fingers over to my right. I can't snap as well on my left, which is the whole thing into itself. Yeah, weak over there on the left side. But when I do that, there are different neurons respond to those. We have a map of visual space. Certain neurons are seeing things in certain portions of visual space and not others. We have a map of motor space, meaning when we move our limbs in particular directions, we know when though where those limbs are, because even if we can't see them, we have what's called proprioceptive feedback. So we have knowledge about where our limbs are. In fact, people that lack certain neurons that for proprioceptive feedback, they are very poor at controlling their motor behavior. They get injured a lot. It's actually a terrible situation. So we've got all these representations inside and we have maps of our motor commands. We know that, for instance, if I want to reach out and grab the pen in front of me, that I need to generate a certain amount of force. So I rarely overshoot. I rarely miss the pen. Okay. So our maps of the motor world and our maps of the sensory world are merged. The way to create plasticity is to create mismatches or errors in how we perform things. And this, I think, is an amazing and important feature of neuroplasticity that is highly underappreciated. The way to create plasticity is to send signals to the brain that something is wrong, something is different and something isn't being achieved. And I think this will completely reframe the way that most people think about plasticity. Most of us think about plasticity as, okay, we're going to get into this optimal learning state or flow. And then suddenly we're going to be able to do all the things that we wish that we could do. While I hate to break it to you, but flow is an expression of what we already know how to do. It is not a state for learning. And I'm willing to go to bat with any of the flow Anistas out there that want to challenge me on that one. Flow is an expression of nervous system capabilities that are already embedded in us. Errors and making errors out of sync with what we would like to do is how our nervous system is queued through very distinct biological mechanisms that something isn't going right. And therefore certain neurochemicals are deployed that will signal the neural circuits that they have to change. So let's talk about the experiments that support what I just said because I'm about to tell you that making errors over and over and over again is the route to shaping your nervous system so that it performs better and better and better. And I'm not going to tell you that the last rep of a set where you hit failure in the gym is anything like neuroplasticity. You hear that too that you know it's pushing to that point of a cliff where you just can't function anymore. That's the signal. That's not the signal. That's a distinct neuromuscular phenomenon that bears zero resemblance to what it takes to get neuroplasticity. So let's talk about errors and making errors and why and how that triggers the release of chemicals that then allow us to not just learn the thing that we're doing in the motor sense play the piano dance, etc. But it also creates an environment to mill you within the brain that allows us to then go learn how to couple or uncouple a particular emotion to an experience or better language learning or better mathematical learning. It's a really fundamental aspect of how we're built. And when you look at it, it's actually very straightforward. It's a series of logical steps that once you learn how to open those hatches, it becomes very straightforward to deploy. Last episode, we discussed some of the basic principles of neuroplasticity. If you didn't hear that episode, no problem. I'll just review it quickly, which is that it's a falsehood that everything that we do in experience changes our brain. The brain changes when certain neurochemicals, namely acetylcholine, epinephrine, endopamin, are released in ways and in the specific time that allow for neural circuits to be marked for change and then the change occurs later during sleep. I'll review that later, but basically you need a certain cocktail of chemicals released in the brain in order for a particular behavior to reshape the way that our brain works. The question really is, what allows those neurochemicals to be released? And last episode, it talked all about focus. If you haven't seen or heard that episode, you might want to check it out about some specific tools and practices that can allow you to build up your capacity for focus and release certain chemicals in that cocktail. Today, we're going to talk about the other chemicals in the cocktail in particular dopamine. We're going to center our discussion around this issue of making errors and why making errors is actually the signal that tells the brain, okay, it's time to change or more generally, it's time to pay attention to things so that you change. And I really want to distinguish this point really clearly, which is that I'm going to talk today a lot about motor and vestibular meaning balance programs, but not just for learning motor commands and balance, not just for learning new motor skills and balance, but also for setting a stage or a condition in your brain where you can go learn other things as well. So let's talk about some classic experiments that really nail down what's most important in this discussion about plasticity. So I mentioned last episode and I'll just tell you right now again, the brain is incredibly plastic from about birth until about age 25. Passive experience will shape the brain just because of the way that the chemicals that are sloshing around in there and the way that the neurons are arranged and all sorts of things, the brain job is to customize itself in response to its experience and then somewhere about 25. It's not like the day after your 26th birthday plasticity closes, there's a high tape ring off of plasticity and you need different mechanisms to engage plasticity as an adult. We're mostly going to be talking about adult plasticity today, but I got a lot of questions about well, what about if I'm younger than 25? First of all, that's great. I wish I could, I wish I had a time machine, but I don't because as I've said before the stinger is when you're young, your brain is very plastic, but you have less control over your experience. When you're older, generally, you have more control over your experience, but your brain is less plastic. If you're already asking the question as a 20-year-old or a 15-year-old, what can I do now that's really enhanced my brain? I guess the simple answer would be an aside which we get the broadest education you can possible. That means math, chemistry, physics, literature, music, learn how to play an instrument. I'm saying that because I wish I had, etc. get a broad training and a number of things and find the thing that really captures your passion and excitement and then put a ton of additional effort there. That's what I recommend, including emotional development, maybe a topic for a future episode. But if you are an adult or if you are a young person knowing how to tap into these plasticity mechanisms is very powerful. You need these chemicals deployed in the nervous system in order to mark whatever nerve cells happen to be firing in the time afterward for change. And people are obsessed with asking what supplements, what drugs, what conditions, what machines will allow for that. But there's a natural set of conditions that allow for that. When we came into this world, we learned to take our different maps of experience, our motor maps, our auditory maps, our visual maps, and to link them. We align those maps. The simplest example is the one I gave before. If I hear something off to my right, like a click, like that, it could come from my finger snapping or it could come from something generated by somebody else or something else to my right, I look to my right. If I hear it on the left, I look to my left. If I hear it right in front of me, I keep looking right in front of me. And if I hear it behind me, I turn around. And that's because our maps of visual space and our maps of auditory space and our maps of motor space are aligned to one another in perfect register. It's an incredible feature of our nervous system. It takes place in a structure called the superior colliculus, although you don't need to know that name. Spirula has layers, literally stacks of neurons, like in a sandwich, where the zero point right in front of me, or maybe, you know, 10 or 15 degrees off to my right or 10 or 15 degrees off to my left, are aligned so that the auditory neurons, the ones that care about sounds at 15 degrees to my right. They sit directly below the neurons that look at 15 degrees to my right in my visual system. And when I reach over to this direction, there's a signal that's that's sent down through those layers that says 15 degrees off to the right is the direction to look, it's the direction to listen, and it's the direction to move if I need to move. So there's an alignment, and this is really powerful, and this is what allows us to move through space and function in a lives in a really fluid way. It's set up during development, but there have been some important experiments that have revealed that these maps are plastic, meaning they can shift their subject to neuroplasticity, and there are specific rules that allow us to shift them. So here's the key experiment. The key experiment was done by a colleague of mine. It's now retired, but whose work is absolutely fundamental in the field of neuroplasticity, Eric Nudson. The Nudson Lab, and many of the Nudson Lab scientific offspring, showed that if one is to wear prism glasses that shift the visual field, that eventually there'll be a shift in the representation of the auditorium motor maps to now what they initially did is they looked at young subjects, and what they did is they moved the visual world by making them wear prism glasses. So that, for instance, if my pen is out in front of me at five degrees off-center, so just a little bit off-center, if you're listening to this, this would be just a little bit to my right. But in these prism glasses, I actually see that pen way over far on my right. So it's actually here, but I see it over there because I'm wearing prisms on my eyes. What happens is, in the first day or so, you ask people or you ask animal subjects or whatever to reach for this object, and they reach to the wrong place because they're seeing it where it isn't. This gets especially complicated when you start including sounds, when you have a thing off to your right, making a sound, but the thing is actually right here. So you're hearing the sound at one location, and you're seeing the object at another location because you're wearing these prisms. And the image of the world is totally distorted. Or, in experiments done by other groups, they wear glasses, subjects wore glasses that completely invert the visual world so that everything is upside down, which is an extreme example of these representational maps being flipped or shifted. But what you find is that in young individuals, within a day or two, they start adjusting their motor behavior in exactly the right way so that they always reach to the correct location. So they hear a sound at one location, they see the object that ought to make that sound at a different location, and they somehow are able to adjust their motor behavior to reach to the correct location. It's incredible. It's absolutely incredible. Or in the case of the people who look at the world upside down, they somehow are able to navigate this upside down world, even though we're completely used to our feet being on the floor and not on the ceiling and people not walking at us by hanging off the ceiling like bats. Amazing. And what it tells us is that these maps that are aligned to one another can move and shift and rotate and even flip themselves. And it happens best in young individuals. If you do this in older individuals, in most cases, it takes a very long time for the maps to shift and in some cases they never shift. This is a very experimental scenario, but it's an important one to understand because it really tamps down the fact that we have the capacity to create dramatic shifts in our representation of the outside world. So how can we get plasticity as adult that mimics the plasticity that we get when we are juveniles? Well, the Newtson Lab and other labs have looked at this, and it's really interesting. First of all, we have to ask, what is the signal for plasticity? Is it just having prison glasses on? No, because they did that experiment and ruled that out. Is it just the fact that the visual thing is over to my appears to be far over to my right when in fact it's right in front of me? No. The signal that generates the plasticity is the making of errors. It's the reaches and failures that signal to the nervous system that this is not working. And therefore the shifts start to take place. And this is so fundamentally important because I think most people think, oh well, practice is going to be, I have to access Beginner's Mind, which is a great concept actually. It's about approaching things expecting to make errors, which is great. I think I am a believer in Beginner's Mind. But people understandably get frustrated. Like they're trying to learn a piece on the piano and they don't know how they can't do it or they're trying to write a piece of code or they're trying to access some sort of motor behavior and they can't do it. And the frustration drives them crazy. Like I can't do it. I can't do it when they don't realize that the errors themselves are signaling to the brain and nervous system. Something's not working. And of course the brain doesn't understand the words something isn't working. The brain doesn't even understand frustration as an emotional state. The brain understands the neurochemicals that are released, namely epinephrine and acetylcholine. But also we'll get into this the molecule dopamine when we start to approximate the correct behavior just a little bit. And we start getting a little bit right. So what happens is when we make errors, the nervous system kind of, I don't want to say freaks out because it's a very mechanistic and controlled situation. And the system starts releasing neurotransmitters and neuromodulators that say we better change something in the circuitry. And so errors are the basis for neuroplasticity and for learning. And I wish that this was more prominent prominent out there. I guess this is why I'm saying it. And humans do not like this feeling of frustration and making errors. The few that do do exceedingly well in whatever pursuits they happen to be involved in. And generally don't do well. They generally don't learn much. And if you think about it, why would your nervous system ever change? Why would it ever change? Unless there was something to be afraid of something that made us feel awful will signal that the nervous system needs to change. Or there's an error in our performance. So it turns out that the feedback of these errors. So reaching to the wrong location starts to release a number of things. And now you've heard about them many times. But this would be epinephrine. It increases alertness. A cytokine focus. And this is why frustration that leads us to just kind of quit and walk away from the endeavor is the absolute worst thing. Because if a cytokine is released, it creates an opportunity to focus on the error margin, the distance between what it is that you're doing and what it is that you would like to do. And then the nervous system starts to make changes almost immediately in order to try and get the behavior right. And when you start getting it even a little bit right, that third molecule comes online or is released, which is dopamine, which allows for the plastic changes to occur very fast. Now this is what all happens very naturally in young brains. But in old brains, it tends to be pretty slow except for in two conditions. So let me just pause and just say this. If you are uncomfortable making errors and you get frustrated easy easily. If you leverage that frustration toward drilling deeper into the endeavor, you are setting yourself up for a terrific set of plasticity mechanisms to engage. But if you take that frustration and you walk away from the endeavor, you are essentially setting up plasticity to rewire you according to what happens afterwards, which is generally feeling pretty miserable. So now you can kind of start to appreciate why it is that continuing to drill into a process to the point of frustration, but then staying with that process for a little bit longer, and I'll define exactly what I mean by a little bit, is the most important thing for adult learning, as well as childhood learning, but adult learning in particular. Now the Nutson Lab did two very important sets of experiments. The first one was published in Nature, very important study, which showed that juveniles can make these massive shifts in their map representations, meaning you can shift the visual world using visual prisms, a huge amount, and very quickly young individuals can shift their representations of the world so that they learn to reach to the correct location. They get a lot of plasticity all at once, and it happens very fast in the period of just a couple days. In adults, it tends to be very slow, and most individuals never actually accomplish the full map shift, they don't get the plasticity. And here we're talking about map shifts, but this could be learning a new language, this could be any number of different things that one we're attempting. So what we're saying is, what I already said before, which is that we learn very well as youngsters, but not as adults after 25. But then what they did is they started making the increment of change smaller. So instead of shifting the world a huge amount by putting prisms that shifted the visual world all the way over to the right, they did this incrementally. So the first they put on prisms that shifted it just a little bit, just like seven degrees, I believe was the exact number. And then it was 14 degrees, and then it was 28 degrees. And so what they found was that the adult nervous system can tolerate smaller and smaller errors over time, but that you can stack those errors so that you can get a lot of plasticity. Put simply incremental learning as an adult is absolutely essential. You are not going to get massive shifts in your representations of the outside world. So how do you make small errors as opposed to big errors? Well, the key is smaller bouts of focused learning for smaller bits of information. It's a mistake to try and learn a lot of information in one learning bout as an adult. What these papers from the Nudson lab show and what others have gone on to show is that the adult nervous system is fully capable of engaging in a huge amount of plasticity, but you need to do it in smaller increments per learning epoch or per learning episode. So how would you do this? Well, let's say, for instance, I'm terrible at free throws. So let's say I wanted to learn free throws. I'm 45 years old, so I'm well past the 25 and under mark. I'm going to make errors, when I make a lot of errors. If I go into learning free throws, knowing that errors are the gate to plasticity, well, then I feel a little bit better, but I still have to aim for the rim of the basket or the net, you know, basically showing how little I know about basketball. But I think I know the general themes around basketball involves a net a backboard and a ball, of course. So I go to the free throw line and I'll throw how long should I go? Well, until I'm hitting the point of frustration. And at that point, continuing probably for anywhere from 10 to 100 more trials should be my limit. Right? That should be my limit if I want to improve some specific aspect of the motor behavior. And so the question then is what should I be paying attention to? What should I be focusing on? Well, obviously trying to get the ball into the basket. But the beauty of motor learning is that the circuits for auditory and visual and motor more or less teach themselves. I don't necessarily have to be paying attention to exactly what, you know, the contact of my fingers with the ball or some random feature like whether or not I'm bending my knees or not. The key is to try a number of different parameters until I start to approximate the behavior that I want to get a little bit better and then trying to get consistent about that. Now many of you involved in sports learning will say, okay, well, that's obvious is just incremental learning. But the key thing is in those errors by isolating the errors and making a number of errors in a particular aspect of the motor movement. It signals to the brain that it's plastic. And if I leave that episode of going and trying to learn how to shoot free throws. My brain is still plastic. Plasticity is a state of the brain and nervous system. It's not just geared toward the specific thing I'm trying to learn. So there are two aspects to plasticity that I think we really need to highlight one is that there's plasticity geared toward the thing that you are trying to learn specifically. And then there are states of mind and body that allow us to access plasticity. Now toward the end of this episode, I'm going to spell out specific protocols in a little more detail. That free throw example might not correlate with what you want to learn. Actually, I don't have a huge desire to learn free throws. I've more or less given up on basketball. But and free throws in particular. But I think that it's important to understand that motor movements are the most straightforward way to access states of plasticity. And that can be for sake of learning the motor movement or for sake of accessing plasticity more generally. One very important aspect to plasticity getting plasticity as an adult is not just smaller increments, meaning shorter. So I gave an example of another hundred free throws or something. But going out there and just getting my 10,000 free throws all at once or packing as much as I can into one one episode is not going to be as efficient for me as shorter about the way I'm going to do. Shorter bouts of intense learning as an adult because the error signals are not as well defined to my nervous system. It's not going to know what needs to change. And so this is really the key element of incremental learning is that you're trying to signal to the nervous system at least one component that needs to change. The nervous system needs to know what the error is. Now when I shoot free throws Lord knows there are a lot of different kinds of errors that happen. The way I'm bending my knees, the arc of the ball, the way I'm organizing my shoulders, probably where my eyes are lots of things. So which ones to focus on. And that's what I said before the beauty of the motor system is I don't have to worry about all of that. I just need to get the reps in a number of times and the nervous system will figure out how far off my motor commands are at the level of these maps that I described earlier. How far those are those deviate from the desired behavior getting the ball into the basket. And it will start making adjustments. But as I make adjustments or as my nervous system makes adjustments for me, the key thing is to not start adding a variety of new errors because then it gets confused. And so this is why short learning ballots are absolutely essential. So let's say it's for learning an instrument as an adult, probably anywhere from seven minutes to 30 minutes is going to provide it that it's fully you're fully attending, you're very focused is going to be a pretty significant stimulus to inspire plasticity in the nervous system. Now there is one way to get a lot of plasticity all at once as an adult. There is that kind of holy grail thing of getting massive plasticity as you would when you were a young person but as an adult. And the Newtson lab revealed this by setting a very serious contingency on the learning. What they did was they had a situation where subjects had to find food that was displaced in their visual world again by putting prisms and they had to find the food and the food made a noise. There was a noise set kind of the location of the food through an array of speakers. Basically what they found was that if people have to adjust their visual world in order to get food, the plasticity would eventually occur but it was very slow as an adult. Unless they actually had the hunt that food they actually if they in order to eat at all they needed plasticity and then what happened was remarkable what they observed is that the plasticity as an adult can be as dramatic as robust as it is in a young person or in a young animal subject provided that there's a serious incentive for the plasticity to occur. And this is absolutely important to understand which is that how badly we need or want the plasticity determines how fast that plasticity will arrive which is incredible because the brain is just neurons and soup of chemicals. So what this but this means that the importance of something how important something is to us actually gates the rate of plasticity and the magnitude of plasticity. And this is why just passively going through most things going through the motions as we say or just getting our reps in quote unquote is not sufficient to get the nervous system to change this study, a beautiful study. Published in the journal neuroscience shows that if we actually have to accomplish something in order to eat or in order to get our ration of income we will reshape our nervous system very very quickly. So the nervous system has a capacity excuse me to change at a tremendous rate to a enormous degree at any stage of life provided it's important enough that that happened. And I think some of you might be saying well duh that's obvious if it's really crucial then of course it's going to change faster but it didn't have to be that way. And for most people who are trying to learn how to learn faster or learn better they probably in most cases they are hitting a limit because the need to change is not crucial enough. And I think there are a number of places where this has important relevance in the people who are battling addiction for instance. I will be the first to say that I sympathize with the fact that addictions have a biological component. There are clearly cases where people struggle tremendously to change their behavior and their nervous system in some cases is so disrupted by whatever substance they've been abusing or behavior that they've been engaging in that it's that much harder for them to change. But we've also seen incredible examples where when people have to change from an internal standpoint from their own belief and desire to change that massive change is possible. And so I think that the studies that Nudson did showing that incremental learning can create a huge degree of plasticity as an adult as well as when the contingency is very high meaning we need to eat or we need to make an income or we need to do something that's vitally important for us. That plasticity can happen in these enormous leaps just like they can in adolescents and young adulthood that points to the fact that it has to be a neurochemical system there has to be an underlying mechanism right this wasn't a case of in you know sticking a wire into the brain or taking a particular drug all the chemicals that we're about to talk about are released from drug stores if you will chemical stores that already reside in all of our brains. And the key is how to tap into those stores and so we're going to next talk about what are the specific behaviors that liberate particular categories of chemicals that allow us to make the most of incremental learning and that set the stage for plasticity that is similar enough or mimics these high contingency states like the need to get food or really create a sense of internal urgency chemical urgency if you will. If you've heard previous episodes of this podcast may have heard me talk about all trading rhythms which are these 90 minute rhythms that break up our 24 hour day they help break up our sleep into different cycles of sleep like REM sleep and non REM sleep and in waking states they help us or I should say they break up our day in ways that allow us to learn best within 90 minute cycles etc so some of you might be saying wait you've been talking about all trading cycles in a moment ago you were talking about. 7 minute or 12 minute or 30 minute learning cycles today we're really talking about how to tap into plasticity through the completion of a task or working towards something repetitively and making errors and so just to frame this in the context of the all trading cycle you might sit down decide that you're going to learn conversational French which we're meeting that you probably don't already speak French. So you're going to sit down you're going to decide you're going to learn some some nouns and some verbs you might do some practice that the the all trading cycle says that for the first 5 to 10 minutes of doing that your mind is going to drift and your focus will probably kick in provided that you're visually you're restricting your visual world to the just the material in front of you something we talked about last episode somewhere around the 10 or 15 minute mark and then at best you're probably going to get about an hour of deliberate kind of talking about. Deliberate kind of tunnel vision learning in there your mind will drift and then toward the end of that what is now an hour and 10 or hour and 20 minute cycle you're going to your brain will start to flicker in an hour you might start thinking about what you need to eat or the fact you have to use the bathroom or something and then by the 90 minutes it's probably time to just stop the learning about and go do something else maybe return for a second learning about later but maybe take an app afterwards or something to enhance the learning but that it's going to happen. Within about a 90 minute block you're going to go through that that cycle of learning but when I referred to the 7 or 12 or 30 minutes of making errors what I mean is when you're really in a mode of repeating errors not deliberately you're trying your best to accomplish something and you're failing you're absolutely failing you're trying to remember say the sign language alphabet. I was trying to teach myself this recently and then I keep repeating repeating and then get to a certain point about making errors making errors making errors you want to keep making errors for this period of time that I'm saying will last anywhere for about 7 to 30 minutes it is exceedingly frustrating but that frustration it liberates the chemical cues that signal that plastic needs to happen and they also signal the particular neurons that are active. So in the case of sign language it might be the ones that control my hand movements as well as me thinking about what the different letters are it's signaling different components within the networks of between the brain and body and it's trying to figure out wait where are these errors coming from where the errors coming from it's those neurons they're making the mistakes they're making the mistakes they're making the mistakes and it essentially highlights that pathway for change and it is the case that when we come back a day or two later in a learning that is going to be a little bit more difficult to do. Later in a learning bout after a nap or a night or two of deep rest then what we find is that we can remember certain things and the motor pathways work and we don't always get it perfectly but we get a lot of it right whereas we got it wrong before so that 7 to 30 minute intense learning about is within the all trading cycle and I want to be clear about that. And some people can tolerate many of these per day most people can only tolerate one or two maybe three this is intense work if you know shooting free throws you could probably do it all day but what I'm talking about is really trying to accelerate plasticity by having a period of the 7 to 30 minutes per learning bout that is specifically about making errors I want to really underscore that. And it's not about as I mentioned before coming up with some little hack or trick or or something of that sort it's really about trying to cue the nervous system that something needs to change because otherwise it simply won't change. Now there's another aspect to learning I think it's only fair to mention which is that we can all learn very easily when there's something very bad happens to us and I don't I don't wish this on anyone but it is the case that the same thing is going to be done. But it is the case that if something really terrible happens that we will have a lifetime memory for that event we there are processes that allow us to uncouple the emotional load of that event I talked about some of those a few episodes back the episode on dreams trauma and hallucinations and we're going to return to trauma release PTSD and some of those other themes in a future episode but the reason why negative experiences are can be wired into us so quickly is because our nervous systems main job. And the nervous systems main job is to keep us safe but at a deeper level it's because negative experiences cue us to the fact that whatever is happening that's really bad is very different than than the other things that tend to happen before so most of our experience doesn't remap us but those negative experiences deploy high levels of North and F and high levels of aceto calling and really make so that whatever it is that we experience in that bad episode is essentially key. Essentially queued up and so we're on the lookout for it and this has a number of negative effects but in terms of psychological and emotional effects but it is really a process designed to keep us safe. The other ways in which we can learn more quickly besides just making errors is when something really surprises us and if we're positively surprised by something or we are just flooded with this molecule dopamine then there is a great opportunity for plasticity. Dopamine is a molecule that's almost always associated with pleasure and with the accomplishment of a particular goal but it's really also a molecule of motivation it's a molecule that is released inside of us when we think we're on the right path and it does have a capacity to increase neuroplasticity motivation etc. It's released in response to a number of natural behaviors just that help with the progression of ours and other species things like food, sex, in some sense social connection although that's more serotonin and serotonin doesn't have the same effects on plasticity quite the same and we'll talk about a few later. Dopamine is when we think we're on the right path toward an external goal a little bit is released and it tends to give us more motivation toward that goal. I think everyone could stand to enhance the rate of learning by doing the following. Learn to attach dopamine in a subjective way to this process of making errors because that's really combining two modes of plasticity in ways that together can accelerate the plasticity. Earlier I talked about making errors and having a focus about of learning that includes making a lot of errors inside of that learning bout that is going to be frustrating but the frustration itself is the Q and epinephrine will be very high under those conditions but if you can just subjectively associate that experience with something good and that you want to continue down that path as opposed to quitting when you hit the point of frustration then you start to create a synergy between the dopamine that's released when we subjectively think something is good or tell ourselves something is good and that situation of making failures. In other words making failures repetitively provided we're engaged in a very specific set of behaviors when we do it as well as telling ourselves that those failures are good for learning and good for us creates an outsized effect on the rate of plasticity. Some of you might be asking and I get asked a lot well how do I get dopamine to be released and can I just tell myself that something is good when it's bad. Well actually yes believe it or not the thing about dopamine is it's highly subjective what's funny to one person is not so funny to the next so it has to have some sense of authenticity for you but if you really want to be learning the thing that you're trying to learn that should be reason enough to tell yourself well I'm frustrated but this the frustration is the source of accelerated learning dopamine is one of these incredible molecules that both can be released according to things that are hard wired in us to release dopamine again things like food sex warm film or cold cool environments when we're too warm it's that kind of pleasure molecule overall but it's also highly subjective what releases dopamine in one person versus the next so everyone releases dopamine in response to those very basic kind of behaviors and activities but dopamine is also released according to what we subjectively believe is good for us and that's what's so powerful about it in fact a book that I highly recommend if you want to read more about dopamine is a book that frankly I wish I had written it's such a wonderful book it's called the molecule of more and it really talks about dopamine not just as a molecule associated with reward but a molecule associated with motivation and pursuit and just how subjectively controlled dopamine can be so make lots of errors tell yourself that those errors are important and good for your overall learning goals so learn to attach dopamine meaning release dopamine in your brain when you start to make errors keep the bouts of learning relatively short if you're an adult younger people can can probably engage in more bouts of learning and it's probably one of the reasons why they learn so much faster they can just pack so much more information into the brains and nervous systems compared to adults it's a little bit like a usual example of performance enhancing drugs you know that some of those drugs probably do enhance performance at the level of increasing red blood cell count etc but a lot of what those drugs do is they allow athletes to recover faster so they can just train more they allow them to do more work and so being a child is a little bit like being in a performance enhanced brain milieu their brains are kind of unnatural healthy neurochemicals that that afford them a lot more learning should they learn more learning should they pursue it so this goes back to my advice for young people early on if you're young what should you do learn as much as you can about as many things as you possibly can and I suggest specializing in something I guess I'm not in a position to give anyone direct advice but I would say hopefully by about age 30 hopefully younger you have some sense of what excites you and try and get really good at that thing provided it serves the world for better but that's all I'll say in terms of parenting advice it's not my place but maybe sometime I'll have an episode completely devoted to sort of youth and learning and youth but once you're attaching dopamine to this process of making errors then I start getting lots of questions I really are the right questions which are you know how often should I do this and when should I be doing this and at what time well I've talked a little bit about this in previous episodes but as long as we're now kind of into the nitty gritty of tools and application each of us have some natural times throughout the day when we are going to be much better at tolerating these errors and much more focused on what it is that we're trying to do last episode was about focus but chances are that you can't focus as well at 4 p.m. as you can at 10 a.m. it differs for everybody depending on when you're sleeping and you're kind of natural chemistry and rhythms but find the time or times of day when you naturally have the highest mental acuity and that's really when you want to engage in these learning bouts and then get to the point where you're making errors and then keep making errors for seven to 30 minutes just keep making those errors and drill through it and you're almost seeking frustration and if you can find some pleasure in the frustration yes that is a state that exists you have created the optimal neurochemical milieu for learning that thing but then here's the beauty of it you also created the optimal milieu for learning other things afterward if you leave that bout of I give the example of free throws or maybe it's playing tennis or maybe it's some other skill and you sit down to read a book your brain is in a heightened state to learn and retain the information because those chemicals don't get released and then shut down you're creating a whole milieu and environment of these chemicals the tale of how long these chemicals stay you know sloshing around your brain has too many factors for me to put a hard number on it it's going to depend on transporters and enzymes and all sorts of things but at least for an hour so I would say you're going to be in a state of heightened learning and the ability to learn not just the motor patterns but cognitive information language information maybe you go to therapy right after that and you work on something in a very deliberate way that you're trying to work on you don't go to therapy maybe you do something else that's important to you again there just a variety of examples I could give there are a number of things that allow us to powerfully access the states of error that are kind of surprising but also kind of fun and these aren't again these aren't gimmicks these tap into these basic mechanisms of plasticity and the three that I'd like to talk about next are balance meaning the vestibular system as well as the two sides of what I call limbic friction or autonomic arousal and if none of that makes sense I'm going to put a fine point on each one of those and what it is and why it works for opening up neural plasticity let's talk about limbic friction now limbic friction is not a term you're going to find in the textbooks so if any of my colleagues are listening I want to repeat limbic friction I realize is not something you're going to find in any of the textbooks but it is an important principle that captures a lot of information that is in textbooks both neurobiology and psychology and it has some really important implications limbic friction is my attempt to give a name to something that is more nuanced and mechanistic than stress because typically when we hear about stress we think of heart rate heart beat going too fast breathing too fast sweating and not being in a state that we want we're too alert and we want to be more calm and indeed that's one condition in which we have limbic friction meaning our limbic system is taking control of a number of different aspects of our autonomic or automatic biology and we are struggling to control that through what we call top down mechanisms we're trying to calm down in order to reduce that level of arousal we're all familiar with this it's called the stress response however there's another aspect of stress that's just as important which is when we're tired and we're fatigued and we need to engage we need to be more alert than we are so what I call limbic friction is really designed to describe the fact that when our autonomic nervous system isn't where we want it meaning we're trying to be more alert or we're trying to be less alert both of those feel stressful to people so the other way to put it is that the word stress is not a very good word to describe what most people experience is stressful because it can either be being too tired or being too alert now why am I bringing this up in a discussion about neuroplasticity this is not a discussion about stress at some point we will talk about stress and tools to deal with stress but the reason I'm bringing this up is that in order to access neuroplasticity you need these components of focus you need the component of of of attaching subjective reward you need to make errors all this stuff and a lot of people find it difficult to just get into the overall state to access those things so now there's a series of gates that people are having a hard time accessing they're too tired and they can't focus for instance well here's the beauty of it if you are too alert meaning you're too you know anxious and you want to calm down in order to learn better there are things that you can do the two that I've spoken about previously on various podcasts I'll just review them really quickly are the double inhale exhale so inhaling twice through the nose and exhaling once through the mouth this is not some yogic trick or some hack this is what's called a physiological sigh offloads carbon dioxide from the lungs it has a number of different effects these were described in textbooks and eating back to the you know the thirties and a number of laboratories have explored the neural circuitry underlying these so-called physiological size that will calm you down faster than anything else that I'm aware of the other thing is starting to remove your tunnel vision you know when you use tunnel vision you very focus that epinephrine is released by dilating your field of gaze so-called panoramic vision great so now you can start to move up and down this level of autonomic arousal the key is you want to be in a state of arousal that's ideally matched to the thing that you're trying to perform or learn so if I'm really anxious and I can't even pick up the basketball or I feel like I'm shaking or my muscles are too tight I don't have that kind of looseness now the one I move like that almost makes it look like I could throw a free throw but I miss 95% of the time unless the basket is very very low and I place it indirectly but I guess that's not a free throw is it in any case the point being that you want to be in a state of alertness but calm and so you need to have ways to calm yourself down when you're when you're too amped up but the other side of limbic friction is important too if you are too tired and you can't focus well then it's going to be impossible to even get to the starting line so to speak for engaging in neural plasticity through incremental learning etc. So in that case there are other methods that you can do to wake yourself up the best thing you should do is get a good night's sleep but that's not always possible or use an NSTR non-sleep deep rest protocol but if you've already done those things or you're simply exhausted for whatever other reason then there are other things that I often get asked about like sure a cup of coffee or super oxygenation breathing which means inhaling more than exhaling on average in a breathing bout these are now we're sort of getting toward the realm of how you could trick your nervous system into waking up and if you bring more oxygen in by making your inhales deeper and longer you will become more alert you'll start to actually deploy nor epinephrine if you breathe very fast so there are things that you can do to move up or down this so-called autonomic arousal arc and what you want to ask before you undergo any learning bout is how much limbic friction am I experiencing? am I too alert and I want to be calmer or am I too calm and too sleepy and I want to be more alert you're going to need to engage in behaviors that bring you to the starting line in order to learn there are other things that you can do in order to then learn better and faster besides incremental learning and those center on the vestibular system and this may come as a surprise to some people but probably not as a surprise to some of you whose professions or whose recreation involves a lot of motor activity and so what we call high-dimensional skill activity not just running or cycling or very linear activities like weightlifting but things that involve inversions and a lot of lateral movement actual sports jumping diving rolling these kinds of things gymnastics type stuff why the vestibular system to access neural plasticity well we have a hard-wired system for balance and here's how it works in as simple terms that I can possibly come up with as we move through space or even if we're stationary there are really three main planes of movement now I realize some people are just listening to this so I'm going to do this for both the folks that are just listening and for those of you that are watching on video so there are three main modes of movement and it turns out that your brain doesn't really know where your body is except when through that proprioceptive feedback the main way it knows is through three planes of movement that we call pitch which is like nodding so if I nod like this that's pitch then there's yaw which is side to side which is like shaking my head no and then there's a roll from side to side like when a puppy looks at you like that kind of thing okay so pitch yaw and roll and the pilot's out there will know exactly what I'm talking about the brain knows the orientation and position of your body relative to gravity depending on whether or not your brain is and your head actually is engaging more in pitch yaw or roll or some combination because if I lean down like so or like so it's a combination of pitch yaw and roll you might say like what is going on here well we have these little things in our inner ear called the semi-circular canals just like our eyes have two main functions one is to see objects in space and the other is to set our circadian clocks through subconscious mechanisms our ears have two main roles one is to hear right to perceive sound waves or taking sound waves for perception so called hearing and the other is balance or vestibular function so sitting in our ears are the semi-circular canals and there these little tubes where these little stones there are actually little bits of calcium roll back and forth like little marbles when we roll this way they roll this way when it pitch when we go from side to side there's something that sit flat like this and they go like marbles inside of a hulu and then we have roll there's something that are kind of at 45 degrees to those and it's kind of pitch yaw and roll okay great that sends signals to the rest of our brain and body that tell us how to compensate for shifts relative to gravity I thought we were talking about plasticity but this is where it gets really really cool errors in vestibular motor sensory experience meaning when we are off balance and we have to compensate by looking at thinking about or responding to the world differently cause an area of our brain called the cerebellum it actually means mini brain and it looks like a little mini brain like tucked below our cortex in the back cause the cerebellum to signal some of these deeper brain centers that release dopamine, norupinephrine and acetylcholine and that's because these circuits in the inner ear, et cetera and the cerebellum they were designed to recalibrate our motor movements when our relationship to gravity changes something fundamental to survival we can't afford to be falling down all the time or missing things that we grab for or you know running in the wrong direction when something is pursuing us these are hardwired circuits that tap right into these chemical pathways and those chemical pathways are the gates to plasticity so I really want to spell this out clearly because I've given a lot of information today the first thing is how are you arriving to the learning bout you need to make sure your level of autonomic arousal is correct the ideal state is going to be clear, calm and focused maybe a little bit more on the arousal level like heightened arousal so understand limbic friction understand that you can be too tired in which case you're going to need to get yourself a little more alert or you can be too alert and you're going to need to get yourself calmer that gets you to the starting line when you're at the starting line then you're going to go into a learning bout and that's when you want to start making these errors but what I'm saying is there's a layer in between where if you are interested in using motor patterns as a way to open up plasticity for all kinds of learning not just motor learning, disrupting your vestibular motor relationship meaning and I'll tell you how to do that in a moment can deploy or release neurochemicals in the brain that place you into a state that makes you much better at learning and makes making errors much more pleasurable you're much more willing to do that now some of you are probably saying flow state, flow state okay I have friends that work on flow states and who are involved in flow states and trying to figure out what they are great respect for those people so when I you know tip my hat to them very important work but again flow is an expression of what you already know how to do it's what it's not how you learn it's how you express what you've already learned so I want to be really clear about that it's been kind of presented as this super state or highly desirable state but it's that you know we can all reach for that's the wrong wrong to reach for until you already know how to do the things that I'm describing in my opinion so the vestibular system if you can engage the vestibular system and create some errors within the vestibular motor operations that you're carrying out you create a neurochemical state that then makes you very very good at learning very quickly regardless of age so what would this look like? does this mean just doing inversions? Well does this mean doing yoga? maybe does this mean taking corners faster on your road bike? does this mean let's say you always swim freestyle or breaststroke? does this mean swimming you know backstroke or butterfly? it depends it depends however on a very very easy to understand parameter which is how regularly you perform a particular motor behavior and how novel a behavior is so the more novel that a behavior is in terms of your relationship to gravity the more it will open up the opportunity for plasticity have you ever seen somebody who just jumped out of the plane for the first time you know with the parachute? I don't even want to think about what if you've just seen somebody who jumped out of the plane for the first time without a parachute I'll just hope the plane was on the ground but if you've seen somebody after that they are in this incredible state because their body and brain are flooded with all these neurochemicals because it's very novel to them however you know I've got friends from communities that do you know have done thousands upon thousands tens of thousands of jumps and they're always alert and aware but it becomes pretty regular for them that's the point and they're not in this kind of buzzed out excited state afterwards because it's routine for them so the key is to bring novelty to the vestibular motor experience the vestibular motor commands that you're performing and how do you do that? well it's all about your orientation relative to gravity now I wouldn't want anyone to place themselves at risk so if you can't do handstands don't try and do them free standing if you're good at handstands guess how much plasticity doing a handstands for half an hour is going to create for you? zero zero your body is fully comfortable walking on your hands I see these people walking on your hands being upside down, being inverted you know you're Cirque du Soleil performers they're very comfortable there and there's zero learning, zero plasticity because the failures and errors and the relationship to gravity are very typical for that individual now what this means is that if we're going to use motor practices to open up plasticity for learning not just those practices but some maybe some cognitive skills or other things in the period that follows we need to create a sense of novelty relative to gravity and that means being either in a new position or slightly unstable believe it or not this I don't want anyone injuring themselves with a sensation of falling or close to falling signals the cerebellum to signal the deep brain centers that release these neurochemicals that something is very different and we need to correct this error very very fast now earlier I was talking about high contingencies for learning and you know you definitely don't want to make it a kind of like either survive this or or die kind of experience I've I confess I occasionally look at these parkour videos on YouTube and I believe in all of those people have died the ones that do these ridiculous things of hanging off of buildings and these I am not suggesting you do that please don't do that what I'm talking about is finding safe ways to explore the sensory motor vestibular space as we call it the relationship between those things so that could be through yoga if you're terrible at yoga there's more opportunity for you to learn than somebody who's very skilled at yoga for instance or gymnastics or handstands or on your road bike this is unfortunately what I don't want to name brands but stationary bikes where they give you the visual experience of moving through space but you're not actually moving through physical space there's no vestibular feedback it's all visual right your stationary on the bike right so unless you're hanging off the bike in your living room like almost to the point you're tipping the bike you're not getting the actual vestibular motor sensory mismatch that mismatch is the signal that deploys dopamine epinephrine and these other things I don't care how excited or how much fun the ride was or how much music you're playing that you love it's not the same situation as being out of your normal relationship to the gravitational pole so the first gate is to arrive at learning at the appropriate level of autonomic arousal clear and focused is best but don't obsess over being right there it's okay be a little anxious or a little bit tired then you want to make errors we talked about that and this vestibular motor sensory relationship is absolutely key if you want to get heightened or accelerated plasticity and we talked about another feature which is setting a contingency if there's a reason an important reason for you to actually learn even if you're making failures the learning will be accelerated so there's really four things that you really need to do for plasticity as an adult and I would say that these also apply to young people and there's an interesting kind of thought experiment there as well which is if you look at children they are moving a lot in different dimensions you know they are hanging sometimes hanging from trees or you know I was a kind of a I was my sports were always things where I tended to get hurt a lot fall lots there's a skateboarding for me when I was younger so a lot of falling and rolling and various things of that sort but whatever sport the kids are playing or even if they don't play a sport they tend to move in a lot of different relationships to gravity more dimensionality to their movements I should say than adults and one of the questions that's always kind of been in the back of my mind is you know as we age we get less good at engaging in neuroplasticity part of that is because as the brain ages there are certain changes to the way that neurons are structured their molecular components etc but it's kind of a self amplifying or I should say a self of self generating self-degenerating cycle where as we get older we tend to get more linear and more regular about specific kinds of movements so we get on the treadmill or we take the walk or we just always go up the same stairs etc and there's less opportunity typically for engaging these relationships to the gravitational pull through the vestibular motor sensory convergence that we talked about a moment ago and so you sort of have to wonder whether or not the lack of plasticity or the reduced plasticity in older individuals which includes me would reflect the fact that those chemicals aren't being deployed because we're not engaging in certain behaviors as opposed to we can't engage in the behaviors because the chemicals aren't being deployed now I have a feeling it's both these have a reciprocal relationship and I certainly again I don't think it would be wise for anyone who doesn't have the muscle stabilizing skills or the bone density etc to start you know like doing inversions and things of that sort that's not what I'm talking about here but it's interesting to think about the sorts of exercise that we engage and we all know that getting the heart rate elevated three to five times a week is really good for us for cardiovascular health I think there's a ton of data to support that now some load bearing exercise is important for increasing bone density and maintaining muscular strength and proper receptive feedback because I'm sure many of you know this but resistance exercise actually trains the nerve to muscle connections as much as it does the muscles themselves something I talked about at the beginning of the episode but I think most of us could stand to increase the degree to which we engage this vestibular system in novel ways and that can be done quite safely through a number of different mechanisms I'm not a surfer but people who do that sort of thing are very familiar with orienting their body differently according to the gravitational pole or they're lying down then they're standing up then they're turning their leaning their head so again it's this pitch yaw roll thing and again if you're very skilled at surfing you're actually not going to open up plasticity just by surfing it's in the learning of these new relationships to gravity that the windows for plasticity are enhanced so I want to make sure that I underscore the fact that this vestibular thing that I've been describing is a way to really accentuate plasticity it's tapping into an inborn biological mechanism where the cerebellum has outputs to these deep brain nuclei associated with dopamine acetocholine and or epinephrine you don't want to endanger yourself in the course of pursuing these activities but it is a powerful mechanism that's an kind of an amplifier on plasticity as is high contingency if you really need to learn conversational French to save your relationship the chances are you're going to learn it there are limits of course to the extent to which one can accentuate or accelerate plasticity you know the ceiling on this is not infinite although we don't know how high it goes I think it's reasonable say that if someone put a gun to my head and said learn conversational French in the next 120 seconds that conversational French would be limited probably to just one word probably the word wheat or something like that because I can't stuff in all the knowledge all at once I mean I think that's the dream of brain machine interface that one will be able to download a chip into their hippocampus or cortex or some other brain structure that would allow them to download conversational French and someday we may get to that as you know that capability may come about right now it does not exist nor is there a specific pillar chemical that will allow you to download more information more quickly this is the the issue around neutropics I've talked about before there are things that can increase focus mainly things that increase the pseudocolline and transmission through the nicotine system things that can increase dopamine things like altiracine again I'm not recommending these you need to heed the warnings on those bottles but they will increase these neurochemicals and there are of course things that will increase up in effort and things like caffeine or some people because of prescription take Adderall I'm again not suggesting people take any of these things in fact today I focused almost exclusively on behavioral tools and ways of structuring learning bouts that will allow you to access more plasticity regardless of age and they center around things that I'm sure if you look around you you'll see evidence for oh incremental learning is powerful or oh the vestibular system can open up opportunities for plasticity I'm sure the yogis out there are all saying wait this sounds exactly like yoga we're supposed to push to an edge and do these inversions and do all those sorts of things well I want to be clear I never said anyone should do inversions I said that the vestibular system is a valuable portal into some of these neurochemical states that favor plasticity but not so seldom I hear from the yogic community and they will say things like much of what you're saying about how the brain works or neuro plasticity has already been described as embedded in the brain has already been described as embedded in yogic practices and I just want to be very clear I have tremendous respect for the yogic community and the practices I've done yoga from time to time I find it challenging and valuable I'm not a regular practitioner but the problem with yoga is exactly the same problem with science which is that yoga has a lot of practices for which there are very specific names but no description or lending of understanding about mechanism and science has a lot of mechanisms and a lot of publications and papers for which there's very little if not no description of tools and practices so my goal in not just today but in many ways throughout the course of the podcast is to bridge the gaps between these various disciplines in ways that are grounded mainly to the fields of neuroscience and some related fields so yes it's true that I look at things mainly through the lens of science but that's not to say that it exhaustively explains everything about anything nor is it to say that it's the only lens through which one could look at something like neuro plasticity so I just want to acknowledge that I have great respect for all these different practices and communities and I think that indeed there are many cases in which different communities and practices have been aimed at targeting the same goals or outcomes. Science and neuroscience through an understanding of mechanism can allow all of us to gain a kind of common understanding about what those practices are and how to access things like neuro plasticity, sleep, etc. and I do believe as I've said previously on this podcast that understanding mechanism affords us a certain flexibility and I don't mean physical flexibility, I mean a flexibility when we can't engage in a particular behavior maybe we're injured or maybe we're not in the right situation to do a particular practice but by thinking about mechanism we can adapt our circumstances. I talked about this with sleep you know if you're rigidly attached to one protocol of always looking at sunlight at one particular time in the morning and in the evening that is not as valuable as understanding the mechanisms of why you might look at sunlight at one particular time versus another because that affords you a flexibility allows you to adapt and life is very dynamic and we don't have control over all the external conditions all the time and so understanding mechanism through the lens of neuroscience I do believe can be very powerful because of course there are multiple ways to access dopamine there are multiple ways to adjust limbic friction it's not just through respiration of course there are many ways to do that and so my overall goal here in this episode and with this podcast is to give you some understanding of the mechanisms and the insights into the underlying biology that allow you to tailor what these kind of foundational mechanisms are to suit your particular learning needs. So I really thank you for your time and attention today covered a lot of material. I very much encourage questions in the comment section if you're looking at this on YouTube and if you're not and you're listening to it on Apple or Spotify please feel free to visit us over on the YouTube channel and put your questions in the comment section. I do read them this entire month is all about neuroplasticity there's a lot to cover but I'm very excited to delve deeper into this topic as it relates to your particular interests. Many of you have graciously asked how you can help support the podcast. And that's why you can do that is to subscribe to the YouTube channel if you haven't done that already as well as to place questions in the comment section below or comments if you'd like to give us feedback. Also to subscribe on Apple and or Spotify and Apple allows you to leave a five star review if you believe we deserve a five star review as well as leave comments about the podcast. In addition if you can suggest the podcast to your friends to your family members or anyone that you think might be able to use and appreciate the information that's a terrific way to support us. And of course check out our sponsors that we mentioned at the beginning that's a terrific way to support us as well. Several times throughout today's episode as well as on previous episodes of the podcast I've talked about various supplements that can be useful for enhancing sleep, enhancing neuroplasticity, etc. And again I want to emphasize that I always think that behavioral practices are the place to start. I don't think supplements should ever be the first line of entry for people looking to enhance these aspects of their nervous system in life. But for those of you that are interested in supplements and the supplements that I take, I'm pleased to announce that we partnered with Thorne, THORNE. And Thorne makes supplements that are in my opinion of the very highest stringency in terms of what's listed on the bottle is actually what you'll find in the bottle. This is a serious issue for the supplement industry as well as just the overall quality of the materials they put into their supplements. If you'd like to take a look at the supplements that I take as well as explore any of them for yourself you can go to thorn.com slash you slash Huberman. And if you look there you'll see a number of the different supplements that I take. And if you decide to purchase any of them you'll get 20% off your order. So that's Thorne, THORNE slash you slash Huberman to see the supplements that I take and to explore if any of them are right for you. In the next episode of this podcast we're going to continue to explore neuroplasticity. This as you may recall is the way that we go about things here at the Huberman lab podcast which is to really drill deeply into a topic for three or four or even five episodes so that by the end of those episodes all of you have a very firm understanding of how to apply the principles of neurobiology to the specific practices and endeavors that are most important to you. So I very much thank you for your time and attention. I know it's a lot of information and it takes a bit of focus and attention and certainly will trigger plasticity to learn all this information. I want to encourage you and just remind you that you don't have to grasp it all at once that it is here archived and then if you want to return to the information it will still be here. And that I most of all really appreciate your interest in science. Thank you so much.