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 are discussing memory, in particular how to improve your memory. The study of memory is one that dates back many decades, and by now there's a pretty good understanding of how memories are formed in the brain. The different structures involved and some of the neurochemicals involved. We will talk about some of that today. Often overlooked however is that memories are not just about learning. Memories are also about placing your entire life into a context. And that's because what's really special about the brain, and in particular the human brain, is its ability to place events in the context of past events, the present, and future events. And sometimes even combinations of the past and present, or present and future, and so on. So when we talk about memory, what we're really talking about is how your immediate experiences relate to previous and future experiences. Today I'm going to make clear how that process occurs. Even if you don't have a background in biology or psychology, I promise to put it into language that anyone can access and understand. And we are going to talk about the science that points to specific tools for enhancing learning and memory. We're also going to talk about unlearning and forgetting. There are of course instances in which we would like to forget things. And that too is a biological process for which great tools exist to, for instance, eliminate or at least reduce the emotional load of our previous experience that you really did not like, or that perhaps even was traumatic to you. So today you're going to learn about the systems in the brain and body that establish memories. You're going to learn why certain memories are easier to form than others. And I'm going to talk about specific tools that are grounded in not just one, not just a dozen, but well over 100 studies in animals and humans that point to specific protocols that you can use in order to stamp down learning of particular things more easily. And you can also leverage that same knowledge to better forget or unload the emotional weight of experiences that you did not like. We are also going to discuss topics like deja vu and photographic memory. And for those of you that do not have a photographic memory, and I should point out that I do not have a photographic memory either, well, you will learn how to use your visual system in order to better learn visual and auditory information. There are protocols to do this grounded in excellent peer reviewed research. So while you may not have a true photographic memory, by the end of the episode you will have tools in hand, or I should say tools in mind or in eyes and mind, to be able to encode and remember specific events better than you would otherwise. Before we begin, I'd like to emphasize 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. Okay, let's talk about memory and let's talk about how to get better at remembering things. In order to address both of those things, we need to do a little bit of brain science 101 review and I promise this will only take two minutes and I promise that even if you don't have a background in biology, it will make sense. We are constantly being bombarded with physical stimuli, patterns of touch on our skin, light to our eyes, light to our skin for that matter, smells, tastes, and sound waves. In fact, if you can hear me saying this right now, well, that's the consequence of sound waves arriving into your ears through headphones, a computer, or some other speaker device. Each one of and all of those sensory stimuli are converted into electricity and chemical signals by your so-called nervous system, your brain, your spinal cord, and all their connections with the organs of the body and all the connections of your organs of the body back to your brain and spinal cord. One of the primary jobs of your nervous system, in fact, is to convert physical events in the world that are non-negotiable, right? Photons of light are photons of light, sound waves are sound waves, there's no changing that, but your nervous system does change that. It converts those things into electrical signals and chemical signals, which are the language of your nervous system. Now, just because you're being bombarded with all the sensory information and it's being converted into a language that neurons and the rest of your nervous system can understand does not mean that you are aware of it all. In fact, you are only going to perceive a small amount of that sensory information, for instance. If you can hear me speaking right now, you are perceiving my voice, but you are also, most likely, neglecting the feeling of the contact of your skin with whichever surface you happen to be sitting or standing on. So, it is only by perceiving a subset, a small fraction of the sensory events in our environment, that we can make sense of the world around us. Otherwise, we would just be overwhelmed with all the things that are happening in any one given moment. Now, memory is simply a bias in which perceptions will be replayed again in the future. Anytime you experience something, that is the consequence of specific chains of neurons that we call neural circuits being activated. And memory is simply a bias in the likelihood that that specific chain of neurons will be activated again. So, for instance, if you can remember your name, and I certainly hope that you can, well, that means that there are specific chains of neurons in your brain that represent your name. And when those neurons connect with one another and communicate electrically with one another in a particular sequence, you remember your name. Were that particular chain of neurons to be disrupted? You would not be able to remember your name. Now, this might seem immensely simple, but it raises this really interesting question, which we talked about before, which is, why do we remember certain things and not others? Because, according to what I've just said, as you go through life, you're experiencing things all the time. You're constantly being bombarded with sensory stimuli, some of those sensory stimuli you perceive, and only some of those perceptions get stamped down as memories. Today, I'm going to teach you how certain things get stamped down as memories. And I'm going to teach you how to leverage that process in order to remember the information that you want far better. Now, even though I told you that a memory is simply a bias in the likelihood that a particular chain of neurons will be activated in a particular sequence again and again, it doesn't operate on its own. In fact, most of what we remember takes place in a context of other events. So, for instance, you can most likely remember your name, and yet you're probably not thinking about when it was that you first learned your name. This generally happens when we are very, very young children. And yet, I'm guessing you could probably remember a time when someone mispronounced your name, or made fun of your name, or, as the case was for me, I got to the third grade, and there were two Andrews. And sadly for me, I lost the coin flip that allowed me to keep Andrew and from about third grade until about 12th grade. People called me Andy, which I really did not prefer. So, if you call me Andy in the comments, I'll delete your comment. Just kidding. It doesn't bother me that much. But, eventually, I reclaimed Andrew as my name. Well, it was mine to begin with and throughout, but I started going by Andrew again. Why do I say this? Well, there's a whole context to my name for me. And there may or may not be a whole context to your name for you, but presumably if you asked your parents why they named you, you're given name, you'll get a context, et cetera. That context reflects the activation of other neural circuits that are also related to other events in your life, not just your name, but probably your siblings' names, and who your parents are, and on and on and on. And so, the way memory works is that each individual thing that we remember or that we want to remember is linked to something by either a close, a medium or a very distant association. This turns out to be immensely important. I know many of you will read or will encounter programs that are designed to help you enhance your memory. You know, you have these phenoms that can remember 50 names in a room full of people, or they can remember a bunch of names of novel objects or maybe even in different languages. And oftentimes that's done by association. So, people come up with little mental tricks to either link the sound of a word or the meaning of a word in some way that's meaningful for them and will enhance their memory. That can be done and is impressive when we see it, and for those of you who can do that, congratulations. Most of us can't do that, or at least it requires a lot of effort in training. However, there are things that we can do that leverage the natural biology of our nervous system to enhance learning and memory of particular perceptions and particular information. Let's first just talk about the most basic ways that we learn and remember things and how to improve learning and memory. And the most basic one is repetition. Now, the study of memory and the role of repetition actually dates back to the late 1800s, early 1900s, when Ebinghaus developed the first so-called learning curves. Now, learning curves are simply what results when you quantify how many repetitions of something are required in order to remember something. In fact, it's been said that Ebinghaus liberated the understanding of learning from the philosophers by generating these learning curves. When you mean by that, well, before Ebinghaus came along, learning and memory were thought to be philosophical ideas. Ebinghaus came along and said, well, let's actually take some measurements. Let's measure how well I can remember a sequence of words or a sequence of numbers if I just repeat them. So what Ebinghaus did is he would take a sequence of numbers or words on a page, and he would read them. And then he would take a separate sheet of paper, and we have to presume he didn't cheat. And he would write down as many of them as he could, and he would try and keep them in the same sequence. Then he would compare to the original list, and he would see how many errors he made. And you do this over and over and over again. And as you would expect early in the training and the learning, it took a lot more repetitions to get the sequence correct. And over time, it took fewer sequences. And he referred to that difference in the initial number of repetitions that he had to perform versus the later number of repetitions that he had to perform as a so-called savings. So he literally thought of the brain as having to generate a kind of a currency of effort. And he talked about savings as the reduction in the amount of effort that he had to put forward in order to learn information. And what he got was a learning curve. And you can imagine what that learning curve looked like. It was at a very sharp peak at the beginning that dropped off over time. And of course, he remembered all this meaningless information. But even though the information might have been meaningless, the experiment itself and what Ebinghaus demonstrated was immensely meaningful. Because what it said was that with repetition, we can activate particular sequences of neurons, and that repeated activation lays down what we call a memory. And that might all seem like a big duh. But prior to Ebinghaus, none of that was known. Now, I should also say Ebinghaus, because of when he was alive, was not aware of these things that we call neural circuits. It was in 1906 that Golgi and Kahal got the Nobel Prize for actually showing that neurons are independent cells connected by synapses, these little gaps between them where they communicate. So he may have been aware of that, but the whole notion of neural circuits hadn't really come about. Nevertheless, what the Ebinghaus learning curves really established was that she or her brain was able to do that. Was that she or repetition, just repeating things over and over and over again, is sufficient to learn something that no doubt had been observed before, but had never been formally quantified. Now, if we look at that result, there's something really important that lies a little bit cryptic that's not so obvious to most people, which is the information that he was trying to learn wasn't any more interesting the second time that it was the first. So, it probably was even less interesting and less and less interesting with each repetition, and yet it was sheer repetition that allowed him to remember. Now, sometime later in the early to mid-1920s, a psychologist in Canada named Donald Hebb came up with what was called Hebb's postulate, and Hebb's postulate, broadly speaking, is this idea that if a sequence of neurons is active at the same time, or at roughly the same time, it would lead to a strengthening of the connections between those neurons. And many, many decades of experimentation later, we now know that postulate to be true. Neurons themselves are not smart, they don't have knowledge. So, every memory is the consequences I told you before of the repeated activation of a particular chain of neurons. And what Ebbinghaus showed through repetition and what Donald Hebb proposed and was eventually verified through experimentation on animals and humans, was that if you encourage the co-activation of neurons, meaning have neurons fire at roughly the same time, they will strengthen their connections. It leads to a bias in the probability that those neurons will be active again. Now, this is vitally important because nowadays we hear a lot about how memories are the consequence of new neurons added in the brain, or that every time you learn something, a new connection in your brain forms. Sorry to break it to you, but that's simply not the case. Most of the time, and I want to emphasize most, not all, but most of the time when we learn something, it's because existing neurons, not new neurons, but existing neurons strengthen their connection through co-activation over and over and over through repetition, or, and this is a very important or, or through very strong activation once and only once. In fact, there's something called one trial learning whereby we experience something and we will remember that thing forever. This is often most associated with negative events, and I'll explain why in a few minutes, but it can also be associated with positive events, like the first time you saw your romantic partner, or something that happened with that romantic partner, or the first time that you saw your child, or any other positive event, as well as any other extremely negative event. So again, both repetition and, I guess we could label it intensity, but what would really mean when we say intensity is strong activation of neurons can lay down these traces, these circuits that are far more likely to be active again, then had there not been repetition or not some strong activation of those circuits. So with that in mind, let's return to the original contrarian question that I raised before, which is, why do we remember anything? Every day you wake up, your neurons in your brain embody are active, different neural circuits are active, and yet you only remember a small fraction of the things that happen each day, and yet you retain a lot of information from previous days and the days before those and so on. It is only with a lot of repetition or with extremely strong activation of a given neural circuit that we will create new memories. And so in a few minutes, I'll explain how to get extremely strong activation of particular neural circuits. Repetition is pretty obvious, repetition is repetition, but in a few minutes, I'll illustrate a whole set of experiments and a whole set of tools that point to how you can get extra strong activation of a given neural circuit, as it relates to learning, so that you will remember that information, perhaps not just with one trial of learning, but certainly with far fewer repetitions than would be required otherwise. Before we go any further, I want to preface the discussion by saying that there are a lot of different kinds of memory. In fact, where you to take a voyage into the neuroscience and or psychology of memory, you would find an immense number of different terms to describe the immense number of different types of memory that researchers focus on. But for sake of today's discussion, I really just want to focus on short term memory, medium term memory, and long term memory. And while there's still debate, as was always the case with scientists, frankly, about the exact divisions between short term, medium, and long term memory, we can broadly define short term memory and long term memory. And we can describe a couple different types of those that I think you can relate to in your everyday life. The most common form of short term memory that we're going to focus on is called working memory. Working memory is your ability to keep a chain of numbers in mind for some period of time, but the expectation really isn't that you would remember those numbers the next day and certainly not the next week. So a good example will be a phone number, if I were to tell you a phone number, 4932938. Well, you could probably remember it, 4932938. But if I came back tomorrow and asked you to repeat that chain of numbers, most likely you would not. Unless, of course, we used a particular tool to stamp down that memory into your mind and commit it to long term memory. Now, of course, in this day and age, most people have phone numbers programmed into their phone. They don't really have to remember the exact numbers. It's usually done by contact, identity, and so forth. So a different example that some of you are probably more familiar with would be those security codes. So you try and log on to an app or a website and it asks you for security code that's been sent to your text messages. And then you can either plug that in directly in some cases or you have to remember that short sequence of anywhere, usually from six to seven, sometimes eight numbers. Your ability to do that to switch back and forth between web pages or apps and plug in that number by remembering the sequence and plugging it in by texting or or king it in on your keyboard. That's a really good example of working memory long term memory of the sort that we're going to be talking a lot about today is your ability to commit certain patterns of information, either cognitive information or motor information, right, the ability to move your limbs in a particular sequence. Over long periods of time such that you could remember it a day or a week or a month or maybe even a year or several years later. So we got short term memory and long term memory and we've got this working memory, which is kind of keeping something online, but then discarding it. Okay, not online on a computer, but online within your brain. There are also two major categories of memory that I'd like you to know about. One is explicit memory. So this is not necessarily explicit of the sort that you're used to thinking about, but rather the fact that you can declare you know something. So you have an explicit memory of your name, presumably you have an explicit memory of the house or the apartment that you grew up in. You know something and you know you know it and you can declare it. So you can ask you what was the color of the first car that you owned or what is the color of your romantic partner's hair, these sorts of things. That's an explicit declarative memory, but you also have explicit procedural memories. Now procedural memories as the name suggests involve action sequences. The simplest one, it's almost ridiculously simple, is walking. So you say, how is it that you walk from one room to the other, you'd probably say, well I go that direction, I turn left, I say, no, no, no, no, how is it exactly that you do it? I say, well I move my left foot, then my right foot, and my left foot. And you could describe that. So it's an explicit procedural memory. So much so that if you were going to teach a young toddler how to walk, you would probably say, okay, good, good, try, okay. And you know, probably that's going to be pre-language for the toddler, but you're going to encourage them to move one leg. Then the other, and you're going to encourage and reward them for moving one leg than the other, because you have an explicit procedural memory of how to walk. Okay, almost ridiculously simple, maybe even truly ridiculously simple, but nonetheless, when you think about in the context of neural circuits and neural firing, pretty amazing. Even more amazing is the fact that all explicit memories, both declarative and procedural explicit memories, can be moved from explicit to implicit. What do I mean by that? Well, in the example of walking, you might have chuckled a little bit or kind of shook your head and said, this is a ridiculous thing to ask, how do I walk from one room to the next? I just walk, I just do it. Well, what is just do it? What it is is that you have an implicit understanding, meaning your nervous system knows how to walk without you actually having to think about what you know about how to walk. You just get up out of your chair or you get up out of bed and you walk. In the brain, you have a structure. In fact, you have one on each side of your brain, it's called the hippocampus. The hippocampus literally means seahorse. Anonymous like the name, brain structures, after things that they think those brain structures resemble. When I look at the hippocampus, frankly, it doesn't look like a seahorse, which either reflects my lack of understanding of what a seahorse really looks like, a visual deficit. Or I think it's fair to say that those anatomists were using a little bit of creative elaboration when thinking about what the hippocampus looks like. Nonetheless, it is a curved structure. It has many layers. It's been described by my colleague Robert Sapolsky and by others as looking more like a jelly roll or a cinnamon roll is what it looks like to me. If you were to take one cinnamon roll, chop it down the middle. Now you've got two half cinnamon rolls and rather than put them back together in the configuration they were before, you just slide one down so that you've got essentially two seas, two sea-shaped halves of the cinnamon roll and you push them together, slightly offset from one another. Well, that's what the hippocampus looks like to me. And I think that's a far better description of its actual physical structure. But I guess if you were to use that physical structure as the name, well then you'd have to open up a brain atlas and it would be called two half-sea cinnamon rolls stuffed halfway together. So that's not very good. So I guess seahorse will work. The hippocampus is the name of this structure and it is the site in your brain and again you have one on each side of your brain in which explicit declarative memories are formed. It is not where those memories are stored and maintained. It is where they are established in the first place. In contrast, implicit memories, these subconscious memories are formed and stored elsewhere in the brain. Mainly by areas like the cerebellum but also the neocortex that kind of outer shell of your brain. The cerebellum literally means mini-brain and it does in fact look like a mini-brain and is in the back of the brain and the neocortex is the outer part of the brain that covers all the other stuff. So the hippocampus is vitally important for establishing these new declarative memories of what you know and what you know how to do. Now in order to really understand the role of the hippocampus in memory, in particular explicit declarative and explicit procedural memory and to really understand how that's distinct from implicit declarative and implicit procedural memories, we have to look to a clinical case and the clinical case that I'm referring to is a patient who went by the name HM, patients go by their initials in order to maintain confidentiality of their real identity. HM had what's called intractable epilepsy. So he would have these really dramatic, so called grandmaw seizures or drop seizures. For those of you that know somebody with epilepsy or that have epilepsy, you might be familiar with this. You can have petite mall seizures which are minor seizures, you can have tonic clonic seizures, which are sometimes not even detectable. You can have absent seizures where people will just stop. It's almost as if their brain goes on pause and they'll just stop there. It was reported actually that Einstein had absent seizures, although I don't know that it's ever really been confirmed neurologically. Grandmaw seizures are extremely severe and that's what HM had. So he could just be going about his day and maybe even cooking or doing something driving, operating any kind of machinery. And then all of a sudden he would just have a drop seizure, so he would just physically drop and go into a grandmaw seizure, convulsing of the whole body, loss of consciousness, etc. Or he would feel it coming on oftentimes people with epilepsy can feel the up like seizure coming on kind of like a wave from the back of the brain. And sometimes they can get to a safe circumstance but not always. And so the frequency and the intensity of his seizures were so robust that the neurosurgeons and neurologists decided that they needed to locate the origin, what they call the foci of those seizures and remove that brain tissue. Because the way seizures work is they spread out from that focus or that foci of brain tissue. And unfortunately for HM, the focus of his seizures was the hippocampus. So after a lot of deliberation, a neurosurgeon, in fact, one of the most famous neurosurgeons in the world at that time, made what are called electrolytic lesions actually burned out the hippocampus in the brain of HM. And as a consequence, he lost all explicit memory. Now the consequence of this was that he couldn't exist in normal everyday life like most people. So he had to live mostly, not entirely, but mostly in a kind of hospital setting. And I've talked to several people who have, I should say, who met HM directly because he's no longer alive. But an interaction with him might look like the following. He would walk up to you, just fine. You wouldn't know that he had any kind of brain damage. He could walk fine. He could speak fine. And he'd say, hi, I'm Andrew. And he'd say, hi, I'm whatever his name happened to be. He wouldn't say HM, but he probably say his real name. And then perhaps someone knew would walk into the room. He might turn around. Look at that person as any of us might do. Then turn around back to me and say, hi, what's your name? And if I were to say, well, I just told you my name. And you just told me your name. Do you remember that he'd say, I'm sorry, I don't remember any of that. What's your name? So you'd go through this over and over again. So a complete lack of explicit declarative memory. Now he did have some memory for previous events in his life that dated way back. Okay. Again, hinting at the idea that memories are not necessarily stored in the hippocampus. They're just formed in the hippocampus. So once they've moved out of the hippocampus to other brain areas, he could still keep those memories. They're in a different database, if you will. They're in a different pattern of firing of other neural circuits, but he couldn't form new memories. Now there's some very important and interesting twists on what HM could and could not do in terms of learning and memory that teach us a lot about the brain. In fact, I think most neuroscientists would agree that this unfortunate case of HM's epilepsy and the subsequent neurosurgery that he had taught us much of what we know or at least think about in terms of human learning and memory. For instance, as I mentioned before, he still had implicit knowledge. He knew how to walk. He knew how to do certain things like make a cup of coffee. He knew the names of people that he had met much earlier in his life and so on. And yet he couldn't form new memories. Now, in violation to that last statement, there were some elements of HM's emotionality that suggests that there was some sort of residual capacity to learn new information, but it wasn't what we normally think of as explicit declarative or procedural memory. For instance, it's been reported or it's been said, I should say, because I don't know that the studies were ever done with intense physiological measurements. So that if you were to tell HM a joke and he thought it was funny, he would laugh really hard. So he liked jokes. So you'd say, HM, I want to tell you a joke, you tell him a joke and he'd laugh really hard. Then you could leave the room, come back and tell him the same joke again. Now, keep in mind, he did not remember that you told him the joke previously. And the second time he would laugh a little bit less. Then you'd leave the room, come back again, say, hi, I'm Andrew, nice to meet you because as you were, no, as you recall, because you can recall things, but he couldn't recall things. He didn't know that he just met you or at least he couldn't remember it. You tell him the joke a third time or a fourth time. And with each subsequent telling of the joke, he found it a little less funny. Just as, keep this in mind, folks, if you tell a joke and you get a big laugh, don't tell it again. It's not immediately, not to the same person or the same crowd because the second time it's a little less funny and the third time it's a little less funny. And that actually has to do with a whole element of dopamine and its relationship to surprise. And that's the topic of a future podcast where we talk all about humor and novelty in the brain. But the point being that certain forms of memory seem to exist in a kind of phantom-like way within HM's brain. What do I mean by that? Well, this underscores the fact that he had an implicit memory of having heard the joke before. And it suggests that humor or at least what we find funny is somehow more related to procedures similar to walking or immoderability than it is to this precise content of that joke. Alright, that's a little bit of an abstract concept, but the point is that HM lacked explicit declarative memory. He couldn't tell you what he had just heard. He could not learn new information. And he couldn't tell you how to do something unless he had learned how to do that something many years prior. Now, there have been a lot of other patients besides HM that have had brain lesions due to epilepsy or I should say due to surgeries to treat epilepsy, due to strokes, due to sadly gunshot wounds and other forms of what we call infarcts-infarct. I-N-F-A-R-C-T-infarct is the word we use to describe damage to a particular brain region. And many different patients with many different patterns of infarct have taught us a lot about how memory and other aspects of the brain work. HM really teaches us that what we know and what we are able to do is the consequence of things that we are aware of and learnings that have been passed off into subconscious knowledge, that our body knows, our brain knows, but we don't know exactly how we know that thing. And I tell you the story about HM's ability to understand a joke, but that with repeated telling of a joke it has less and less and less of an impact in creating a sense of laughter, of humor in HM, not as just an antidote to flesh out his story, but because emotion itself turns out to be the way in which we can enhance memories, even if those are memories for things that are not funny, are not intensely sad, are not immensely happy, or don't evoke a really strong emotional response or even any emotional response. And the reason for that is that emotions, just like perception, just like sensation, are the consequence of particular neurochemicals being present in our brain and body. And as I'm going to tell you next, there are particular neurochemicals that you can leverage in order to learn specific information faster and to remember it for a much longer period of time, maybe even forever. And you can do that by leveraging the relationship in your nervous system between your brain and your body and your body back to your brain. So let's talk about tools for enhancing memory. Now there's one tool that is absolutely clear works. And it's always worked, it works now, and it will work forever. And that's repetition. The more often that you perform something or that you recite something, the more likely you are to remember it in the future. And while that might seem obvious, it's worth thinking about what's happening when you repeat something, but when I say what's happening, I mean at the neural level. What's happening is that you're encouraging the firing of particular chains of neurons that reside in a particular circuit, right? So a particular sequence of neurons playing neuron A, B, C, D, played in that particular sequence over and over and over again. And with more repetitions, you get more strengthening of those nerve connections. Now, repetition works, but the problem for most people is that they either don't have the patience, they don't have the time, and sometimes they literally don't have the time because they've got a deadline on something that they're trying to remember and learn. Or they simply would like to be able to remember things better in general, remember them more quickly. This process of accelerating repetition based learning so that your learning curve doesn't go from having to perform something a thousand times and then gradually over time is a thousand, 750 times a day, 500 times a day, 300 times a day and down to no repetitions, right? You can just perform that thing the first time and every time. Well, there is a way to shift that curve so that you can essentially establish stronger connections between the neurons that are involved in generating that memory or behavior more quickly. How do you do that? Well, in order to answer that, we have to look at the beautiful work of James McGaw and Larry K. Hill. James McGaw and Larry K. Hill did a number of experiments over several decades, really, based on a lot of animal literature, but mainly focused on humans that really established what's required to get better at remembering things and to do so very quickly. I want to talk about one experiment that they did that was particularly important. We will provide a link to this paper. It's some years old now, but the results still hold up. In fact, the results establish an entire field of memory and neuroscience and psychology. What they did is they had human subjects come into the laboratory and to read a short paragraph of about 12 sentences. The key thing is that some subjects read a paragraph that was pretty mundane. The content, the information within the paragraph, was all related to the content of the previous sentence. It was a cogent paragraph. It just wasn't meaningless scramble of words. But it described a mundane set of circumstances. Maybe it would be a story about someone who walked into a room, sat down at a desk, wrote for a little bit, then got up and had lunch, just mundane information, not very interesting. Another group of subjects read also a 12 sentence paragraph, but that paragraph included a subset of sentences that had a lot of emotionally intense language or that had language that could evoke an emotionally intense response in the person reading it. It might have talked about a car accident or a very intense surgery, but it also could be positive stuff, things like a birthday party or a celebration of some other kind or a big sports win. In other words, you have two conditions of this study. People either read a boring paragraph or they read a really emotionally laden paragraph. And again, the emotions could either be positive or negative emotions. Subjects left the laboratory and sometime later they were called back to the laboratory. And I should say, at no point in the experiment, did they know they were part of a memory experiment? They don't know why they're reading this paragraph. They came in either for class credit or to get paid. It's typically how these things are done on college campuses or elsewhere. They come back into the lab and they would get a pop quiz. They would be asked to recall the content of the paragraph that they had read previously. Now, as is probably expected, perhaps even obvious to you, the subjects that read the emotionally intense paragraph, remembered far more of the content of that paragraph and were far more accurate in the remembering of that information. Now, that particular finding wasn't very novel. Many people had previously described how emotionally intense events are better remembered than non-emotionally intense events. In fact, way back in the 1600s, Francis Bacon, who's largely credited with developing the scientific method, said, quote, memory is assisted by anything that makes an impression on a powerful passion, inspiring fear, for example, or wonder, shame, or joy. Francis Bacon said that in 1620. So Jim McGon, Larry K. Hill, we're certainly not the first to demonstrate or to conceive of the idea that emotionally laid in experiences are more easily remembered than other experiences. However, what they did next was immensely important for our understanding of memory and for our building of tools to enhance learning and memory. What they did was they evaluated the capacity for stress and for particular neurochemicals associated with stress to improve our ability to learn information, not just information that is emotional, but information of all kinds. So I'm going to describe some experiments done in animal models, just very briefly, and then experiments done on human subjects because McGon worked mainly on animals also human subjects, Larry K. Hill, almost exclusively on human subjects. If you take a rat or a mouse and put it in an arena, where at one location the animal receives an electrical shock, and then you come back the next day, you remove the shock of oaking device, and you let the animal move around that arena, that animal will quite understandably avoid the location where it was shocked, so called conditioned place aversion. That effect of avoiding that particular location occurs in one trial. That's a good example of one trial learning. So somehow the animal knows that it was shocked at that location, it remembers that it is a hippocampal dependent learning, so animals that lack a hippocampus or have their hippocampus pharmacologically or otherwise incapacitated will not learn that new bit of information, but for animals that do they remember it after the first time and every time. Unless you are to block the release of certain chemicals in the brain and body, and then chemicals I'm referring to are epinephrine adrenaline, and to some extent the corticosterones, things like cortisol. Now we know that the effect of getting one trial learning somehow involves epinephrine at least in this particular experimental scenario, because if researchers do the exact same experiment, and they have done the exact same experiment, but they introduce a pharmacological blocker of epinephrine so that epinephrine is released in response to the shock, but it cannot actually bind to its receptors and have all of its biological effects. Well then the animal is perfectly happy to tread back into the area where it received the shock. It's almost as if it didn't know or we have to assume that it didn't remember that it received the shock at that location. So it all seems pretty obvious when you hear it, something bad happens in a location and we'll go back to that location. So that's condition place avoidance, but it turns out that the opposite is also true, meaning for something called condition place preference, you can take an animal, put it into an arena, feed it, or reward it somehow at one location in that arena so you can give a hungry, rat or mouse food at one particular location, take the animal out, come back the next day, no food is introduced, but it will go back to the location where it received the food. Or you can do any variant of this, you can make the arena a little bit chilly and provide warmth at that location, or you can take a male animal and turns out male rats and mice will mate at any point or a female animal, that's it, the particular so-called receptive phase of her mating cycle and give them an opportunity to mate at a given location, they'll go back to that location and wait and wait. This is perhaps why people go back to the same bar or the bar, see that the bar or the same restaurant and wait because of the one time they, you know, things worked out for them, whatever the context was condition place preference, condition place preference, as with condition place avoidance depends on the release of adrenaline, right? It's not just about stress, it's about a heightened emotional state in the brain and body, okay, this is really important, it's not just about stress, you can get one trial learning for positive events, condition place preference, and you can get one trial learning for negative events. Here I say positive negative, I'm putting what's called valence on, I'm making a value judgment about whether or not the animal liked it or didn't like it and we have to presume what the animal liked or didn't like and how it felt, but this turns out all to be important. It turns out all to be true for humans as well. We know that because McGon K. Hill did experiments where they gave people a boring paragraph to read and only a boring paragraph to read, but one group of subjects was asked to read the paragraph and then to place their arm into very, very cold water. We know that placing one's arm into ice water, especially if it's up to the shoulder or near to it, evokes the release of adrenaline in the body. It's not an enormous release, but it's a significant increase. And yes, they measured adrenaline release, in some cases they also measured for things like cortisol, et cetera. And what they found is that if one evokes the release of adrenaline through this arm into ice water approach, the information that they read previously, just a few minutes before, was remembered. It was retained as well as emotionally intense information, but keep in mind the information that they read was not interesting at all, or at least it wasn't emotionally laden. This had to be the effect of adrenaline released into the brain in body, because if they blocked the release or the function of adrenaline in the brain and or body, they could block this effect. Now, the biology of epinephrine and cortisol are a little bit complex, but there's some nuance there that's actually interesting and important to us. First of all, adrenaline is released in the body and in the brain. It's released in the body from the adrenals. Remember epinephrine and adrenaline are the same thing. Cortisol is also released from the adrenal glands. These two little glands that ride to top our kidneys, but it can't cross into the brain. It only has what we call peripheral effects, quickening of the heart rate, right? Changes the patterns of blood flow, changes our patterns of breathing. In general, makes our breathing more shallow and faster. In general, makes our heart beat more quickly, et cetera. Within our brain, we have a little brain area called locus serulius, which is in the back of the brain, which has the opportunity to sprinkler the rest of the brain with the neuromodulator epinephrine, adrenaline, as well as nor epinephrine related neuromodulator, and to essentially wake up or create a state of alertness throughout the brain. This is a very general effect. The reason we have two sites of release is because these neurochemicals do not cross the blood brain barrier, and so waking up the body with adrenaline and waking up the brain are two separate so-called parallel phenomena. Cortisol can cross the blood brain barrier because it's lipophilic, meaning it can move through fatty tissue. And we'll get into the biology of that in another episode, but Cortisol in general is released and has much longer term effects, and as I've just told you, can permeate throughout the brain in body. Adrenaline has more local effects, or at least has segregated between the brain and the body. This will turn out to be important later. The important thing to keep in mind is that it is the emotionality evoked by an experience, or to be more precise, it is the emotional state that you were in after you experienced something that dictates whether or not you will learn it quickly or not. This is absolutely important in terms of thinking about tools to improve your memory, and no, I am not going to suggest that every time you want to learn something, you plunge your arm into ice water. Why won't I suggest that? Well, it will induce the release of adrenaline, but there are better ways to get that adrenaline release. Before I explain exactly what those tools are, I want to tamp down the biology of how all this works, because in that understanding, you will have access to the best possible tools to improve your memory. First of all, McGon, K. Hill were excellent experimentalists. They did not just establish that you could quicken the formation of a memory by accessing material that was very emotionally laid in, or creating an emotional, high adrenaline state after interacting with some things, some words, some person, some information. They also tested whether or not that whole effect could be blocked by blocking the emotional state or by blocking adrenaline. So what they did is they had people read paragraphs that were either had a lot of emotional content, or they had people read paragraphs that were pretty boring, but then had them put their arm into ice water. They did other experiments to increase adrenaline. There were even some shock experiments that were done by other groups. Any number of things to evoke the release of adrenaline, even people taking drugs that increase adrenaline. But then they also did what are called blocking experiments. They did experiments where they had people get into a highly emotional state from reading highly emotional material, or they got people to get into a highly emotional neurochemical state by reading boring material and then taking a drug to increase adrenaline or ice bath or a shock. And then they also administered a drug called a beta blocker to block the effect of adrenaline and related chemicals in the brain and body. And what they found is that even if people were exposed to something really emotional or had a lot of adrenaline in their system because they received a drug to increase the amount of adrenaline, two manipulations that normally would increase memory, keep that in mind. If they gave them a beta blocker, which reduced the response to that adrenaline, right? So no quickening of the heart rate, no quickening of the breathing, no increase in the activity of locus cerulius and these kind of wake up signals to the rest of the brain. Well then the material wasn't remembered better at all. What this tells us is that yes, Francis Bacon was right. McGon K. Hill were right. Hundreds, if not thousands of philosophers and psychologists and neuroscientists were right in stating and in thinking that high emotional states help you learn things. But what McGon K. Hill really showed and what's most important to know is that it is the presence of high adrenaline, high amounts of nor epinephrine and epinephrine and perhaps cortisol as well as you'll soon see that allows a memory to be stamped down quickly. It is not the emotion. It is the neurochemical state that you go into as a consequence of the emotion. And it's very important to understand that while those two things are related, they are not one in the same thing. Because what that means is that we're you to evoke the release of epinephrine, nor epinephrine and cortisol or even just one or two of those chemicals after experiencing something, you are stamping down the experience that you just previously had. This is fundamentally important and far and away different than the idea that we remember things because they're important to us or because they evoke emotion. That's true, but the real reason, the neurochemical reason, the mechanism behind all that is these neurochemicals have the ability to strengthen neural connections by making them active just once. There's something truly magic about that neurochemical cocktail that removes the need for repetition. Okay, so let's apply this knowledge. Let's establish a scientifically grounded set of tools, meaning tools that take into account the identity of the neurochemicals that are important for enhancing learning and the timing of the release of those chemicals in order to enhance learning. When I first learned about the results of McGon K. Hill, I was just blown away. I was also pretty upset, but not with them. I was upset with myself because I realized that the way that I had been approaching learning and memory was not optimal. In fact, it was probably in the opposite direction to the enhanced protocol for learning and memory that I'm going to teach you today. My typical mode of trying to learn something while I was in college or while I was in graduate school or as a junior professor or even a tenured professor was to sit down to whatever it is I was going to try and learn, perhaps even memorize, or if it was a physical skill move to whatever environment I was going to learn that physical skill in. And prior to that, to make sure that I was hydrated, because that's important to me, and certainly can contribute to your brain's ability to function in your body's ability to function and general patterns of alertness, but also to caffeinate. I would have a nice strong cup of coffee or espresso. I would have a nice strong cup of yerba mate. And I still drink coffee or yerba mate very regularly. I drink them in moderation, I think, certainly for me. But typically I would drink those things before I would engage in any kind of attempt to learn or memorize or to acquire a new skill. Now, caffeine in the form of coffee or yerba mate or any other form of caffeine does create a sense of alertness in our brain and body, and it does that through two major mechanisms. The first mechanism is by blocking the effects of adenosine. Adenosine is a molecule that builds up in the brain and body the longer that we are awake, and it's largely what's responsible for our feelings of sleepiness and fatigue when we've been awake for a very long time. Caffeine essentially acts to block the effects of adenosine. It's a competing agonist, not to get technical, but it binds to the receptor for adenosine for some period of time and prevents adenosine from having its normal pattern of action, and thereby reduces our feelings of fatigue. But it also increases state of alertness. So while it's reducing fatigue, it's also pushing on neurochemical systems in order to directly increase our alertness, and it does that in large part by increasing the transmission of epinephrine adrenaline in the brain and body. It also has this interesting effect of up regulating the number and or efficiency, or we say the efficacy of dopamine receptors such that when dopamine is present and as a molecule that increases motivation and craving and pursuit, that dopamine can have a more potent effect than it would otherwise. So caffeine really hits these three systems. It hits other systems too, but it mainly reduces fatigue by reducing adenosine, increases alertness by increasing epinephrine release or adrenaline release. I should say both from the adrenals in your body and from locusts are released within the brain, and it can in parallel to all that increase the action or the efficacy of the action of dopamine. So my typical way of approaching learning a memory would be to drink some caffeine and then focus really hard on whatever it is that I'm trying to learn, try and eliminate distractions, and then hope, hope, hope, or try, try, try to remember that information as best as I could. Frankly, I felt like it was working pretty well for me. And typically if I leveraged other forms of pharmacology in order to enhance learning a memory, things like alpha GPC, or phosphatidal serine, I would do that. By taking those things before I sat down to learn a particular set of information or before I went off to learn a particular physical skill. Now, for those of you out there listening to this, you're probably thinking, well, okay, the results of McGon K. Hill pointed to the fact that having adrenaline released after learning something enhanced learning of that thing. But a lot of these things like caffeine or alpha GPC can increase epinephrine and adrenaline or dopamine or other molecules in the brain embody the enhanced memory for a long period of time. So it makes sense to take it first or even during learning and then allow that increase to occur and the increase will occur over a long period of time and will enhance learning a memory. And while that is partially true, it is not entirely true and it turns out it's not optimal. Work that was done by the McGon laboratory and other laboratories evaluated the precise temporal relationship between neurochemical activation of these pathways and learning and memory. What they did is they had animals and or people depending on the experiment, take a drug, could be caffeine, could be in pill form, something that would increase adrenaline or related molecules that create the state of alertness that are related to emotionality. And they had them do it either an hour before 30 minutes before 10 minutes before 5 minutes before learning or during the bout of learning, right, the reading of the information or the performing of the skill that one is trying to learn or 5 minutes, 10 minutes, 15 minutes, 30 minutes, etc. afterwards. So they looked very precisely at when exactly is best to evoke this adrenaline release and it turns out that the best time window to evoke the release of these chemicals, if the goal is to enhance learning and memory of the material is either immediately after or just a few minutes, 5, 10, maybe 15 minutes after you're repeating that information, you're trying to learn that information. Again, this could be cognitive information or this could be a physical skill. Now this really spits in the face of the way that most of us approach learning and memory, most of us, if we use stimulants like caffeine or alpha GPC, we're taking those before or during an attempt to learn, not afterwards. These results point to the fact that it is after the learning and memory that you really want to get that big increase in epinephrine and the related molecules that will tamp down memory. So what this means is that if you are currently using caffeine or other compounds and we'll talk about what those are and safety issues and so forth in a moment, if you're using those compounds in order to enhance learning and memory by taking them before or during a learning episode. Well, then I encourage you to try and take them either late in the learning episode or immediately after the learning episode. Now given everything I've told you up until now, why would I say late in the learning episode or immediately after? Well, when you ingest something by drinking it or you take it in capsule form, there's a period of time before that gets absorbed into the body in different substances such as caffeine, alpha GPC, etc. Or absorbed in from the gut and into the bloodstream and reach the brain and trigger these effects in the brain body at different rates. So it's not instantaneous. Some have effects within minutes, others within tens of minutes and so on. It's really going to depend on the pharmacology of those things and it's also going to depend on whether or not you have food in your gut, what else you happen to have circulating in your bloodstream, etc. But at a very basic level, we can confidently say that there are not one, not dozens, but as I mentioned before, hundreds of studies in animals and in humans that point to the fact that triggering the increase of adrenaline, late in learning or immediately after learning is going to be most beneficial if your goal is to retain that information for some period of time and to reduce the number of repetitions required in order to learn that information. Now, I want to acknowledge that on previous episodes of this podcast and in appearing on other podcasts, I've talked a lot about things like non-sleep deep rest and naps and sleep as vital to the learning process. And I want to emphasize that none of that information has changed. I don't look at any of that information differently as the consequence of what I'm talking about today. It is still true that the strengthening of connections in the brain, the literal neuroplasticity, the changing of the circuits occurs during deep sleep and non-sleep deep rest. And it is also true, and I've mentioned these results earlier, that two papers were published in cell reports, cell press journal, excellent journal over the last few years showing that brief naps of about 20 to up to 90 minutes, in some period of time after an attempt to learn can enhance the rate of learning and memory. However, those bouts of sleep, the deep sleep that night, I should say, or those brief naps, or even the so-called NSDR as we call it, non-sleep deep rest that was used to enhance the learning and memory of particular pieces of information, either cognitive or physical information, or both. That still can be performed, but it can be performed some hours later, even an hour later, it can be performed two hours later, four hours later. Remember, it's in these naps and in deep sleep that the actual reconfiguration of the neural circuits occurs, the strengthening of those neural circuits occurs. It is not the case that you need to finish about of learning and drop immediately into a nap or sleep. Some people might do that, but if you're really trying to optimize and enhance and improve your memory, the data from a gone K-hill and many other laboratories that stemmed out from their initial work really points to the fact that the ideal protocol would be focused on the thing you're trying to learn very intensely. There are also some other things like error rates, etc. Please see our episodes on learning. We have a newsletter on how to learn better. You can access that at HubermanLab.com. It's a zero-cost newsletter. You can grab that PDF. It lists out the things to do during the learning bout. Still try and get excellent sleep. Again, fundamentally important for mental health, physical health and performance. We can now extend from performance to saying, including learning and memory. NAP, if it doesn't interrupt your nighttime sleep, naps of anywhere from 10 to 90 minutes or non-sleep deep rest protocols will enhance learning and memory. We can now add to that that spiking adrenaline, providing it can be done in a safe way, is going to reduce the number of repetitions required to learn. That should be done at the very tail end or immediately after a learning bout, which is compatible with all the other protocols that I mentioned. The reason I'm revisiting this stuff about sleep and non-sleep deep rest is that some people got the impression that they need to do that immediately after learning. Today I'm saying to the contrary, immediately after learning, you need to go into a heightened state of emotionality and alertness. It's vitally important to point out that you do not need pharmacology. You don't need caffeine. You don't need alpha GPC. You don't need any pharmacologic substance to spike adrenaline unless that's something that you already are doing or that you can do safely or that you know that you can do safely. I always say it again, I'm not a physician, so I'm not prescribing anything. I'm a professor, so I profess things. You need to do what's safe for you. If you're somebody who's not used to drinking caffeine and you suddenly drink for espresso after trying to learn something, you are going to have a severe increase in alertness and probably even anxiety. If you're panic attack prone, please don't start taking stimulants in order to learn things better. Please be safe. I don't just say that to protect me. I say that to protect you. I should mention that if you're not accustomed to taking something, you always want to first check with your doctor, of course, but also move into that gradually. Start with the lowest effective dose, the minimal effective dose. Sometimes the minimal effective dose is zero milligrams. It's nothing. Why do I say that? Well, we already talked about results where they put people's arms into an ice bath in order to a vulcadrenaline release. You are welcome to do that if you want. In fact, that's a pretty low cost zero pharmacology, at least exogenous pharmacology way to approach this whole thing. That's a way of evoking your own natural epinephrine, and it turns out also dopamine release. You could take a cold shower. You could do an ice bath or get into a cold circulating bath. We've done several episodes on the utility of cold for health and performance. You can find those episodes at huberunlab.com, also the episode with my colleague at Stanford from the biology department, Dr. Craig Heller, lots of protocols in particular in the episode on cold for health and performance that describe how best to use the cold shower or the ice bath or the circulating cold bath in order to evoke epinephrine and dopamine release. The point is that the time in which you would want to do those protocols is after, ideally immediately after you're learning about, meaning when you're sitting down to learn new information or after trying to learn some new physical skill. Now, whether or not that's compatible with the other reasons you're doing cold, deliberate cold exposure and whether or not that's compatible with the other things you're doing, that depends on the contour of your lifestyle, your training, your academic goals, your learning goals, etc. But if your specific purpose is to enhance learning and memory, you want to spike adrenaline afterwards. And so what I'm telling you is you can do that with caffeine, you can do that with alpha GPC, you can do that with a combination of caffeine and alpha GPC, if you can do that safely. Some of you I know are using other forms of pharmacology. I did a long episode all about ADHD. I have to just really declare my stance very clearly that I am not a fan. I am actually opposed to people using prescription drugs who are not prescribed those drugs in order to enhance alertness. I think there's a big addictive potential. There also is a potential to really disrupt one's own pharmacology around the dopaminergic system. However, some of you I know are prescribed things like riddlein, Adderall, and Modaphanil and things of that sort in order to crease alertness and focus. So for those of you that are prescribed those things from a board certified physician, you're going to have to decide if you're going to take them before trying to learn or after trying to learn. You also have to take into consideration that some of those drugs are very long acting, some are shorter acting, and time that according to what you're trying to learn and when. So that's pharmacology, but as I've mentioned there are the behavioral protocols you can use cold and cold is an excellent stimulus because first of all it doesn't evolve pharmacology. Second of all you can generally access it at low to zero cost, especially the cold shower approach. And third you can titrate it you can start with warmer water you can make it very very cold if that's your thing and you're able to tolerate that safely you can make it moderately cold. How cold should it be in order to evoke adrenaline release well it should be uncomfortably cold but cold enough that you feel like you really want to get out but can stay in safely. That's going to evoke adrenaline release if it quickens your breathing if it makes you go wide eyed that's increasing adrenaline release in fact those effects of going wide eyed and quickening of the breathing and the challenges and thinking clearly those are the direct effects of adrenaline on your brain and body. And of course there are other ways to increase adrenaline you could go out for a hard run you could do any number of things that would increase adrenaline in your body which things you choose is up to you but from a very clear solid grounding in research data we can confidently say that spiking adrenaline after interacting with some material physical or cognitive material that you're trying to learn is going to be the best time to spike that adrenaline. Now I realize that I'm being a bit redundant today or perhaps a lot redundant in repeating over and over that the increase in epinephrine should occur either very late in an attempt to learn something or immediately after an attempt to learn something. I also want to emphasize the general contour of pharmacologic effects and of behavioral tools to create adrenaline what do I mean by that sentence what I mean is that McGaw and colleagues explored a huge number of different compounds and approaches every single day. And then I'm going to add some compounds and approaches everything from the hand into the ice back to injecting adrenaline to caffeine to drugs that block the effects of adrenaline and caffeine. Drugs like musamol and picrotoxin please don't take those these are drugs that reduce or enhance the amount of adrenaline and the overall takeaway is that anything that increases adrenaline will increase learning and memory and will reduce the number of repetitions required to learn something. And I'm not that something has an emotional intensity or not provided that that spike in adrenaline occurs late in the learning or immediately after and anything that reduces epinephrine and adrenaline will impair learning and that's the key and novel piece of information that I'm adding now which is if you're taking beta blockers for instance or if you're trying to learn something and it's not evoking much of an emotional response. And you're not using any pharmacology or other methods to enhance adrenaline release after learning that thing well you're not going to learn it very well in fact McGaw and K. Hill did beautiful experiments in humans looking at how much adrenaline is increased by varying the emotional intensity of different things that they were trying to get people to learn or by changing the dosage of epinephrine or by changing the amount of epinephrine blocker that they injected lots and lots of studies. The key thing to take away from those studies is that for some people adrenaline was increased 600 to 700 percent so 6 to 7 fold over baseline in the amount of circulating epinephrine or adrenaline and keep in mind sometimes that increase was due to the actual thing they were trying to learn being very emotional positive or negative emotion and sometimes it was because they were using a pharmacologic approach or the ice bath approach I don't think they ever used a cold shower approach but that would have been a very effective one we can be sure. However, other people had a zero to 10 percent increase or a very small increase in epinephrine. What we can confidently say on the basis of all those data is that the more epinephrine release the better that people remembered the material over and over again this was shown whether or not it was for cognitive material so learning a language learning a passage of words learning mathematics or whether or not it was for physical learning. I want to emphasize something about physical learning because I know a number of you are probably drinking a cup of coffee or having a couple of your remata or maybe even an energy drink and taking some alpha GPC or something before physical exercise. I'm not saying that's a bad thing to do or that you wouldn't want to do that but that's really to increase alertness it won't enhance learning at least not as well as doing those things after the physical exercise. Now again many of you including myself exercise for sake of the physical benefits of that exercise cardiovascular resistance training but we're not really focused on learning and memory so. I emphasize this just so it's immensely clear to everybody if you want to use those approaches of increasing adrenaline prior to or during physical training or cognitive work for that matter be my guest I think that's perfectly fine provided that say for you. It's only by moving it to late or after the learning that you're really shifting the role of that adrenaline increase to enhancing memory specifically and as a cautionary note don't think that you can push this entire system to the extreme over and over again or chronically as we say and get away with it in other words you're not going to be able to take a alpha GPC and a double espresso do. Your focus out of work cognitive or physical work and then spike adrenaline again afterwards and remember that stuff even better right I'm not encouraging in fact I'm discouraging you from. Chronically increasing adrenaline both during and after a given bout of work if the goal is to learn why do I say that well work from a gone kehil and others has shown that it's not the absolute amount of. Adrenaline that you release in your brain and body that matters for enhancing memory it's the amount of adrenaline that you release relative to the amount of adrenaline that was in your system just prior in particular in the hour or two prior so again it's the delta as we say it's the difference so if you're going to chronically increase adrenaline you're not going to learn as well. The real key is to have adrenaline modestly low perhaps even just as much as you need in order to be able to focus on something pay attention to it and then spike it afterwards this is immensely important because well much of what we're talking about is actually a form of inducing a neurochemical acute stress mean a brief. And rapid onset of stress well chronic stress the chronic elevation of epinephrine and cortisol is actually detrimental to learning and there's an entire category of literature mainly from the work of the great and sadly the late Bruce McEwen from the Rockefeller University and some of his scientific offspring like the great Robert Sapolsky showing that chronic stress chronic elevation of epinephrine actually inhibits learning and memory and also can inhibit immune system. We're looking at a new system function whereas acute right sharp increases in adrenaline and cortisol actually can enhance learning and indeed can enhance the immune system so if you really want to leverage this information you might consider getting your brain and body into a very calm and yet alert state so a high attentional state that will allow you to focus on what it is that you're trying to learn we know focuses vital for encoding information and for triggering neuroplasticity. And then in the main calm throughout that time and then afterwards spiking adrenaline and allowing adrenaline to have these incredible effects on reducing the number of repetitions required to learn. So if you're like me you're learning about this information this beautiful work of McGon K. Hill and others and thinking wow I should perhaps consider spiking my adrenaline in one form or another at the tail end or immediately following an attempt to learn something. So if you're not the first to have this conversation nor were McGon K. Hill or any other researchers that I've discussed today the first to start using this technique in fact there is a beautiful review that was published just this year May of 2022 in the journal neuron cell press journal excellent journal called mechanisms of memory under stress. So here I'm reading and I quote in medieval times communities through young children in the river when they wanted them to remember important events they believe that throwing a child in the water after witnessing historic proceedings would leave a lifelong memory for the events in the child. So this is not this is true this is a practice that somehow people arrived at I don't know if they were aware of what adrenaline was probably not but somehow in medieval times it was understood that spiking adrenaline or creating a robust emotional experience after an experience that one hoped a child would learn would encourage the child's nervous system and they even know what a nervous system was but would encourage the brain and body of that child. To remember those particular events very counterintuitive if you ask me I would have thought that the kid would remember only being thrown into the river my guess is that they remember that but that they the idea here anyways that they also remember the things that preceded being thrown into the river. So I think that this is a practice that has been going on for many hundreds of years and we are not the first to start thinking about using cold water as an adrenaline stimulus nor are we the first to start thinking about using cold water induced adrenaline as a way to enhance learning a memory. So I've been happening since medieval times so up until now I've been talking about pretty broad contour of these experiments I've been talking about the underlying pharmacology the role of epinephrine and so forth haven't really talked a lot about the underlying neural mechanisms. So I'm just going to take a minute to describe those for you because they are informative. We all have a brain structure called the amygdala a lot of people think it's associated with fear but it's actually associated with threat detection and more generally and I should say more specifically with detecting what sorts of events in the environment are novel and our linked to particular emotional states both positive emotional states and negative emotional states. So the neurons in the amygdala are exquisitely good at figuring out right they don't have their own mind but detecting correlations between sensory events in the environment that trigger the release of adrenaline and what's going on in the brain and because the amygdala is so extensively interconnected with other areas of the brain I basically connects to everything and everything connects back to it. The amygdala is in a position to strengthen particular connections in the brain very easily provided certain conditions are met and those conditions of the ones we've been talking about up until now emotional saliency that results in increases in epinephrine and cortisol or circulating epinephrine and cortisol being much higher than it was 10 minutes or 15 minutes before and the net effect of the amygdala in this context is to take whatever patterns of neural activity preceded that increase in adrenaline and corticosterone. And strengthen those synapses that were involved in that neural activity. So the amygdala doesn't have knowledge it's not a thinking area it's a correlation detector and it's correlating neurochemical states of the brain in body with different patterns of electrical activity in the brain. This is important because it really emphasizes the fact that both negative and positive emotional states and the different but somewhat overlapping chemical states that they create are the conditions as we say the and gates through which memory is laid down. And gates will be familiar to those of you who have done a bit of computer programming. And gate is simply a condition in which you need one thing and another to happen in order for a third thing to happen. So you need epinephrine elevated and you need robust activity in a particular brain circuit if in fact that brain circuit is going to be strengthened. It's not sufficient to have one or the other you need both hence the name and gate and the amygdala is very good at establishing these and gate contingencies. It's also a very generic brain structure in the sense that it doesn't really care what sorts of sensory events are involved provided they correlated in time with that increase in adrenaline and corticosterone. This has a wonderful side and a kind of dark side the dark side is that PTSD and traumas of various kinds often involve a increase in adrenaline because whatever it was that caused the PTSD was indeed very stressful cause these big increases in these chemicals. And because the amygdala is rather general in its functions right it's not tuned or designed in any kind of way to be specifically active in response to particular types of sensory events or perceptions. Well then what it means is that we can start to become afraid of entire city blocks where one bad thing happened in a particular room of a particular building in a city block. We can become fearful of any place that contains a lot of people if something bad happened to us in a place that contained a lot of people. The amygdala is not so much of a splitter as we say in science we talk about lumpers and splitters lumpers are kind of generalize generalizers if that's even a word and I think it is someone will tell me one way or the other and splitters are people that are ultra precise and specific and nuanced about every little detail. The amygdala is more of a lumper than a splitter when it comes to sensory events other areas of the brain only become active under very very specific conditions and only those conditions and similarly epinephrine is just a molecule it's just a chemical that's circulating in our brain in body there's no epinephrine specifically for a cold shower that is distinct from the epinephrine associated with a bad event which is distinct from the epinephrine associated with a really exciting event that makes you really alert. Epinephrine is just a molecule it's generic and so these systems have a lot of overlap and that can explain in large part why when good things happen in particular locations and in the company of particular people we often generalize to large categories of people places and things and when negative things happen in particular circumstances we often generalize about people places and things associated with that negative event. So now I'd like to talk about other tools that you can leverage that have been shown in quality peer reviewed studies to enhance learning and memory and perhaps one of the most potent of those tools is exercise. There are numerous studies on this in both animal models and fortunately now also in humans thanks to the beautiful work of people like Wendy Suzuki from New York University. Wendy's lab has identified how exercise works to enhance learning and memory and other forms of cognition I should mention as well as things that can augment can enhance the effects of exercise on learning and memory and other forms of cognition. Wendy is going to be a guest on this podcast it's actually the episode that follows this episode and includes a lot of material that we have not covered today and she's an incredible scientist and has some incredible findings that I know. Everyone is going to find immensely useful in the meantime want to talk about some of the general effects of exercise on learning and memory that she's discovered and the other laboratories have discovered. If you recall earlier I mentioned that learning and memory almost always involves the strengthening of particular synapses and neural circuits in the brain and not so much the increase in the number of neurons in the brain. There is one exception however and we now have both animal data and some human data to support the fact that cardiovascular exercise seems to increase what we call dentate gyros neurogenesis. Neurogenesis is the creation of new neurons the dentate gyros is a sub region of the hippocampus that's involved in learning and memory of particular kinds right certain types of events in particular contextual learning but some other things as well. Sometimes involved in spatial learning there's a lot of debate about exactly what the dentate gyros does but for sake of this discussion and I think everyone in the neuroscience community would agree that the dentate gyros is important for memory formation and consolidation. The dentate gyros does seem to be one region of the brain certainly in the rodent brain but more and more it's seeming also in the human brain where at least some new neurons are added throughout the lifespan and as it turns out that cardiovascular exercise can increase the proliferation of new neurons in the structure and that those new neurons excuse me are important for the formation of certain types of new memories. There are wonderful data showing that if you use exer radiation which is a way to eliminate the formation of those new cells or other tools and tricks to eliminate the formation of those cells that you block the formation of certain kinds of learning and memory what does this mean well there are a lot of reasons for the statement I'm about to make that extend far beyond neurogenesis and the hippocampus learning and memory but it's very clear that getting anywhere from 180 I should say a minimum of 180 to 200 minutes. So so called zone to cardiovascular exercise so this is cardiovascular exercise that can be performed at a pretty steady state which would allow you to just barely hold a conversation so breathing hard but not super hard. This isn't sprints or high intensity interval training but doing that for 180 to 200 minutes per week total is it appears the minimum threshold for enhancing some of the longevity effects associated with improvements in cardiovascular fitness and we believe that it is indirectly I should say indirectly through enhancements in cardiovascular fitness that there are improvements in hippocampal dentary gyros neurogenesis what does that mean the improvements in cardiovascular function are indirectly impacting the ability of the dentary gyros to create these new neurons to my knowledge there's no direct relationship between exercise and stimulating the production of new neurons in the brain. It seems that it's the improvements in blood flow that also relate to improvements in things like lymphatic flow the circulation of lymph fluid within the brain that are enhancing neurogenesis and that neurogenesis is it appears is important now in fairness to the landscape of neuroscience and my colleagues at Stanford and elsewhere there is a lot of debate as to whether or not there is much if any neurogenesis in the adult human brain. But regardless I think the data are quite clear that the 180 to 200 minutes minimum of cardiovascular exercise is going to be important for other health metrics now it is clear that exercise can impact learning and memory through other non neurogenesis non new neuron type mechanisms and one of the more exciting one that has been studied over the years. This notion of hormones from bone traveling in the bloodstream to the brain and enhancing the function of the hippocampus. The words hormones from bones is surprising to you here to tell you that yes indeed your bones make hormones we call these endocrine effects so in biology we hear about autocrine, pericren and endocrine and those different terms refer to over what distance a given chemical has an effect on a. For instance the cell can have an effect on itself it can have an effect on immediately neighboring cells or can have an effect on both itself immediately neighboring cells and cells far far away in the body and that last example of a given chemical or substance having an effect on the cell that produced it plus neighboring cells plus cells far away is an endocrine effect and a lot of hormones not all work in this fashion. Hence why we sometimes hear about endocrine and hormone is kind of synonymous terms your bones make chemicals that travel in the bloodstream and have these endocrine effects are they're effectively acting as hormones and one such chemical is something called osteocalcin. These findings arrived to us through various labs but one of the more important labs for sake of this discussion today is the laboratory of Eric Candell at Columbia Medical School. Eric is now I believe in his mid to late 90s still very sharp and has studied learning and memory it also turns out that he is an avid swimmer now I happen to know that Eric swims anywhere from a half a mile to a mile a day and again this is anacdata this is I'm not referring to the published data just yet but he credits that exercise. As one of the ways in which he keeps his brain sharp and has indeed kept his brain sharp for many many decades and as I mentioned before he's well into his 90s so pretty impressive his laboratory has studied the effects of exercise on hippocampal function and memory and other laboratories have done that as well and what they found is that cardiovascular exercise and perhaps other forms of exercise to but mainly cardiovascular exercise creates the release of osteocalcin from the bone and the bone is very important. From the bones that travels to the brain and to sub regions of the hippocampus and encourages the electrical activity and the formation and maintenance of connections within the hippocampus and keeps the hippocampus functioning well in order to lay down new memories. Now, osteocalcin has a lot of effects besides just improving the function of the hippocampus osteocalcin is involved in bone growth itself it's involved in hormone regulation in fact there's really nice evidence they can regulate testosterone and estrogen production by the testes and ovaries and a bunch of other effects in other organs of the body because again it's acting in this endocrine manner it's arriving from bone to a lot of different organs to have effects. Load bearing exercise in particular turns out to be important for inducing the release of osteocalcin and when you think about this it makes sense a nervous system exists for a lot of reasons to sense perceive etc you've got taste you got smell you got hearing but the vast majority of brain real estate especially in humans is dedicated to two things one vision we have an enormous amount of brain real estate devoted to vision certainly compared to other senses and to movement the ability to generate course movements of the body the generate the ability excuse me to generate find movements of the body like the digits or to wink one eye or to tilt your head in a particular way or move your lips and do all sorts of different things in a very nuanced and detailed way so much of our brain real estate is devoted to movement that it's been hypothesized for more than a half century but especially in recent years as we've learned more about the function of the brain at a really detailed circuit level that the relationship between the brain and body and the maintenance and perhaps even the improvement of neural circuitry in the brain depends on our body movements and the signal from the body that our brain is still moving so think about that how would your brain know if your body was moving regularly and how would it know how much it was moving how would it know which limbs it was moving well you could say if the heart rate is increased then the blood flow will be increased and then the brain will know ah but how does your brain know that it's increased blood flow due to movement and not to for instance just stress right maybe you actually can't move and you're very stressed about that and so the increased blood flow is simply a consequence of increased stress the fact that osteocalcin is released from bone and in particular can be released in response to load bearing exercise so this would be running again weightlifting hasn't been tested directly but one would imagine anything that involves jumping and landing or weight lifting or body body weight movements and things of that sort that's a signal to release osteocalcin and we know that signal occurs that is directly reflective of the fact that the body was moving and moving in particular ways in fact you could imagine that big bones like your femur are going to release more osteocalcin or being a position to release more osteocalcin then five movements like the movements of the digits and this idea that the body is constantly signaling to the brain about the status of the body and the varying needs of the brain to update its brain circuitry is a really attractive idea that fits entirely with the biology of exercise osteocalcin and hippocampal function I do want to mention that I'm not the first to raise this hypothesis this hypothesis actually was discussed in the fair amount of detail by John Raidie who's a professor in Harvard Medical School he wrote a book called Spark which was one of the early books at least from an academic about brain plasticity in the relationship between exercise and movement in plasticity and John who I have the good fortune to know has described to me experiments or I should say observations of species of ocean dwelling animals that have at least for the early part of their life a very robust and complicated nervous system but then these particular animals are in the habit of plopping down onto a rock they find a kind of a safe comfy space and they actually stick to that rock and they don't move anymore for a certain portion I should say the late portion of their life and it is at the transition between moving a lot and being stationary that those animals actually digest their own brain they literally metabolize a good portion of their nervous system because they decide they don't need this anymore and gobble it up use it for its nutritional value and then sit there like a moron version of themselves with a limited amount of brain tissue because they don't need to move anymore now I certainly don't want to give the message that just moving just exercise is sufficient to keep the neural architecture of your brain healthy young and able to learn well that might be true it's also important to actually engage in attempts to learn new material either physical material so new types of movements and skills and or new types of cognitive information languages mathematics history current events all sorts of things that involve your brain nonetheless it's clear that physical movement and cognitive ability and the potential to enhance cognitive ability and the ability to learn new physical skills are intimately connected and osteocalcin appears to be at least one way in which that brain body relationship is established and maintained so given the information about osteocalcin and movement and given the information about spiking adrenaline late or after a period of attempt to learn you might be asking when is the best time to exercise now unfortunately that has not been addressed in a lot of varying detail where every sort of variation on the theme has been carried out and yet when he Suzuki's lab has done really beautiful experiments where they have people exercise generally it was in the morning but at other periods of the day as well and what they find is that at least as late as two hours after that exercise there is an enhancement and learning and memory now I want to be clear we don't know whether or not that exercise led to big increases in adrenaline it may be that those forms of exercise were modest enough or didn't challenge people enough that they merely got a lot of blood flow going and that the improvements and learning and memory were related to blood flow and we presume increases in osteocalcin however you could imagine a couple of different logical protocols based on what we've talked about let's say you were going to do a form of exercise that was going to spike adrenaline a lot so this would be exercise that really challenges your system and forces you kind of push through a burn so here I'm mainly thinking about cardiovascular exercise but it could be it could even be yoga it could be resistance training if it's going to give you a big spike in adrenaline it's going to take some serious effort then logically speaking you would want to place that after a learning about in order to increase learning and memory however if you're using the exercise in order to enhance blood flow and to enhance osteocalcin release in efforts to augment the function of your hippocampus I think it stands to reason that doing that exercise sometime within the hour to three hours preceding an attempt to learn makes a lot of sense and there I'm basing it on the human data from when you Suzuki's lab I'm basing it on the studies from American Dell and from others labs again right now there hasn't been an evaluation of a lot of different protocols to arrive at the you know peer reviewed laboratory super protocol however since what we're talking about is using activities like exercise that most of us probably perhaps all of us should be doing regularly anyway and I do believe most if not all of us should regularly be trying to learn and keep our brain functioning well and acquire new knowledge because it's just a wonderful part of life and there is evidence that that actually can keep your brain young so to speak well then exercising either before or after a learning about makes a lot of sense with the emphasis on after a learning about if the form of exercise spikes a lot of adrenaline for all the reasons we talked about before okay so we've talked about two major categories of protocols to improve memory that are grounded in quality peer reviewed science and there is yet another third protocol that we'll talk about in a few minutes but before we do that want to briefly touch on an aspect of memory in fact two aspects of memory that I get a lot of questions about the first one is photographic memory to be clear there are people out there who have a true photographic memory they can look at a page of text they can scan it with their eyes and they can essentially commit that to memory with very little if any effort while it might seem that having a photographic memory is a very attractive skill to have should caution you against believing that because it turns out that people with true photographic memory are often very challenged at remembering things that they hear and oftentimes are not so good at learning physical skills it's not always the case but often that's the case so be careful what you wish for if you do have a photographic memory there are certain professions that lend themselves particularly well to you and indeed a lot of people with photographic memory have to find a profession and have to move through life in a way that is in concert with that photographic memory so again it's a super ability it's a hyper ability and yet it's not necessarily one that is does that is not necessarily a good example of a photographic memory and that is desirable for most people there's also this category of what are called super recognizers these people are I should mention highly employable by government agencies these are people that have an absolutely astonishing ability to recognize faces and to match faces to templates they can look at a photograph of say somebody on a most wanted list they can look at video footage of let's say an airport or a mall or a city street at fairly low resolution and they can spot the person whose face matches that photograph that they looked at even if that video or other footage is of people's profiles or even the tops of their heads and just a portion of their forehead these people have just an incredible ability to recognize faces and to template match and these people often will take jobs with agencies where this sort of thing is important some of you out there probably are super recognizers and may or may not notice it if you ever had the experience of watching a movie and thought to yourself how her mouth looks so much like my cousins mouth or you look at a character in a movie or television show and you think how they look almost like the younger sister of so and so well then it's very likely that you have this or at least a mild form of the super recognizer ability that is not memory per se that is the hyper functioning of an area of the brain that we call the fuse of form gyros the fuse of form gyros is literally a face recognition area and a face template matching area and it harbors neurons that respond to faces generally so as humans and other non human primates and primates care a lot about faces and their emotional content and the identity of faces is super important to us for all the kinds of reasons that are probably obvious knowing whose friend whose foe who do you know well whose famous who's not famous et cetera that is not memory per se and yet if you're a super recognizer or I guess we could call it a moderate face recognizer or not very good at recognizing faces because indeed there are some people that are kind of face blind they don't actually recognize people when they walk in the room I used to work with somebody like this I'd walk into his office and he'd say are you rich or are you Andrew I'd say well my rich rich like you know wealth rich no and he'd say no are you Richard or are you Andrew and I'd say I'm Andrew we know each other really well I said oh I'm sorry my fate I'm kind of face blind and it actually I'm tend to be better worse on depending on how much he was working ironically the more rested he was the more face blind he would become so it wasn't a sleep deprivation thing that exists that's out there there's the full constellation of people's ability recognize faces that's not really memory and yet visual function is a profoundly powerful way in which we can enhance our memory so whether or not you're a super recognizer of faces whether or not you are face blind or anything that's not really good or not face blind or anything in between next I'm going to tell you about a study which points out the immense value of visual images for laying down memories and you can leverage this information and this involves both the taking a photograph something that's actually quite easy easily done these days with your phone as well as your ability to take mental photographs by literally snapping your eyelid shut just briefly want to describe this paper because it provides a tool that you can leverage in your attempt to learn and remember things better the title of this paper is photographic memory the effects of our volitional photo taking on memory for visual and auditory aspects of an experience really like this paper because it refers to photographic memory not in the context of photographic memory that we normally hear about where people are truly photographic look at a page and somehow absorb all that information and commit it to memory but rather the use of camera photographs or the use of mental camera photographs literally looking at something and deciding blink and snapping a so to speak snapping a snapshot of whatever it is that you're looking at and remembering the content reason I like this paper and the reason I'm attracted to this issue of mental snapshots is this is something that I've been doing since I was a kid I don't know why I started doing it but every once in a while I would say maybe twice a year I would look at something and decide to just snap a mental snapshot of it and I've maintained very clear memories of those visual scenes two years ago I was in an Uber and I looked out the window and it was a street scene I was actually in New York at the time and I decided for reasons that are still unclear to me to take a mental snapshot of this city street image even though nothing interesting in particular was happening and I do recall that there was a guy wearing a yellow shirt walking there was some construction etc. I can still see that image in my mind's eye because I took this mental snapshot this paper addresses whether or not this mental snapshotting thing is real and this is something that I think a lot of people will resonate with whether or not the constant taking of pictures on our phones or with other devices is either improving or degrading our memory you can imagine an argument for both a lot of people are taking pictures that they never look at again and so in a sense they're outsourcing their their visual memory of events into their phone. Or to some other device and they're not ever accessing the actual image and they're not looking at it right you're not printing out those photos you're not scanning through your phone again sometimes you might do that but most of the time people don't most of the photographs that people taking they're not revisiting again so the motivation for the study was that previous experiments had shown that if people take photos of a scene or a person or an object that they are actually less good at remembering the details of that scene or the picture. This study challenged that idea and raised the hypothesis that if people are allowed to choose what they take photos of that taking photos again this is with a camera not mental snapshotting that taking those photos would actually enhance their memory for those objects those places those people and in fact details of those object places and people and indeed that's what they found so in contrast to previous studies where people had been more or less good at that. And more or less told take photos of these following objects or these following people are these following places and then they were given a memory test at some point later in this study people were given volitional control right they were given agency in making the decision of what to take photos of and I'll just summarize the results will provide a link to this study should say that some of the stuff that they tested was actually pretty challenging some of them were pottery and other forms of ceramics that are of the sort that you see if you go to a big museum. And if you've ever done that you see all the different objects a lot of details in those objects and a lot of those objects look a lot alike and so you know some will have two handles what some will have one handle the position of the handles how broad or narrow these things are you know a lot of this is pretty detailed stuff they also took photos of other other things. So basically what they found was that if people take pictures of things and they choose which things they're taking pictures of right up to them it's volitional that there's enhanced memory for those objects later on. However it degraded their ability to remember auditory information so what this means is that when we take a picture of something or a person we are stamping down a visual memory of that thing and that makes sense it's a photograph after all but we are actually inhibiting our ability to remember the auditory the sound components of that visual scene or what the person was saying very interesting and points to the fact that the visual system can out compete the auditory system at least in terms of how the hippocampus is encoding this information the other finding I find particularly interesting within this study is that it didn't matter whether or not they ever looked at the photos again so they actually had people take photos or not take photos of different objects they had some people keep their photos and they had other people delete the photos and turns out that whether or not people kept the photos or deleted those photos had no bearing on whether or not they were better or worse remembering things they were always better remembering them as compared to not taking photos of them. What does this mean? It means if you really want to remember something or somebody take a photo of that thing or person pay attention while you take the photo but it doesn't really matter if you look at the photo again somehow the process of taking that photo probably looking at it you know in a camera typically we take through the viewfinder or now because of digital cameras on the screen on the back of that camera or on your phone that framing up of the photograph stamps down a visual image in your mind that is the more robust at serving a memory than had you just looked at that thing with your own eyes very interesting and it raises all sorts of questions for me about whether or not it's because you're framing up a small aperture a small portion of the visual scene that's one logical interpretation although they didn't test that I should also say that they found that whether or not you looked at a photo that you took or whether or not you deleted it never looked at again didn't just enhance visual memory or the memory for those for the visual components of that image but it all always reduced your ability to remember sounds associated with that experience so that's interesting and then last but not least and perhaps most interesting at least to me was the fact that you didn't even need a camera to see this effect if subjects looked at something and took a mental photograph of that thing it enhanced their visual memory of that thing significantly more than had they not taken a mental picture in fact it increased their memory of that thing almost as much as taking an actual photograph with an actual camera and the reason I find this so interesting is that a lot of what we try and learn is visual and for a lot of people the ability to learn visual information feels challenging and we'll look at something and we'll try and create some detailed understanding of it we'll try and understand the relationships between things in that scene it does appear based on the study that the mere decision to take a mental snapshot like okay I'm going to blink my eye and I'm going to take a snapshot of whatever it is I see can actually stamp down a visual memory much in the same way that a camera can stamp down a visual memory of course through vastly distinct mechanisms no discussion of memory would be complete without a discussion of the ever intriguing phenomenon known as deja vu this sense that we've experienced something before but we can't quite put our finger on it where and when did it happen where the sense that we've been someplace before or that we are in a familiar state of the world. We're in a state or place or context of some kind now I've talked about this on the podcast before at least I think I have and the way this works has been defined largely by the wonderful work of Jesus Institute of Technology MIT so sumo collected a Nobel Prize quite appropriately for his beautiful work on immunology and he's also a highly accomplished neuroscientist who studies memory and learning and deja vu and I should also mention the beautiful work of Mark Mayford at the scripture institute and UC San Diego beautiful work on this notion of deja vu here's what they discovered they evaluated the patterns of neural firing in the hippocampus as subjects learn new things okay so neuron a fires the neuron b fires the neuron c fires in a particular sequence again the firing of neurons in a particular sequence like the playing of keys on a piano in a particular sequence leads to a particular song in the piano and leads to a particular memory of an experience within the brain. They then used some molecular tools and tricks to label and capture those neurons such that they could go back later and activate those neurons in either the same sequence or in a different sequence to the one that occurred during the formation of the memory and to make a long story short and to summarize multiple papers published in incredibly high to your journals journals like nature and science which are extremely stringent found that whether or not those particular neurons were played in the precise sequence that happened when they encoded the memory or whether or not those neurons were played in a different sequence or even if those neurons were played activated that is all at once with no temporal sequence all firing in concert all at once evoked the same behavior and in some sense the same memory so at a neural circuit level this is deja vu this is a different pattern of firing of neurons in the brain leading to the same sense of what happened leading to a particular emotional state or behavior whether or not the same sort of phenomenon occurs when you're walking down the street and suddenly you feel as if wow I feel like I've been here before you meet someone and you feel like gosh I feel like I know you I feel like there's some familiarity here that I can't quite put my finger on we don't know for sure that that's what's happening but this is the most mechanistic and logical explanation for what has for many decades if not hundreds of years has been described as deja vu so for those of you that experienced deja vu often just know that this reflects a normal pattern of encoding experiences and events within your hippocampus I know not aware of any pathological situations where the presence of deja vu inhibits daily life some people like the sensation of deja vu other people don't almost everybody however describes it as somewhat eerie this idea that even though you're in a very different place even though you're interacting with a very different person that you could somehow feel as if this has happened before and just realize this that your hippocampus well it is exquisitely good at encoding new types of perceptions new experiences new emotions new contingencies and relationships of life events it is not infinitely large nor does it have an infinite bucket full of different options of different sequences for those neurons to play so in a lot of ways it makes perfect sense that sometimes we would feel as if a given experience had happened previously I'd like to cover one additional tool that you can use to improve learning and memory and I should mention this is a particularly powerful one and it's one that I'm definitely going to employ myself this is based on a paper from none other than Wendy Suzuki at New York University we talked about her a little bit earlier and again she's going to be on the podcast in our next episode and it's just an incredible researcher I've known Wendy for a number of years and it's only in the last I would say five or six years that she's really shifted her laboratory toward generating protocols that human beings can use and she's putting that to great effect great positive effect I should say publishing papers of the sort that I'm about to describe but also incorporating some of these tools and protocols into the learning curriculum and the lifestyle curriculum of students at NYU which I think is a terrific initiative so you don't need to be an NYU student in order to benefit from her work I'm going to tell you about some of that work now and she'll tell you about this and much more in the episode that follows this one the title of this paper will tell you a lot about where we're going the title is a brief daily meditation enhances attention, memory, mood and emotional regulation in non-experienced meditators if ever there was an incentive to meditate it is the data contained within this paper when I briefly describe the study and then I also want to emphasize that when you meditate is absolutely critical I'll talk about that just at the end this is a study that involves subjects aged 18 to 45 none of whom were experienced meditators prior to this study there were two general groups in this study one group did a 13 minute long meditation and this meditation was a fairly conventional meditation they would sit or lie down they would do somewhat of a body scan evaluating for instance how tense or relax they felt throughout their body and they would focus on their breathing trying to bring their attention back to their breathing and to the state of their body as the meditation progressed the other group which we can call the control group listen to of all things a podcast they did not listen to this podcast they listened to radio lab which is a popular podcast for an equivalent amount of time but they were not instructed to do any kind of body scan or pay attention to their breathing every subject in the study either meditated daily or listen to a equivalent duration podcast daily for a period of eight weeks and the experimenters measured a large number of things of variables as we say they looked at measures of emotion regulation they actually measured cortisol a stress hormone they measured as the title suggests attention and memory and so forth and the basic takeaway of the study is that eight weeks but not four weeks of this daily 13 minute day meditation had a significant effect in improving attention memory mood and emotion regulation I find this study to be very interesting and in fact important because most of us have heard about the positive effects of meditation on things like stress reduction or on things such as improving sleep and I want to come back to sleep in a few moments because it turns out to be very important feature of this study this particular study I like so much because they used a really broad array of measurements for cognitive function things like the Wisconsin card sorting task I'm not going to this things like the strup task and they also as I mentioned measured cortisol and many other things including not surprisingly memory and people's ability to remember certain types of information in fact varied types of information and the basic takeaway was again that you could get really robust improvements in learning and memory mood and attention from just 13 minutes a day of meditation now there's an important twist in this study that I want to emphasize if you read into the discussion of this study it's mentioned that somehow meditation did not improve but actually impaired sleep quality compared to the condition of the control subjects you might think wow why would that be I mean meditation is supposed to reduce our stress stress is supposed to inhibit sleep and therefore why would sleep get worse well what's interesting is the time of day when most of these subjects tended to do their meditation most of the subjects in this study did their meditation late in the day this is often the case in experiments I know this because when we run experiments with human subjects in my laboratory and people are paid some amount of money in order to participate or they're given something as compensation for being the study but oftentimes the meditation or in the case of my lab the respiration work or other kinds of things that they're assigned to do are not their top top priority and we understand this but in this study the majority of subjects here I'm reading completed their meditation and sent sessions from eight somewhere between eight and 11 p.m. and sometimes even between 12 and 3 a.m. I think there probably were a lot of college students enrolled in this study and their hours often are late shifted that impaired sleep and this raises a bigger theme that I think is important many times before on this podcast and certainly in the episode on mastering sleep and conquering or mastering stress those episodes we talked about the value again of these non sleep depressed protocols for the activity of your sympathetic nervous system this the alertness so called stress arm of your autonomic nervousness in the world that makes you feel really alert and as the are superb for reducing your level of alertness increasing your level of calmness and putting you into a so called more parasympathetic relaxed state meditation does that too but it also increases attention if you think about meditation meditation involves focusing on your breath and constantly focusing back on your breath and trying to avoid the distraction of things you're thinking or things that you're hearing and coming so called back to your body back to your breath so meditation is actually has a high attention load it requires a lot of prefrontal cortical activity that's involved in attention which then logically relates to the one of the outcomes of this study which is that attention abilities improved in daily meditators it also points out that increasing the level of attention and the activity of your prefrontal cortex may and I want to emphasize may because I'm here I'm speculating about the underlying mechanism inhibit your ability to fall asleep so while we have meditation on the one hand that does tend to put us into a calm state but it is a calm very focused state in fact attention and focus are inherent to most forms of meditation non sleep deep rest such as yoga nidra as some of you know it to be or nsdr there's a terrific nsdr script that's available free online that's put out by made for so you can go to youtube nsdr made for you can also just do a search for nsdr their number of these available out there again at no cost those nsdr protocols tend to put people into a state of deep relaxation but also very low attention and we have to assume very low activation of the prefrontal cortex so the takeaways from the study are several fold first of all that daily meditation of 13 minutes can enhance your ability to pay attention and to learn it can truly enhance memory however you need to do that for at least eight weeks in order to start to see the effects to occur and we have to presume that you have to continue those meditation training sessions in fact they found that if people only did four weeks of meditation these effects didn't show up eight weeks might seem like a long time but I think that 13 minutes a day is not actually that big of a time commitment and the results of this study certainly incentivize me to start adopting a I'm going for 15 minutes a day now I've been on and off meditator for a number of years I've been pretty good about it lately but I confess I've been doing far shorter meditations of anywhere from 3 to 5 or maybe 10 minutes I'm going to ramp that up to 15 minutes a day and I'm doing that specifically to try and access these improvements in cognitive ability and our abilities to learn also based on the data in this paper I'm going to do those meditation sessions either early in the day such as immediately after waking or close to it I get my sunshine first as you all know very big on getting sunlight in the eyes early in the day as much as one can and as early as one can once the sun is out but certainly doing it early in the day and not past 5 p.m. or so in order to make sure that I don't inhibit sleep because I think this result that they describe of meditation inhibiting quality sleep compared to controls is an important one to pay attention to no pun intended today we covered a lot of aspects of memory and how to improve your memory we talked about the different forms of memory and we talked about some of the underlying neural circuitry of memory formation and we talked about how the emotional saliency and intensity of what you're trying to learn has a profound impact on whether or not you learn in response to some sort of experience whether or not that experience is reading or mathematics or music or language or a physical skill doesn't matter the more intense of an emotional state that you're in in the period immediately following that learning the more likely you are to remember whatever it is that you're trying to learn and we talked about the neurochemicals that explain that effect about epinephrine and corticosterones like cortisol and how adjusting the timing of those is so key to enhancing your memory and we talked about the different ways to enhance those chemicals everything ranging from cold water to pharmacology and even just adjusting the emotional state within your mind in order to stamp down and remember experiences better we also talked about how to leverage exercise in particular load bearing exercise in order to evoke the release of hormones like osteocalcin which can travel from your bones to your brain and enhance your ability to learn and we talked about a new form of photographic memory not the traditional type of photographic memory in which people can remember everything they look at very easily but rather taking mental snapshots of things that you see again emphasizing that that will create a better memory of what you see when you take that mental snapshot but will actually reduce your memory for the things that you hear at that moment and we discussed the really exciting data looking at how particular meditation protocols can enhance memory but also attention and mood however if done too late in the day can actually disrupt sleep precisely because those meditation protocols can enhance attention now I know that many of you are interested in neurochemicals that can enhance learning and memory and I intend to cover those in deep detail in a future episode however for sake of what was discussed today please understand that any number of different neurochemicals can evoke or can increase the amount of adrenaline that's circulating in your brain and body and it's less important how one accesses that increase in adrenaline right again this can be done through behavioral protocols or through pharmacology assuming that those behavioral protocols and pharmacology are safe for you it really doesn't matter how you evoke the adrenaline release because remember adrenaline is the final common pathway by which particular experiences particular perceptions are stamped into memory which answers are very first question raised at the beginning of the episode which is why do we remember anything at all right that was the question that we raised why is it that from morning till night and throughout your entire life you have tons of sensory experience tons of perceptions why is it that some are remembered at others or not while I would never want to distill a important question such as that down to a one molecule type of answer I think we can confidently say based on the vast amount of animal and human research data that epinephrine adrenaline and some of the other chemicals that it acts with in concert is in fact the way that we remember particular events and not all events if you're learning from and or enjoying this podcast please subscribe to our YouTube channel that's a terrific zero cost way to support us in addition please subscribe to our podcast on Spotify and on Apple and now on both Spotify and Apple you can leave us up to a five star review please also leave us comments and feedback in the comment section on our YouTube channel you can also suggest future guests that you'd like us to cover we do read all those comments please also check out the sponsors mentioned at the beginning of today's podcast that's a terrific perhaps the best way to support this podcast we also have a patreon it's patreon.com slash Andrew Huberman and there you can support this podcast at any level that you like during today's episode and on many previous episodes of the Huberman lab podcast we discuss supplements while supplements aren't necessary for everybody many people drive tremendous benefit from them for things like enhancing sleep and focus and indeed for learning and memory for that reason the Huberman lab podcast is now partnered with momentous supplements the reason we partnered with momentous is several fold first of all we wanted to have one location where people could go to access single ingredient high quality versions of the supplements that we were discussing on this podcast this is a critical issue a lot of supplement companies out there sell excellent supplements but they combine different ingredients into different formulations which make it very hard to figure out exactly what works for you and to arrive at the minimal effective dose of the various compounds that are best for you which we think is extremely important and that's certainly the most scientific way or rigorous way to approach any kind of supplementation regimen so momentous has made these single ingredient formulations on the basis of what we suggested to them and I'm happy to say they also ship internationally so whether or not you're in the US or abroad they'll ship to you if you'd like to see the supplements recommended on the Huberman lab podcast you can go to live romantous calm slash Huberman they've started to assemble the supplements that we talked about on the podcast and in the upcoming weeks they will be adding many more supplements such that in a brief period of time most if not all of the compounds that are discussed on this podcast will be there again in single ingredient extremely high quality formulations that you can use to arrive at the best supplement protocols for you we also include behavioral protocols that can be combined with supplementation protocols in order to deliver the maximum effect once again that's live momentous calm slash Huberman and if you're not already following us on Twitter and Instagram it's Huberman lab on both Twitter and Instagram there I describe science and science related tools some of which overlap with the content of the Huberman lab podcast but much of which is distinct from the content of the Huberman lab podcast we also have a newsletter called the Huberman lab neural network that newsletter provides summary protocols and information from our various podcast episodes it does not cost anything to sign up you can go to Huberman lab calm go to the menu and click on newsletter you just provide your email and I should point out we do not share your email with anyone else we have a very clear privacy policy that you can read there and that newsletter comes out about once a month you can also see some sample newsletters things like the toolkit for sleep or for neural biology and for various other topics covered on the Huberman lab podcast once again thank you for joining me today to discuss the neuro biology of learning and memory and how to improve your memory using science tools and last but certainly not least thank you for your interest in science