Understand & Improve Memory Using Science-Based Tools | Huberman Lab Podcast #72

This episode I explain the mechanisms by which different types of memories are established in our brain and how to leverage the amount and timing of key neurochemicals and hormones, such as adrenaline (aka epinephrine) and cortisol, to improve your learning and memory abilities. I describe multiple science-based protocols to do this, including repetition, caffeine, emotional states, deliberate cold exposure, sleep, meditation, and the role of vision, including taking “mental snapshots.” I also describe how exercise and an associated hormone, osteocalcin, can improve cognitive ability and memory formation. I also describe unique aspects and forms of memory such as photographic memory, extreme facial recognition (aka super recognition), and the phenomenon known as déjà vu.

#HubermanLab #Memory

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- Welcome to the Huberman Lab Podcast, where we discuss science, and science based tools for everyday life. I'm Andrew Huberman and I'm a professor of neurobiology and ophthalmology at Stanford School of Medicine. Today we are discussing memory. In particular, how to improve your memory. Now 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 neuro chemicals involved. And 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 incidences 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 a 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're 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,

00:02:45 Eight Sleep, Thesis, InsideTracker

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 would 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. In keeping with that theme, I'd like to thank the sponsors of today's podcast. Our first sponsor is Eight Sleep. Eight Sleep makes smart mattress covers with cooling, heating, and sleep tracking. Many times on this podcast I've talked about the incredible relationship between temperature and sleep as well as temperature and wakefulness. Many people aren't aware of this, but waking up in the morning is in part the consequence of your body heating up. And falling asleep at night and remaining in deep sleep is in part the consequence of your body temperature dropping by one to three degrees. So it's vitally important that the temperature of your sleeping environment is controlled. I've had trouble over the years falling and staying asleep. Or I should say, falling asleep hasn't been so much of an issue for me, but waking up two or three or four hours later has been an issue. Often times I'm too warm, I need to open a window. I need to adjust the temperature of the room and so on. Eight Sleep mattress covers are terrific because you can program the specific patterns of temperature that you want in your bed, or I should say below you, coming from the mattress, throughout the night. So I've programmed my Eight Sleep to put my mattress into a state of coolness in order to fall asleep. And then to get slightly cooler as the night goes on. To get into even deeper sleep. And then to warm up as morning approaches. Now, as mentioned before, Eight Sleep mattresses can be used for cooling and heating. So some of you may actually need to heat your mattress and Eight Sleep's terrific for that. For me, I use Eight Sleep to keep the mattress really cool. And I have to say, even though I thought I was sleeping pretty well before, I have not experienced the sort of sleep that I've been getting with Eight Sleep until now. By creating this descending temperature in the beginning part of the night, cooler, cooler, cooler. And then warming up towards morning. It even has a nice little vibration function so I wake up now to a slightly vibrating bed. And the sleep that I'm getting is just amazing. And I feel so much better during the day as a consequence. If you'd like to try Eight Sleep you can go to EightSleep.com/Huberman and check out the pod pro cover and save 150 dollars at checkout. Eight Sleep currently ships within the USA, Canada, and the UK. Again, that's EightSleep.com/Huberman to save 150 dollars at checkout. Today's episode is also brought to us by Thesis. Thesis makes custom nootropics. And to be quite honest, I don't like the word nootropics. Because nootropics means smart drugs. And there really isn't a neuroscience of smart. Of course, there is this notion of intelligence, but we now know there are lots of different forms of intelligence. Also, as a neuroscientist, we don't really think about intelligence, we think about those particular types of operations that you want your brain to perform in different contexts. So for instance, some tasks and life experiences require that you remember information better. Other tasks and life experiences and forms of learning involve focus and task switching. Others creativity, and so on, and so on. So the word nootropics is too much of a catchall or throw away phrase to appeal to me. Thesis understands this. And what they've done is they've created nootropics that are each designed toward a particular end goal. For instance, they have blends for focus. Blend for motivation. A blend for clarity. They use only the highest quality ingredients. Things like Alpha GPC and phosphatidyl serine. I've been using Thesis for close to six months now and I can confidently say their nootropics have been a game changer for me. I often take the clarity formula prior to long bouts of work, meaning cognitive work. And the energy formula prior to physical workouts. To get your own personalized nootropics starter kit, you can go online to TakeThesis.com/Huberman. Take the three minute quiz and Thesis will send you four different formulas to try in your first month. Again, that's TakeThesis.com/Huberman and use the code Huberman at checkout to get 10% off your first box. Today's podcast is also brought to us by InsideTracker. InsideTracker is a personalized nutrition platform that analyzes data from your blood and DNA to help you better understand your body and help you reach your health goals. I've long been a believer in getting regular blood work done. For the simple reason that many of the factors that impact your immediate and long term health can only be assessed from a quality blood test. One of the challenges with a lot of blood tests and DNA tests out there, however, is that you'll get the numbers back. You'll get information about your blood lipids and hormones and so forth. But there are no directives as to what to do with that information. InsideTracker has solved that problem by creating a very easy to use dashboard. So you'll get your numbers back and you see what's in range and what's out of range. And then they will point you to specific nutritional supplementation and behavioral tools that will allow you to bring those numbers into the proper ranges for you. And I find that immensely beneficial because just having a bunch of data without any knowledge of what to do with that data is more overwhelming than having no data at all, frankly. If you'd like to try InsideTracker, you can go to InsideTracker.com/Huberman to get 20% off any of InsideTracker's plans.

00:07:54 Sensory Stimuli, Nervous System & Encoding Memory

Again, that's InsideTracker.com/Huberman to get 20% off. Okay, let's talk about memory. And let's talk about how to get better at remembering things. Now 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 this 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 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've 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

00:11:12 Context & Memory Formation

to leverage that process in order to remember the information that you want far better. Now, even though I've 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 or name. Or, as the case was for me, I got to the 3rd grade and there were two Andrews. And sadly for me, I lost the coin flip that allowed me to keep Andrew. And from about 3rd 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, 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 not be a whole context to your name for you. But presumably, if you asked your parents why they named you your given name, you'll get a context, etc. 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 often times that's done by association. So people will 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 and training. However, there are things that we can do that leverage the natural biology of our nervous system to enhance

00:13:46 Tool: Repetition, Improving Learning & Memory

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 Ebbinghaus 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 Ebbinghaus liberated the understanding of learning from the philosophers by generating these learning curves. What do we mean by that? Well, before Ebbinghaus came along, learning and memory were thought to be philosophical ideas. Ebbinghaus 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 Ebbinghaus 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 he would 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 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 had 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 Ebbinghaus 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 Ebbinghaus, none of that was known. Now, I should also say Ebbinghaus, because of when he was alive, was not aware of these things that we called neural circuits. It was in 1906 that Golgi and Cajal 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 Ebbinghaus learning curves really established was that sheer 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 than it was the first, probably it was even less interesting and less and less interesting with each repetition.

00:17:11 Co-Activation and intensity Neuron Activation

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, that would lead to a strengthening of a 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 consequence, as 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 into the brain. Or that every time you learn something, a new connection in your brain forms. Well, 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 connections 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 we 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, than 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? Everyday you wake up, your neurons in your brain and body 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,

00:20:50 Different Types of Memory

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, were 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 the sake of today's discussion, I really just want to focus on short term memory, medium term memory, and longterm memory. And while there is still debate, as is always the case with scientists, frankly, about the exact divisions between short term, medium, and longterm memory, we can broadly define short term memory and longterm 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 would be a phone number. If I were to tell ya a phone number, 493-2938, well you could probably remember it. 493-2938. 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 longterm memory. Now of course, in this day in age, most people have phone numbers programmed into their phone and 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 unto an app or a website and it asks you for a security code that's been sent to your text messages and 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 keying it in on your keyboard, that's a really good example of working memory. Longterm 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've got short term memory and longterm memory. And we've got this working memory which is sort of keeping something online but then discarding 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 I 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. If I say, how is it that you walk from one room to the other? You'd probably say, well, I go that direction and then I turn left. I say, no, no, no. How is it exactly that you do it? You say, well, I move my left foot, then my right foot, then 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, then 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 then 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 it 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. Ah, 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

00:25:40 Memory Formation in the Brain, Hippocampus

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. Anatomists like to 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. And if you were to take one cinnamon roll, chop it down the middle. So 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 C's. Two C-shaped halves of this cinnamon roll and you push them together, right, slightly off set 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-C cinnamon rolls stuffed halfway together. So that's not very good. So I guess, seahorse will work. 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, the subconscious memories, are formed and stored elsewhere in the brain. Mainly by areas like the cerebellum, but also the neocortex, the 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

00:28:00 Hippocampus, Role in Memory & Learning, Explicit vs. Implicit Memory

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. Patient's 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 grand mal 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 mal 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 kind of goes on pause and they'll just stop there. It was reported actually that Einstein had absent seizures. Although I don't know that's ever really been confirmed neurologically. Grand mal 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 grand mal seizure. So convulsing of the whole body, loss of consciousness, etc. Or he would feel it coming on. Often times people with epilepsy can feel the epileptic 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 you'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'd probably say his real name. And then perhaps someone new 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? And 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

00:31:49 Emotion & Memory Enhancement

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 neuro surgery 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, that if you were to tell HM a joke, and he thought it was funny, he would laugh really hard. He liked jokes, so you'd say hey, 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. And then you'd leave the room, come back again. Say hi, I'm Andrew. And he'd say, oh, nice to meet you. Because as you know, 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. At least 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 it's 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 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 a motor ability than it is to this precise content of that joke. All right, 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 the 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 anecdote 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 neuro chemicals being present in our brain and body. And as I'm going to tell you next, there are particular neuro chemicals 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

00:36:44 Tool: Emotion Saliency & Improved Memory

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 it's 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 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 and remember them more quickly. This process of accelerating repetition based learning so that your learning curve doesn't go from having to perform something 1,000 times and then gradually over time it's 1,000, 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 McGaugh and Larry Cahill. James McGaugh and Larry Cahill did a number 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. And we will provide a link to this paper, it's some years old now, but the results still hold up. In fact, the results established 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. And 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. So it was a cogent paragraph. Right, it just wasn't a meaningless scramble of words. But it described a kind of 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. You know, just kind of 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. So 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. So 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. Okay, they don't even know why they were reading this paragraph. They came in either for class credit or to get paid. That'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 their 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.

00:41:42 Conditioned-Placed Avoidance/Preference, Adrenaline

Francis Bacon said that in 1620. So Jim McGaugh and Larry Cahill were certainly not the first to demonstrate or to conceive of the idea that emotionally laden 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 neuro chemicals 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 humans subjects. Because McGaugh worked mainly on animals, also human subjects. Larry Cahill, 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 evoking 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 affect 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 who 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 the 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 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, 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, you don't 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 some how 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 it turns out male rats and mice will mate at any point. Or a female animal that's at the particular so called receptive phase of her mating cycle and give them an opportunity to mate at a give location, they'll go back to that location and wait away. This is perhaps why people go back to the same bar, or the seat at 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 and negative, I'm putting what's called valence on it. Making a value judgment about whether 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 true for humans as well. We know that because McGaugh and Cahill 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. In fact, it was ice 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, etc. 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 and body, because if they blocked the release

00:47:14 Adrenaline & Cortisol

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 atop 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, etc. Within our brain we have a little brain area called locus coeruleus, 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 norepinephrine, a related neuromodulator. And to essentially wake up or create a state of alertness throughout the brain. So it's a very general effect. The reason we have two sites of release is because these neuro chemicals 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 just told you, can permeate throughout the brain and body. Adrenaline has more local effects. Or at least is 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 are in after you experience 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 on the biology of how all this works.

00:49:35 Accelerating the Repetition Curve & Adrenaline

Because in that understanding you will have access to the best possible tools to improve your memory. First of all, McGaugh and Cahill were excellent experimentalists. They did not just establish that you could quicken the formation of a memory by accessing material that was very emotionally laden or creating an emotional, high adrenaline state after interacting with some thing. Some word, 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 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. And I should say they did other experiments too 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 neuro chemical state by reading boring material and then taking a drug to increase adrenaline, or an ice bath, or a shock. And then they also administered a drug called a beta blocker to block the affect 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 coeruleus 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. McGaugh and Cahill 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 McGaugh and Cahill really showed, and what's most important to know, is that it is the presence of high adrenaline, high amounts of norepinephrine 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 neuro chemical 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 and the same thing. Because what that means is that were you to evoke the release of epinephrine, norepinephrine, 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. Now 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 neuro chemical reason, the mechanism behind all that is these neuro chemicals have the ability to strengthen neural connections by making them active just once. There's something truly magic about

00:53:03 Tool: Enhancing Learning & Memory - Caffeine, Alpha-GPC & Stimulant Timing

that neuro chemical 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 neuro chemicals 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 McGaugh and Cahill, 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 a tenured professor was to sit down to whatever it is I was going to try and learn, and 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 and 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 neuro chemical 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 is 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 form locus coeruleus from 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 and 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. And 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 and memory, things like Alpha GPC, or phosphatidyl 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 McGaugh and Cahill 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 and body that can enhance 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 and 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 McGaugh laboratory, and in other laboratories evaluated the precise temporal relationship between neuro chemical 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. It could be caffeine. It could be in pill form. Something that would increase adrenaline or related molecules that create this state of alertness that are related to emotionality. And they had them do it either an hour before, 30 minutes before, 10 minutes before, or five minutes before learning, or during the about of learning, right? The reading of the information or the performing of the skill that one is trying to learn. Or five 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, five, 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. And different substances, such as caffeine, Alpha GPC, etc are absorbed from the gut and into the blood stream and reach the brain and trigger these affects in the brain and 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 blood stream, 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.

01:00:50 Tool: Enhancing Learning & Memory - Sleep, Non-Sleep Deep Rest (NSDR)

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 neural plasticity, 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 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 or 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 a 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 McGaugh and Cahill and many other laboratories that stemmed out from their initial work really point to the fact that the ideal protocol would be focus 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 about. Still try and get excellent sleep. Again, fundamentally important for mental health, physical health, and performance. And 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, but we can now add to that, that spiking adrenaline provided it can be done in a safe way, is going to reduce the number of repetitions required to learn. And that should be done at the very tail end or immediately after a learning about. Which is compatible with all the other protocols that I mentioned. And the reason I'm revisiting this stuff about sleep and non-sleep deep rest is I think that some people got the impression that they need to do that immediately after learning and today I'm saying to the contrary. Immediately after learning you need to go into a heightened state of emotionality and alertness. Now 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 you can do safely. And I always say, and I'll 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 what's safe for you. So if you're somebody who's not used to drinking caffeine and you suddenly drink four 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. And I should mention that if you're not accustomed to taking something, you always want to first check with your doctor, of course,

01:04:48 Tool: Enhancing Learning & Memory - Deliberate Cold Exposure, Adrenaline

but also move into that gradually, right? Start with the lowest effective dose. The minimal effective dose. And 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 evoke adrenaline 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 that 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 HubermanLab.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 your 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 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 ritalin, Adderall and modafinil and things of that sort in order to increase 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 mentioned, there are the behavioral protocols. You can use cold and cold is an excellent stimulus because first of all, it doesn't involve 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 invoke 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 in 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

01:08:42 Timing of Adrenaline Release & Memory Formation

that you're trying to learn, is going to be the best time to spike that adrenaline. Now I realize 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 McGaugh and colleagues explored a huge number of different compounds and approaches. Everything from the hand into the ice bath to injecting adrenaline, to caffeine, to drugs that block the affects of adrenaline and caffeine. Drugs like muscimol 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. Regardless of whether or not that something has an emotional intensity or not. Provided 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, McGaugh and Cahill 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%. So six to seven 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% increase. So 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 cup of yerba mate 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 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 the sake of the physical benefits of that exercise. So 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's safe for you. It's only by moving it to late or after the learning that you're really shifting

01:12:36 Chronically High Adrenaline & Cortisol, Impact on Learning & Memory

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 about of work, cognitive or physical work, and then spike adrenaline again afterwards and remember that stuff you did better, right. I'm not encouraging you, in fact I'm discouraging you from chronically increasing adrenaline both during and after a given about of work if the goal is to learn. Why do I say that? Well, work from McGaugh and Cahill 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 you release relative to the amount of adrenaline that was in your system just prior. Particularly 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 while much of what we're talking about is actually a form of inducing a neuro chemical acute stress. Meaning 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 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 focus is vital for encoding information and for triggering neuroplasticity. But remaining calm throughout that time and then afterwards spiking adrenaline and allowing adrenaline to have these incredible effects

01:15:12 Adrenaline Linked with Learning: Not a New Principle

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 McGaugh and Cahill 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. And yet, we are not the first to have this conversation. Nor were McGaugh and Cahill 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. And I just want to read to you the first opening paragraph of this review, which is, as the name suggests, all about memory and stress. So here I'm reading, and I quote, "In Medieval times communities threw" "young children in the river when" "they wanted them to remember important events." "They believed that throwing a child in the water" "after witnessing historic proceedings" "would leave a life long memory" "for the events in the child." Believe it or 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, they didn't even know what a nervous system was, but would encourage the brain and body of that child to remember those particular events. Very counter intuitive 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 the idea here anyway, is they also remember the things that preceded being thrown into the river. So both interesting and amusing and somewhat, I should say thought stimulating, really. 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

01:17:25 Amygdala, Adrenaline & Memory Formation, Generalization of Memories as a way to enhance learning and memory. This has 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. I haven't really talked a lot about the underlying neural mechanisms. So we're just going to take a minute or two and 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 are 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 at 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. It 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 are 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 neural chemical states of the brain and body, 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, or 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 a computer programming. An 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 adrenal 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 an increase in adrenaline because whatever it was that caused the PTSD was indeed very stressful. Caused 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 anyplace 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 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 and 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. 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

01:22:20 Tool: Cardiovascular Exercise & Neurogenesis

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 animals 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 it 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, I want to talk about some of the general effects of exercise on learning and memory that she's discovered and that 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 gyrus neurogenesis. Neurogenesis is the creation of new neurons. The dentate gyrus is a subregion of the hippocampus that's involved in learning and memory of particular kinds. Right, certain types of events, particular contextual learning, but some other things as well. Sometimes involved in spacial learning. There's a lot debate about exactly what the dentate gyrus does, but for the sake of this discussion, and I think everyone in the neuroscience community would agree that the dentate gyrus is important for memory formation and consolidation. The dentate gyrus does seem to be one region in 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 this 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 X-irradiation, 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, or I should say a minimum of 180 to 200 minutes of so called zone two 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. Such as in 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 dentate gyrus neurogenesis. What does that mean? The improvements in cardiovascular function are indirectly impacting the ability of the dentate gyrus 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 improvement 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, 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

01:27:00 Cardiovascular Exercise, Osteocalcin & Improved Hippocampal Function

and memory through other non-neurogenesis, non-neuron type mechanisms. And one of the more exciting ones that has been studied over the years is this notion of hormones from bone traveling in the blood stream to the brain and enhancing the function of the hippocampus. If the words hormones from bones is surprising to you, I'm here to tell you that yes, indeed, your bones make hormones. We call these endocrine effects. So in biology we hear about autocrine, paracrine, and endocrine. Those different terms refer to over what distance a given chemical has an affect on a cell. For instance, a cell can have an affect on itself. It can have an affect on immediately neighboring cells or it can have an affect 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 and affect 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 as kind of synonymous terms. Your bones make chemicals that travel in the blood stream and have these endocrine effects. So they're effectively acting as hormones. And one such chemical is something called osteocalcin. Now these findings arrived to us through various labs but one of the more important labs for the sake of this discussion today is the laboratory of Eric Kandel 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 anecdotal. 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've found is that cardiovascular exercise and perhaps other forms of exercise too, but mainly cardiovascular exercise creates the release of osteocalcin from the bones that travels to the brain and to sub regions of the hippocampus and encourages the electrical activity and 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 that it 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

01:29:59 Load-Bearing Exercise, Osteocalcin & Cognitive Ability

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've got smell, you've 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 ability, excuse me, to generate fine 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 move your face 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 in a really detailed circuit level, that the relationship between the brain and body and the maintenance and perhaps even the improvement of the 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 its 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 weightlifting, or 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 be in a position to release more osteocalcin then fine 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 a fair amount of detail by John Ratey who's a professor at Harvard Medical School. He wrote a book called, "Spark" which was one of the early books at least from an academic about brain plasticity and the relationship between exercise and movement and 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 unto a rock. They find 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 later 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. The literally metabolize a good portion of their nervous system because they decide, oh, 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. While 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

01:34:41 Tool: Timing of Exercise, Learning & Memory Enhancement

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 an 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, Wendy 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 in 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 in 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 to kind of push through a burn. Right, so here I'm mainly thinking about cardiovascular exercise. But 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 Wendy Suzuki's lab. I'm basing it on the studies from Eric Kandel and from others labs. Again, right now, there hasn't been an evaluation of a lot of different protocols to arrive at the 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 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

01:37:29 Photographic Memory

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, I 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, I 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 often times 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 desirable for most people.

01:38:49 “Super Recognizers,” Facial Recognition

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 and then 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 who's 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 again, 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've ever had the experience of watching a movie and thought to yourself, wow, her mouth looks so much like my cousin's mouth. Or you look at a character in a movie or a television show and you think, wow, 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 this super recognizer ability. That is not memory per se. That is the hyper functioning of an area of the brain that we call the fusiform gyrus. The fusiform gyrus 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, we 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 who's friend, who's foe. Who do you know well? Who's famous, who's not famous? Etc. That is not memory, per se. And yet, if you're a super recognizer, or I guess you 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? And I would say, well am I 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. And he'd say, oh I'm sorry. I'm kind of face blind. And it actually tended to be better or worse 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 to recognize faces. That's not really memory. And yet, visual function is a profoundly powerful way in which we can enhance our memories. So whether or not you're a super recognizer of faces,

01:41:46 Tool: Mental Snapshots, Photographs & Memory Enhancement

whether or not you are 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 of photographs, something that's quite easily done these days with your phone. As well as your ability to take mental photographs by literally snapping your eyelids shut. So I 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. I 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 deciding, blink, snapping a, so to speak, snapping a snapshot of whatever it is that you are looking at and remembering the content. The 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 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 could 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 visual memory of events into their phone or some other device and they're not ever accessing the actual image again. 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 people are taking they're not revisiting again. So the motivation for this 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 object, etc. 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 the 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 objects, places, and people. And indeed, that's what they found. So in contrast to previous studies where people had been more or less told, take photos of these following objects, or these following people, or 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. We'll provide a link to this study. I 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 in a big city. And if you've ever done that, and you see all the different objects, there are a lot of details in those objects and a lot of those objects look a lot alike. And so someone will have two handles. 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 things. So basically what they found was that if people take pictures of things and they choose which things they are taking pictures of, right. It's 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 component 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 it 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 at remembering things. They were always better at remembering them as compared to not taking photos of them. What does this mean? It means that 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'd say 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 more robust at serving a memory then 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 or 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 that you looked at a photo that you took, or whether or not you deleted it and never looked at it again, didn't just enhance visual memory or the memory from the visual components of that image but it 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 this study that the mere decision to take a mental snapshot, like, okay I'm going to blink my eyelids 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.

01:49:12 Déjà Vu

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 is a sense that we've experienced something before but we can't quite put our finger on it. Where and when did it happen? Or the sense that we've been someplace before. Or that we are in a familiar 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 Susumu Tonegawa at Massachusetts Institute of Technology, MIT. Susumu 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 Scripps 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, then neuron B fires, then 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 on 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. To make a long story short, and to summarize multiple papers published in incredibly high tier 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 this 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'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 experience deja vu often, just know that this reflects a normal pattern of encoding experiences and events within your hippocampus. I'm 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, while 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

01:53:24 Tool: Meditation, Daily Timing of Meditation

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 is 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 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. I want to 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 mediators 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 relaxed 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 listened 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 listened 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 this study is that eight weeks but not four weeks of this daily 13 minute a day mediation 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 go into this. Things like the Stroop 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 the study it's mentioned that somehow meditation did not improve but actually impaired sleep quality compared to the control subjects. And 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 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 in the study. But often times 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 sessions from somewhere between 8:00 and 11:00 P.M. And sometimes even between 12:00 and 3:00 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 deep rest protocols, NSDR, for reducing the activity of your sympathetic nervous system. The alertness, so-called stress arm of your autonomic nervous system. The one that makes you feel really alert. NSDR is 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, it has a high attentional load. It requires a lot of prefrontal cortical activity that's involved in attention. Which then logically relates to one of the outcomes of this study which is that attention ability is 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 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 Madefor. So you can go to YouTube, NSDR, Madefor. You can also go do a search for NSDR. There's a 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 this 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. Now 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 an 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 three to five, 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. So I might get my sunshine first. I'm, 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 5:00 P.M. or so in order to make sure that I don't inhibit sleep. Because I think this, the result that they describe of meditation inhibiting quality sleep compared to controls is an important one

02:02:21 How to Enhance Memory

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 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. It 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 neuro chemicals 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 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 neuro chemicals that can enhance learning and memory. And I intend to cover those in deep detail in a future episode. However, for the sake of what was discussed today, please understand that any number of different neuro chemicals 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. 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 our 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 'til night throughout your entire life you have tons of sensory experience, tons of perceptions. Why is it that some are remembered and others are not? While I would never want to distill an 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

02:05:51 Zero-Cost Support, YouTube Feedback, Spotify & Apple Reviews, Sponsors, Patreon, Momentous Supplements, Instagram, Twitter, Neural Network Newsletter

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/andrewhuberman. 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 derive 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've 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 and rigorous way to approach any kind of supplementation regime. 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 LiveMomentous.com/Huberman. They've started to assemble the supplements that we've 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 combined with supplementation protocols in order to deliver the maximum effect. Once again, that's LiveMomentous.com/Huberman. And if you're not already following us on Twitter and Instagram, it's HubermanLab 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 HubermanLab.com, 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 plasticity and for various other topics covered on the Huberman Lab Podcast. Once again, thank you for joining me today to discuss the neurobiology of learning and memory and how to improve your memory using science based tools. And last, but certainly not least, thank you for your interest in science. [light music]