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 talking about time perception. Our perception of time is perhaps the most important factor in how we gauge our life. Whether or not we think we are being successful, whether or not we are failing, whether or not we live in fear, whether or not we live in relation to things in a way that's positive. And the reason for that is that our perception of time is directly linked to the neurochemical states that control mood, stress, happiness, excitement. And of course, it frames the way in which we evaluate our past. So whether or not we think of our past as successful or unsuccessful, it frames our present. Whether or not we think we are on track or off track and it frames our sense of the future. Whether or not we think we have a bright future, a dim future or whether or not the future is very uncertain or not. Today we are going to talk about the science of time perception and we are going to talk about tools and protocols that you can use that can enhance your ability to dilate and develop. To dilate and contract time, what do we mean by dilate and contract time? We can control the speed at which we experience life. We can slow things down or we can speed our experience of life up. And we can do that in a very direct and dynamic way. It's actually not that hard. Once you understand how time perception works. So that's where we're headed. I think you're going to come away from today's episode with a lot of new knowledge and certainly with many tools that you can try in your daily life. Whether or not that's work, sport, relational, emotional and so on. Before we begin our discussion about time perception, I'd like to answer some questions that I received related to the episode on fasting and time restricted feeding. If you haven't seen that episode, this information should still be of use to you. Time restricted feeding involves eating for a particular period of time in each 24 hour cycle. That's fairly regular. So this would be an eight hour most often or a 10 hour block. Some people do shorter, shorter feeding windows. But regardless that feeding window is supposed to fall at more or less the same period within each 24 hour day. This has a number of positive effects on gene expression that regulate a number of positive effects on the different issues of the body. And for some people, not all, but for some people makes weight loss easier because of the way that they are not eating for large periods of each 24 hour cycle. In any event, one of the major questions I got after that episode was do supplements break a fast? And during that episode, I talked about what breaks a fast is highly contextual. It basically boils down to whether or not something you ingest, whether it be liquid or food, increases your resting blood glucose, how much it increases that resting blood glucose, and how long that increase lasts. So you can check out the episode for more about what breaks a fast. But to address this issue about supplements and whether or not supplements a particular break a fast, many of the questions were about athletic greens. Athletic greens is a sponsor of this podcast. It is also a terrific supplement that I had been taking for more than a decade before this podcast launched. And many people have been using and continue to use athletic greens. Does athletic greens break a fast? Well, that will somewhat depend on whether or not your resting blood glucose tends to run high or low. But for most people, including me, because I've measured it, ingesting athletic greens does not break a fast. And if it happens to break a fast, it would be a very transient break in fast. So without knowing your resting blood glucose levels on an individual basis, there's no way I can say for sure that it doesn't break a fast. But chances are it does not because it doesn't contain much carbohydrate or sugar and it doesn't tend to therefore pull you out of the molecular milieu associated with low blood glucose states. The other question I get is whether or not things like fish oil break a fast. And once again, this will be contextual, but because fish oil is a fat, mainly if it's central fatty acids, in particular EPA and DHA, those don't tend to raise blood glucose very much. In my case, having measured using and continuing with glucose monitor, my resting blood glucose, fish oil does not in any way change my resting blood glucose. Chances are it won't do that for most people as well. So does fish oil break a fast? Chances are it does not. And of course, people wanted to know about pill type supplements, caffeine and things that raise dopamine and their vitamins and minerals. In general, if something doesn't contain sugar or much carbohydrate of any kind, it's not going to raise blood glucose very much. Now of course, protein can raise blood glucose and fat can too as well, although to a lesser extent. So again, this is all contextual, but at least by the logic that I just spelled out, athletic greens, fish oil, and most forms of supplements provided they don't have any sugar or protein content should not quote unquote break a fast. Before we begin, I'd like to emphasize that this podcast is separate from my teaching and research roles at Stanford. It is however part of my desire and effort to bring zero cost to consumer information about science and science related tools to the general public. So let's talk about time perception. And the most fundamental aspect of time perception is something called entrainment. Entrainment is the way in which your internal processes, your biology and your psychology are linked to some external thing. And the most basic form of entrainment that we are all a slave to all year round for our entire life are so called sircannual rhythms. We have neurons, nerve cells in our eye, in our brain, and in our body that are marking off the passage of time throughout the year. Literally a calendar system in your brain and body. And the way this works is beautifully simple. Light, seen by your eyes, inhibits, meaning it reduces the amount of a hormone released in your brain called melatonin. Melatonin has two major functions. One function is to make you sleepy at night. And the other is to regulate some of the other hormones of the body in particular testosterone and estrogen. When we view light, we reduce the amount of melatonin released. In fact, if you wake up in the middle of the night when melatonin typically is pretty high in your brain and body, and you flip on a bright light in the bathroom, your melatonin levels crash down to almost zero and stay there. Light is a very powerful modulator of melatonin and light inhibits melatonin. Throughout the year, depending on where you live, day length varies. And as a consequence, the amount of light from the sun that is available to you varies. So when days are long, the amount of melatonin in your brain and body that's released tends to be less. There's less of it and it's released for shorter amounts of time, okay, because light inhibits melatonin. When days are very short, the amount of melatonin that's released and the duration that that melatonin exists in your brain and body tends to be much longer. So melatonin correlates with day length. And if we are viewing more light, we have less melatonin, we view less light, we have more melatonin. You see different amounts of light each day, but we have a process in our brain and body that averages the amount of light that you're seeing, both from artificial sources and from sunlight, and measures that off. And it's so exquisitely precise that for a given, say, eight hour day in the spring, because spring in the northern hemisphere or elsewhere, you know, days are getting longer, that means that the amount of melatonin is getting progressively less and less, and that signal is conveyed to all the systems of your brain and body. And this is why most people, not all, but most people feel like they have more energy in the spring. Conversely, when you have an eight hour day in the winter, the amount of melatonin that corresponds to that eight hour day is getting progressively greater and greater. Because why days are getting shorter, so melatonin is increasing from day to day to day. Every cell and system of your body pays attention to this. And as a consequence, most people, not all, but most people feel they have a little less or sometimes a lot less energy and a slightly lower mood in the winter months. Now there are exceptions to this, of course. But the melatonin signal is the way in which your internal state, your mood, your sense of energy, even your appetite, is entrained, is matched to some external event. In this case, the event is the rotation of the earth around the sun. There are other forms of entrainment, meaning the matching of your brain and body to things that are happening in your external environment. One particularly interesting example of this was published last year by Peric at all in cell report, Cell Press Journal, excellent journal, showing that across the calendar year, the amount of testosterone and estrogen that human beings make varies. Such that in longer days, they tend to make more testosterone and estrogen than in shorter days. And this was correlated with things like desire to seek out romantic partners or have romantic interactions with their existing partners, even aggression, although not violent aggression, but sense of kind of willingness to argue and to get into kind of combative states and overall energy and mood. This is something that had been hypothesized for a long time, but it never really been cleanly demonstrated. And what they showed was that it's actually the skin that's taking information about the amount of light and converting it into these increases in testosterone and estrogen. Light exposure to the skin turns out about two hours a day. This was sunlight in this case to the upper body. These people weren't naked. They were wearing clothes, but their arms were exposed. They're upper back and neck and face were exposed that we're not wearing hats resulted in large increases, significant increases in testosterone and estrogen. Now you could probably export a tool from that if you liked. That's not really what this podcast is about, but it's very clear that because the skin is acting as an endocrine organ, excuse me, is kind of a hormone influencing organ that getting light on the skin, not just to the eyes, can influence our sense of well-being by these people. And the threshold there again, seem to be about two hours a day. It doesn't have to be very bright outside. There can be cloud cover and so on. Many people will probably ask, will sunscreen inhibit this effect? And it doesn't appear that it does. Obviously prioritize skin health and avoiding skin cancer. Sunscreen is kind of a controversial topic nowadays. Maybe the topic for another podcast episode at some point. But nonetheless, what the paracetal study shows, and that's most relevant to today's podcast is that we are entrained. We are matched to the external light dark cycle. And as the day length changes, our hormones change. And overrides that with exposure to bright lights, you know, people go on tanning beds. That's not a practice I particularly myself engage in. But you know, there are a number of different ways that people can override these processes. But the point is very simple. The point is that our perception of time is both conscious. You know, it's waiting watching the clock tick down. And they're the slower what we call oscillatory, meaning up and down repeatedly slower. And the oscillatory events related to day length that are influencing our hormones like melatonin testosterone and estrogen. And therefore our mood, our outlook and even our behavior. The next level of time or bin of time, as we say, that we are all entrained or matched to is the so called circadian time cycle, which is 24 hour rhythm. This is perhaps the most powerful rhythm that we all contain and that none of us can escape from. We all have that is circadian clock that resides over the roof of our mouth, the cells in that circadian clock fire, meaning they release chemicals into our brain and body on a very regular rhythm. So across the 24 hour cycle, they will be very active at some periods and less active at others. Not surprisingly, there are periods of every 24 hour cycle when we are very active and we tend to be alert and others when we are asleep. Now I've talked a lot about circadian rhythms and sleep on this podcast previously. And so I don't want to repeat too much of that information in detail. But I'm just going to give a summary of how circadian entrainment works because I haven't really covered that in the context of time perception. We have this circadian clock. It oscillates. It goes up and down once every 24 hours and then repeats. Every cell of our body has a 24 hour oscillation in the expression of various genes. How that works is actually really simple, elegant and interesting. DNA, genes make RNA. RNA is converted into proteins. Every cell in our body has this beautiful 24 hour timer where a gene is expressed. And the important thing to understand about a given gene in this context is that that gene is inhibited, meaning it's reduced by a particular protein, by a little biological molecule in that cell. So the gene gets expressed when there's very little of that other molecule around. DNA then becomes RNA. RNA is translated into a protein and that protein goes way, way up and the gene shuts down. But as that protein gets used up and its levels eventually drop low, low, low, low to zero, the gene cycle kicks in again and the gene gets expressed. The RNA gets expressed in the protein again. This all happens on a 24 hour cycle. So it's a little built in timer in each and every one of our cells. And I didn't list off the genes, but for the aficionados out there, they go by names like purr, for period, b-mail, clock and all these different things we call them the clock genes. And those clock genes regulate a number of different functions. So every cell in our body has a 24 hour cycle of gene and protein expression. And the Earth rotates once every 24 hours and the processes that are happening in every cell of our body are linked. They are entrained as we say to the outside light dark cycle because morning sunlight, evening sunlight, and the lack of light in the middle of the night, make sure that the changes, these oscillations that are occurring within the cells of our brain and body are matched to the outside light dark cycle. And I want to go into all the details of how that happens, but there's some very simple tools that one can use to ensure that your entrainment, your circadian entrainment is precise. And I cannot emphasize enough how important it is that your circadian entrainment be precise. Why? Because disruptions in circadian entrainment cause huge health problems. They increase cancer risk, they increase obesity, they increase mental health issues, they decrease wound healing, they decrease physical and mental performance, they disrupt hormones. You want your cells to be linked to the circadian cycle that's outside you in the circadian cycle outside you mainly consists of when there's sunlight and when there is not. And that's why the simple protocols to fall out of this whole discussion about circadian entrainment are the following. View 10 to 30 minutes of bright light ideally sunlight within an hour of waking assuming that you're waking early in the day, especially you wake up early in the day, get outside, see sunlight do that again in the afternoon or around evening 10 to 30 minutes depending on how bright it is outside artificial lights throughout the day or if you want to be awake and you wake up early. And there's no sunlight outside you can of course turn on artificial lights if you want to be awake, but basically you want as much bright light ideally from sunlight in coming in through your eyes throughout the day. And then in the evening you want as little bright light coming in through your eyes. I said this over and over and over again on this podcast there's always a lot of negotiations, but I want to make a few things clear. Try not to wear sunglasses if you can do it safely. Find to wear eyeglasses or contacts that's not going to be a problem. The light viewing that you do and the avoidance of light at night set the fundamental layer of your time perception. One of the best ways to disrupt your perception of time in the ways that we're going to talk about in the subsequent portions of the podcast is to disrupt your circadian clock and that is not a good thing for a number of different reasons. There are other ways to so called in train your circadian clock. One of the best ways to do that is to engage in physical activity at fairly regular times of day. You don't have to do it every day, but if you're going to exercise trying exercise that a fairly consistent time of day, probably better to exercise than to not exercise even if you have to move that time of day. But light activity and we'll talk about the third in a minute food are the major ways that you in train your internal perception of time to the external events of the of the world, meaning that the turning of the earth and therefore the exposure to sunlight or not. So in addition, the sunlight viewing in the morning and throughout the day and avoiding bright light at night of any kind not just blue light trying to get your activity or exercise at fairly fairly regular within plus or minus two hours from each day to the next is going to have a very positive effect on so called circadian entrainment and also eating at fairly regular times. However, this is exciting the data mainly point to the fact that you need to eat within more or less the same time window each day, not that you always need to eat your meals at exactly the same time. So you don't necessarily have to eat lunch at noon and a snack at four and dinner at eight in order to keep your circadian entrainment aligned or sharp. You could for instance have a small snack at noon and then eat at two and then have dinner at six and then a small snack at eight it doesn't so much matter when the exact meals fall so much is that they fall more or less within a consistent period or phase of each 24 hour cycle. What happens when this circadian clock starts getting disrupted I mean this is after all an episode about time perception is not an episode about circadian rhythms and entrainment. Well, there's a classic study by Ashoft on in 1985 that's now been repeated many times where they had people go into environments where they didn't have clocks and they didn't have windows and they didn't have watches and there were sometimes even in constant dark or constant light and they evaluated how well people perceive the passage of time on shorter time scales. And what they found was really interesting what they found is that people underestimate how long they were in these isolated environment so after 42 days or so they'd ask people how long do you think you've been in here and people would say 28 days or 36 days they generally underestimated how long they'd been in this very odd environment with no clocks or watches or exposure to sunlight or regular rhythms of artificial light. In addition they found that their perception of shorter time intervals was also really disrupted so if they asked them to measure off two minutes they normally people are pretty good at measuring off two minutes people come within you know five to 15 seconds at most of you kind of to sit there and just wait you have a pretty good idea when two minutes up he said two minutes is up well when people circadian clocks or circadian entrainment I should say was disrupted their perception of time measure. So time measurement on shorter time scales of minutes or even seconds was greatly disrupted and as we'll see in a couple of minutes that actually causes great problems for how you contend with work how you contend with challenges of different kinds you want your circadian entrainment to be pretty locked in or pretty entrained to the outside light dark cycle so that your perception of time on shorter time intervals can be precise. So we've talked about circanular entrainment the matching of the cells and tissues in the organs of our body to the 365 day journey that the Earth takes around the sun each year and we talked about circadian entrainment the way that the 24 hours of the day is going to be very important. So the way that the 24 hour genetic and protein clocks of each and every one of ourselves is matched to the rotation of the Earth on its axis and the exposure or lack of exposure to the sun because of that rotation on its axis. Next I'd like to talk about so called ultraadian entrainment, ultraadian rhythms are rhythms of about 90 minutes or so and all of our existence is broken up into these 90 minute ultraadian cycles when you go to sleep at night whether night you sleep six hours or four hours or eight hours or 10 hours that entire period of sleep is broken up into these 90 minute ultraadian cycles early in the night you tend to have more slow wave sleep later in the night you tend to have more REM sleep. But nonetheless your sleep is broken up into these 90 minute cycles. However, when you wake up in the morning many of the things that you do are governed by these ultraadian rhythms. For instance, if you were to work meaning do math or try and learn a language or do physical work of any kind or work out the 90 minute time block seems to be the one in which the brain can enter a state of focus and alertness and do hard work and focus focus focus and then about 90 minutes there's a significant drop in your ability to engage in this mental or physical work. Now everybody from the self-help literature to the business literature to the pop psychology literature has tried to leverage these ultraadian cycles by saying if you're going to do something hard and you want to focus on it limit it to 90 minutes or less and I am one of those people who's also joined that conversation and indeed I use 90 minute work cycles and I think they are extremely powerful one should never expect that you're going to drop immediately into a state of high focus at the beginning and then it's remained there for 90 minutes. We all struggle to varying degrees to achieve focus and motivation and drive within those 90 minutes cycles but it is true meaning there is ample literature to support the idea that after about 90 minutes we tend to go into a state of less ability to focus. So while this isn't time perception per se it is again an example of entrainment what are we in training to right went just because we can focus for 90 minutes and then not so well at 100 minutes or 120 minutes what are we in training to what you're in training to is the release of particular nor chemicals in this case aceto calling and dopamine that allow your brain to focus for particular periods of time 90 minutes or so and after about 90 minutes or so. The amount of those chemicals that can be released tends to drop very low which is why your ability to focus becomes diminished. If one would like to explore more about the backbone and basis of these alternating rhythms it goes by a different name this was originally called the basic rest activity cycle this was proposed many years ago by the annual climate it was established to be true within sleep states as I mentioned before then it was debated for a long time whether or not these 90 minutes cycles also control our ability to focus and perform work in wakeful states and it turns out that they do now there's a lot of literature to support that I always get the question how do you know when the 90 minutes cycle begins in other words let's say you wake up at 8 a.m. and you just finished a 90 minute sleep cycles that mean that your next 90 minute cycle where you could do work begins right at 801 no. The interesting thing about these basic rest activity cycles these all trading rhythms is that you can initiate them whenever you want this is not like a circadian rhythm which is a hard wired un-airing signal of 24 hours. The all trading rhythms that occur during sleep are hard wired un-airing you don't get the option of making your sleep cycles at 120 minutes or five minutes you don't get that option. But if you decide that you want to apply all trading rhythms to work in performance you can set a clock and decide okay now the focus begins now the work begins and this 90 minute cycle is the period in which I'm going to do work. And I actually do this I you know mid-morning and sometimes twice a day I do a 90 minute cycle where I limit all distraction as much as possible put away my phone often turn off the internet as well I talked about this in an episode on an optimal work day at least for me just to give an example of how this might work. But I want to emphasize again that these all trading rhythms are ones that you set so you decide I'm going to work for 90 minutes what you can't negotiate however is that at about a hundred minutes or 120 minutes no matter who you are you're going to see a diminishment in performance you're not going to focus as well. And that's again because of the way that these 90 minute cycles are linked to the ability of the neurons that release a citocholine and dopamine and to some extent nor up and effort the things that give us narrow focus motivation and drive the way that these 90 minute cycles are involved in those circuits after about 90 minutes those circuits are far less willing to engage and therefore it's much harder to continue to focus to a high degree. Some people like to do multiple 90 minute cycles per day of focus in that case you need to separate them out you can't do one 90 minute cycle then go right into another 90 minutes cycle that another 90 minutes cycle you can't cheat these circuits related to a citocholine and dopamine and or up and effort unfortunately I suggest that people do no more than three and ideally it would be two or just one of these 90 minutes cycles what I say ideally well they are very taxing you are in a very narrow tunnel of focus. So for me I can do one mid-morning and I probably do another one in the afternoon this is not the kind of work that's like checking email or text messaging or social media this is very focused hard work working on hard problems of various kinds and this will be different for everybody. So I recommend that they be spaced by at least two to four hours and most people probably won't be able to handle more than two per day there are probably some mutants out there that could do three or four but that's exceedingly rare. I think even one a day is going to feel like a significant mental investment and afterwards you're going to feel pretty taxed. So now we've talked about circadian and ultra-dian rhythms but we haven't really talked about time perception per se we've mainly talked about the subconscious slow oscillatory ways in which we are entrained or matched to the year or to the day and these ultra-dian cycles that we can impose on our work and that we can leverage toward more focus if we like. But what about the actual perception of time what actually controls how fast or how slowly we perceive time going by. There are basically three forms of time perception that we should all be aware of. One is our perception of the passage of time in the present how quickly or slowly things seem to be happening for us. This is kind of like an interval timer ticking off time tick tick tick tick tick tick tick it's either fine slicing like that or tick tick tick tick we have interval timers I'll discuss the basis of those interval timers. We also engage in what's called prospective timing which is like a stopwatch measuring off things as they go forward that might sound a little bit like what I just described but it's actually a little bit different for instance if I told you to start measuring off a two minute time interval into the future you could do that pretty well. If I told you you had to measure a five minute timer interval into the future and you couldn't use any clocks or watches or your phone or anything like that you would have to set the tick marks you would have to decide how many times you were going to count off during that five minute time block. There's also retrospective time which is how you measure off time in the past so if I say you know last week I know you went to the park you did some things with friends you know you went out in the evening. How long was it between lunch and when you went to dinner with friends you probably think okay well I remember I went to dinner at seven and we had lunch right around two you're using memory to reconstruct certain sets of events in the past and get a sense of their relative positioning within time. Okay so we have retrospective current time interval measurements and then prospective time measurement into the future. The beauty of time perception in the human nervous system is that it boils down to a couple of simple molecules that govern whether or not we are fine slicing time or whether or not we are batching time in larger bins. Those molecules go by names that maybe you've heard things like dopamine and nor epinephrine neuromodulators called neuromodulators because they modulate they change the way the other neural circuits work. Also things like serotonin serotonin is released from a different site in the brain than dopamine and or epinephrine is and has a different effect on time perception. So just to give you an example of how things like dopamine and serotonin can modulate our perception of time when I focus on a little bit of literature that now has been done fortunately in animals and humans and which essentially shows that the more dopamine that's released into our brain. The more we tend to overestimate the amount of time that is just past let me repeat that the more dopamine that is released into our brain the more we tend to overestimate how much time has passed these experiments are very straight straight forward excuse me and they're very objective which is really nice which is you can give people or an animal a drug that increases the amount of dopamine and then ask them to measure off without any measurement device like a watch or a clock. When one minute has passed as dopamine levels of rise in the brain people tend to think that the minute is up before a minute so they at the 38 second mark they'll say okay I think a minute is up so they've overestimated how much time has passed okay. The higher level of dopamine the more people tend to overestimate now it's also true that nor epinephrine also called nor adrenaline plays a role and its role is very similar to that of dopamine and that's because nor epinephrine and dopamine are close cousins as some of you may recall that they are actually manufactured from one another okay so dopamine can actually make epinephrine and nor epinephrine biochemically it's they there's a cascade in which dopamine can be made into nor epinephrine and epinephrine. Which is remarkable how does having elevated levels of dopamine and nor epinephrine cause one to overestimate how much time has passed. Well it does it because of the way that it causes fine slicing of your time bins so fine slicing of time is like increasing the frame rate on your camera right slow motion is achieved in movies and elsewhere by increasing the frame rate. So if you take a movie at 30 frames per second and watch it it will appear to have a certain speed right because those are just snapshots 30 frames per second in contrast if you took that same movie at 4,000 frames per second you are fine slicing and you're going to see every little detail as you play each one of those frames it's going to look like it moved slower okay whatever so the kind of jump shot in basketball that's done slowly any any slow motion is the consequence of higher frame rate. So dopamine and nor epinephrine increase frame rate and as a consequence they tend to lead us to overestimate the amount of time that's passed. Conversely the neuromodulator serotonin causes people to underestimate the amount of time that's passed so they've done these experiments they actually have done these experiments using in humans with drugs the increase serotonin they've also done them with cannabis which is a lot of time. So the synobus which increases serotonin among other things including the cannabinoid receptor activation and when people have elevated levels of 5 ht or whether or not they've ingested cannabis they tend to underestimate how much time has passed you do the equivalent experiment you tell people that they have to guess or tell you when 5 minutes for instance has passed just to use them and say it was 5 minutes when they've underestimated how much time has passed and that's because serotonin and some of the related molecules in the brain tend to lead to slower frame rates right they take the frame rate from in the example I used before from 4,000 frames per second down to say 20 frames per second. So this is very interesting it's interesting in terms of how pharmacology can be used to adjust time perception but it's also interesting in the context of that circadian rhythm there's some emerging evidence that throughout the 24 hour cycle there are robust changes in the amount of dopamine or epinephrine and serotonin that are present in the brain and bloodstream and body depending on time of day within the circadian cycle. Now I'm not talking about during sleep during sleep there are definitely variations and things like dopamine or epinephrine and serotonin I talked about then the episodes on sleep here I'm just talking about the role of these molecules in time perception during wakefulness. So much of the evidence points to the fact that in the first half of the day approximate first half of the day dopamine and nor epinephrine are elevated in the brain body and bloodstream much more than is serotonin. And that in the second half of the day and in particular towards evening and nighttime serotonin levels are going up. I think that's fairly well established now what that means based on what we just discussed about the role of dopamine or epinephrine and serotonin in setting the frame rate of time perception is that our perception of the passage of time will be very different in the early part of the day and in the later half of the day. And there's starting to be some evidence to support this that early in the day people tend to overestimate how much time has passed and later in the day they tend to underestimate how much time has passed and this is independent of taking any kind of substance that would increase or decrease dopamine or serotonin. Now this is important in terms of how one thinks about structuring their day because I know many people are thinking about the various tasks that they need to do throughout their day. Many or I should say all of the literature at least that I can find on productivity and things that sort point to the idea that we should be doing the hardest task, the thing that we want to do the least or the most important task early in the day as a kind of a psychological tool for getting it done and feeling as if we accomplished something. I think that's an excellent protocol, frankly, but I'm not sure it's an excellent protocol because of the way that we sense accomplishment or at least it's not only an excellent protocol because of the way that we sense accomplishment. Another reason to move something that's very hard into the early part of the day is that if indeed the dopamine or agronergic circuits are more active at that time. We are actually in a better position cognitively to parse that hard problem because of the way that we are able to find slice our perception of time and find slice all the perceptual events outside us. So what I'm really saying is that early in the day you are a much more high resolution camera, so to speak, than you are later in the day. Now, different types of tasks and different types of things require different frame rates or different ways of perceiving time. And indeed this also lends itself to a tool whereby for activities that involve more kind of creative thinking that aren't as constrained by particular answers or outcomes and in which we need to kind of blend different aspects of our memory, different aspects of task utilization. In other words, for creative works, for brainstorming, for things that are a bit more fluid, so to speak, the more serotonergic second half of the day and because of the way the serotonergic second half of the day lends itself to our time perception may actually be more beneficial for those sorts of tasks. And I'll put a reference to a couple of the studies that point to this idea that in these higher dopaminergic states, we are better at doing certain sorts of tasks and in these more serotonergic states where better at doing other sorts of tasks and how the dopamine tends to be earlier than the day and the serotonin later in the day. So to speak, these are broad, I'm painting with broad strokes here, but I think these lend themselves to some really excellent tools because I think we all understand the value of doing something that's harder challenging early in the day, but we should ask ourselves harder challenging how? What does that task actually really require in terms of time perception? Some people might appreciate some examples of how this might work. Basically, what I'm saying is if you are doing work that involves adhering to some rigid rules, so math or a recipe or execution of musical skills or physical skills or accounting or something that requires a lot of precision where there's a right and wrong answer and it's hard. I would suggest that you do that in the early part of the day because of the way that dopamine and or epinephrine impact time perception, you are literally better at slicing up time, you are a higher resolution brain during those times, and so that's going to lend itself better to events and demands that require high resolution. So as in the afternoon, in this more what I'm calling serotonergic state, that's when you're going to be better at brainstorming and creative works where there's some flexibility in terms of how you're batching time and perceiving time and there isn't so much rigid oversight of a right or wrong answer. And as an aside to support what I said, but also to take us back to this critical role of the circadian rhythm, there is a lot of evidence that when one's sleep is disrupted when sleep is either too short or is fragmented or is not a high enough quality for enough days. One of the first things to happen is that there is a dysregulation of these dopamine or agon or chick and serotonergic states throughout the day, they get kind of mishmashed up. It's not that they're a total mess, but they aren't as cleanly defined. And I think this is one of the reasons why when we haven't slept well or we haven't slept enough, we tend to feel a little off like we can't concentrate. Part of that lack of concentration is due to other things, but part of that concentration could be due to the fact that our sense of the passage of time is disrupted. So there seems to be some value in keeping the dopamine or agon or agon or agon or agon or agon or state kind of limited to the early part of the day, and the serotonergic state is we're calling it and push towards the second half of the day. Now there is a version of how dopamine and norapinephrine can impact our perception of the passage of time in ways that can be very disruptive or even maladaptive. And the best example that I'm aware of is trauma. Many people who have been in car accidents or who have experienced some other form of major trauma do what's called overclocking. Overclocking is when levels of dopamine and norapinephrine increase so much during a particular event, our level of alertness has increased so much during a given event that we find slice, in other words, the frame rate is increased so much so that we perceive things as happening in ultra slow motion. Now that might not seem like a bad thing overall but the problem with overclocking is the way in which that information gets stamped down into the memory system. So the memory system which involves areas of the brain like the hippocampus but also the neocortex is basically a space time recorder. What do I mean by space time recorder? Well, your nervous system of course is housed in the darkness of your skull. It doesn't have a whole lot of information about the outside world except light coming in through the eyes and whatever happens to hit our ears in terms of sound waves and skin and so forth. So it has to take all those neural signals and it has to create a record of what happened. Now, it doesn't create a record of everything that happened but car accidents and trauma and things of that sort oftentimes are stamped down into our record of what happened. And what gets stamped down, what we actually mean by the phrase stamp down is that the precise firing of the sequence of neurons that reflected some events. So let's say I'm in a car accident, certain neurons are firing because of the flipping of the car or their screams or their blood or things of that sort. All of that neural activity gets repeated in the hippocampus and then the sequence of the firing of those neurons is also remembered. So it's not just that neuron 12345 fired in that sequence. It's also that neuron 12345 fired at a particular rate. So it would be 12345 during the actual event and then the memory is stored as firing of those neurons as 12345, right? If it if during the event it was 12345 at that rate, the storage of the memory is not going to be 12345. Okay, in other words, there's both a space code as we say, meaning the particular neurons that fire is important and there's a rate code. How quickly those neurons fire or the relative firing, the timing of the firing of those neurons is also part of the memory. This affords our memory system tremendous flexibility. What it means is that you can take the same set of neurons in the hippocampus and stamp down many, many more memories because all you have to do is use a match of the different rates of the different neurons that we're firing in order to set that code, right? You don't otherwise if you needed a different set of neurons for every memory, you need any enormous hippocampus, you need an enormous head. So I think I think you get the basic idea. Overclocking is a case in which the frame rate is so high that a memory gets stamped down and people have a very hard time shaking that memory and the emotions associated with that memory. It's not the topic of today's conversation, but we will cover trauma in a future episode in detail, but many of the treatments for trauma EMDR nowadays, there's a lot of excitement also about ketamine therapies, exposure therapies, you know, like cognitive behavioral therapies, involved not just trying to reduce the amount of emotion associated with a memory, but also a deliberate speeding up or slowing down of that memory. In other words, trying to allow the person who experienced the trauma to take control of the rate of the experience in their memory, not just whether or not the memory happened at all. In fact, you know, one of the first things that trauma victims learn is that they aren't going to forget what happened, what's eventually going to happen, ideally with good treatment, is that the emotional weight of the experience will eventually be divorced from the memory of the experience. And that's done again by trying to reduce the amount of emotional activation during the recall of that experience, and one of the best ways to do that is to alter the rate of the memory playback. In other words, taking that firing of neurons that might have been one, two, three, four, again, it would be much more complicated, but one, two, three, four for the car crash and getting the memory to play back at a rate of one, two, three, four, or even one, two, three, four, one, two, three, four. In other words, allowing the person or instructing the person to take control of the rate of the playback. And in that way, there seems to be still yet unknown mechanism by which people can uncouple some of the emotional weight that's associated with that memory. So overclocking is a kind of extreme example of where the dopaminergic and the noradginer system is ramped up so high that people have this, unfortunately, what seems like indelible mark in their brain of a particular event, but again, trauma treatment is designed to uncouple the emotional load of that event. Some of you are probably saying, why dopamine during trauma? I thought dopamine was the feel good molecule. Well, in reality, dopamine is not necessarily a molecule of reward. It's a molecule of motivation, pursuit, and drive. And because of the close relationship between dopamine and noraponephrine, oftentimes they are co-released. So whether or not dopamine is released during car crashes or other forms of trauma, we don't know. But what we do know is that both the dopamine system and noradginergic system, when we say noradginergic, we mean noraponephrine, those systems are greatly increased. Anytime there's a heightened state of arousal and arousal can have negative valence, like a meaning associated with an event that we really hate that we would prefer not to be of molten or can have positive valence. But dopamine and noraponephrine are kind of the common hallmark of all things of elevated arousal. And that's why we see evidence for dopamine being associated with these changes in time perception, both for positive events and for negative events. There's a very interesting relationship between arousal, dopamine, time perception, and blinking. And this is all supported by a really interesting paper. First author, Terroun, is the last name, T-E-R-H-U-N-E, is publishing current biology, self-presternal, excellent journal. The title of the paper is Time dilates after spontaneous blinking. So heightened states of arousal are associated with heightened levels of dopamine. You now know that dopamine leads to a kind of fine slicing of time. And one of the ways that we find sliced time is by blinking. We think of blinking as just a thing to lubricate our eyes or to limit the amount of light coming into our eyes. But it's a shutter on our experience. So much of the information that coming into the brain through our eyes impacts our attention. I've said it before on this podcast that cognitive attention follows visual attention, least for sighted individuals. Well it turns out that dopamine and increases in dopamine are associated with increases in spontaneous blink rate. So the more arous we are, the more awake we are. There are a number of effects, pupils, dilate, heart rate increases, etc. But also blink rate increases. And every time we blink, this study cleanly shows, we shift our perception of time, leading to, as I mentioned before, overestimations of time. So it seems as though in some way, blink rate is actually related to frame rate. And so this is very, very interesting. And the way that you could think about leveraging this would be, if you wanted to actually slow down your perception of time, you would blink less. And if you wanted to speed up your perception of time, you would blink more. Now you'd have to think of a scenario in which that would be useful to you. Obviously, if you're going to blink, you're going to miss things as well. But I think it's a very interesting parameter of our visual attention as it relates to time perception. Because what it really speaks to is that these neuromodulators, like dopamine or serotonin, that adjust frame rate, they're not doing it through some magical mechanism. In fact, there's no single brain area that we can say controls time perception. I haven't said today, oh, you know, it's the striatum. Well, it involves the striatum. But I'm not going to say, for instance, oh, it's the cerebellum. The cerebellum is definitely involved in timing of movement, something for a future podcast. But time perception is what we call a distributed phenomenon. It's a network of areas in the brain working together. But dopamine in the way that it relates to the shuttering of your eyes seems to be controlling the frame rate on your experience. Numbers times on this podcast, I've talked about cold exposure. Nowadays, there's a lot of interest in things like cold showers, ice baths, immersion in cold water tanks and lakes and oceans and things of that sort. There are a lot of different positive effects of cold exposure. Provide it's done properly. It can lead to increases in metabolism, brown fat stores, which are the good fat stores that you want. There's sort of like a furnace that allow you to heat yourself up. Stay warming cold environments to reduce inflammation, to increase resilience and so forth. There's a study published in the European Journal of Physiology showing that cold exposure can increase our baseline levels of dopamine robustly, 2.5x. It's a long lasting increase in dopamine and it appears to be a healthy one. Meaning it doesn't seem to be addictive. I'm sure there are some people out there addicted to ice baths. But when you think about the range of dopamine inducing behaviors that are addictive, it seems to be more on the health promoting side. What's interesting is that because cold water exposure increases dopamine, it will also change your perception of time. And if you've ever done one of these cold water exposures, you've experienced this. You've experienced getting in and feeling like, wow, making it three minutes is a really, really long time. And you are fine slicing time. Your framerate is going up. Part of that, just at a course level as you're thinking, this is painful. I don't like this. I want to get out. But part of it is also that your dopamine levels are going up very quickly. And therefore, your perception of that discomfort is also being fine sliced. And so you could leverage a tool, for instance, where you try and train your thinking to something other than your immediate experience. This is a kind of a controversy, if you will, in the cold exposure world. The question is, do you try and lean into the experience and really feel it? Or do you try and distract yourself? Sing a song or count off from one to a hundred. Just know that whatever tactic you use to get through the cold exposure, that the dopamine level that's now increased in your system is going to cause you to find slice or experience that at slow motion. So a minute is going to seem like a lot longer than a minute in reality. So you could, for instance, decide to pay attention to some external cue. Maybe it's a metronome that ticks once every 10 seconds. You could decide to think about something else. You could decide to sing a song in your head or sing a song out loud. All of that will divorce you from the sensation that you're experienced somewhat. But more so, it will divorce you from the perception of your experience as governed by that dopamine increase in frame rate. If that isn't clear, just know this. When you're in the ice bath, your dopamine levels are high. When your dopamine levels are high, your experience of the discomfort that at ice bath is at higher resolution. Now, up until now, I've been talking about how dopamine and to some extent serotonin can differentially impact your perception of how fast or how slowly things are happening in the moment. But remember, we have prospective time, we have our experience of time in the moment and we have retrospective time. And there are beautiful studies that have showed that the dopaminergic state changes the way, not just that we experience things now, but that it changes the way in which we remember things in the past and the rate at which those things occurred. And those are in opposite direction. So to make this very simple, if something that you experience is fun or varied, meaning it has a lot of different components in it, and in other words, it's associated with an increase in dopamine in your brain. You will experience that as going by very fast. Now this is different than the ice bath, which I just said that you experience is going by very slowly. But here I'm talking about something that's fun and varied that you really like. And you feel like it goes by very, very fast. Imagine an amazing day for a kid at an amusement park. They can do a ton of things that's all new, they're very excited, and they'll feel like it goes by very fast. But later, they will remember that experience as being very long, that it was a long day full of many, many events. And so there's this paradoxical relationship between how we perceive fun, exciting, varied events in the present and how we remember them in the past. For those of you who've gone on vacation, if you've had an amazing day on vacation, it'll seem like or an amazing vacation overall. It will seem like it goes by very fast. The last day of vacation, you sort of go, whoa, it went by so fast because there's so much happening. But in memory, six, eight months later, you remember, wow, that just went, you know, that was a long, long thing. We had this, then we had that, then we did this, then we had that, it tends to spool out in a longer memory than the actual experience. Conversely, if you are bored with something or it's something you really don't like, it's going to seem like it takes a long time to go through that experience in the moment. But retroactively looking back, it will seem like that moment was very short. So if the other day I was waiting in the waiting room for the dentist, it was pretty boring. I was just going to sit there. There wasn't much going on. And it did seem like it was going on an awfully long time. But indeed, looking back, it just seems like, okay, I sat in that room not much happened and so it seems like a very short time been. This seems to be an efficiency of how the brain stores information. Dopamine being associated, of course, with fun and varied experiences and low dopamine being associated with empty boring or what at the time seemed like long experiences. And this whole thing has been stamped down into the scientific literature by those earlier experiments where they take human beings and isolate them in certain environments. Take away all the clocks and watches and cues and about what time of day it is and what time of night it is and allow people to have a life where they can either read and work and do things or would have very little to do. When people are isolated in very boring environments and they don't have access to time cues, time dilates. They tend to assume that time has gone on very, very long. And so the reason I bring this up is we aren't just driven by these circadian clocks and these circadian clocks and these old trading clocks. We are driven by these timers that vary depending on our level of excitement and they vary depending on our level of excitement because of these neuromodulators, dopamine and serotonin. So the way I like to think about it is that you have two clocks, two stopwatches. One is a dopamine-ergic stopwatch that finds slices really closely. It's like counts off milliseconds and it's grabbing a movie of your experience at very high resolution. And then the other hand, you have a stopwatch that's gathering big time bins, big ticks along that the end is moving at bigger intervals, marking off time. And depending on whether you're not you're excited or whether you're bored, you're using different stopwatches on time and therefore you're perceiving your experience differently. One very interesting aspect to the way that neuromodulators like dopamine and novelty interact with time perception and memory is how we perceive our relationship to places and people. The really interesting literature showing that the more novel experiences we have in a place, the more we feel we know that place obviously, but the longer we feel we've been there. So here's the kind of Gedunkin or Thought Experiment that illustrates what's in the literature. Let's say I were to move to New York City. I happen to really like New York City. I've never lived there, but let's say I lived there. I lived in a given apartment for a year and I would have a number of different experiences in this mental experiment. I'd say I had 100 different exciting and new experiences. I would at the end of that year feel as if I lived there a certain period of time, one year. I would actually know I lived there one year. If however I lived in three different places in New York City and I met three times as many people and I had three times as many novel experiences, I would actually feel as if I had been there much longer than had I only lived in one location. This is also true for social interactions. When we move to multiple or several novel environments with somebody else, we tend to feel as if we know that person much better and that they know us much better. Now, of course, we get the opportunity to interact with those people in different contexts. So indeed, we do get the opportunity to see them. For instance, at the coffee shop, how they order coffee, you maybe go to a sports event, how they act there, maybe how they interact with your family. You're getting a sense of them in different contexts. That's certainly playing a role. But it seems that if the more novelty you experience with somebody, not only the more familiar they are to you, but the more time you feel you've spent with them, even though the total amount of time can be exactly the same. That's a very interesting aspect of how our perception of time in these neuromodulators and novelty can shape the way not just that we perceive a given event in our world, but how we relate to a place or relate to a person. So we've talked a lot about the different neurochemicals and how those neurochemicals can influence our perception of time. We haven't talked a lot about the neural circuits in the various areas of the brain that underlie this. I do want to touch on that by highlighting a really wonderful study. This was a study published in neuron, also a cell press journal, excellent journal. The title of the paper is Behavioral, Physiological and Neural Signatures of Surprise during naturalistic sports viewing. This experiment is really cool. They did brain imaging on individuals who are watching basketball games. These were basketball games that actually took place that were recorded and the subjects watching these basketball games in some cases not all had some interest in who would win or lose. And in some cases not all, the subjects in these studies had some prior knowledge of which team they thought was better, which team was likely to win or not likely to win. The basic findings of the study were that they could measure surprise by the release of dopamine in two areas of the brain, part of what are called is called, excuse me, the mesolimbic reward pathway. So the two areas of the brain that are important here are the nucleus accumbens and the VTA, the ventral tegmental area. These are areas that release dopamine is kind of a token of reward anytime something is surprising or a positive expectation is met. So if I predict that my team dribbling down court is going to score on this drive and they get the ball in the basket, a little bit of dopamine is released. These two brain areas light up in the functional imaging, so called FMRI, functional magnetic resonance imaging that they used in the study. What's really interesting about this study is not just that dopamine is released anytime that something the subject wanted to see happened, right? Anytime they wanted to see their team score, they scored. But also during surprise, so if they thought, for instance, and they would hit a button to predict that their team was going to score on this particular drive and they didn't, well, then dopamine could also be released in response to that surprise. So this speaks again to dopamine being something that's important, not just for positive events but for unexpected events. Now that's all very interesting and speaks to the fact that dopamine is a kind of flexible currency in the brain, it's doled out, if you will, or released when something that one hopes will happen happens and it's released when there's a surprise, even if it's a kind of a negative surprise, it's not something that the subject wanted to happen. But the more interesting thing is how that relates to time perception. What they found was regardless of what caused the dopamine release, the frequency of dopamine release predicted how the subjects parsed the time bins of the game they were watching. What do I mean by that? Well, when you watch a basketball game where you watch anything, children playing or talking to your spouse or whatever, you're batching time. How are you batching time? Well, you could batch a meal by the, I don't know, the appetizer, the main course and the dessert, but it turns out that's not what you're doing. You're batching time according to the frequency of dopamine pulses, the frequency of dopamine release. That's what they saw in this study. If they evaluated people's perceptions of the passage of time, what they found is that that matched not whether or not it was a particular time point in the game, not whether or not their team was going down court or running back up court to play defense, but the dopamine release served as markers, which would predict the frame rate of their perception of the experience. And if that sounds complicated, what I mean is how often and when you release dopamine is actually setting the frame rate on the entire perception of everything, not just of her positive events or negative events. So what this means is as you're going through life, dopamine and the release of dopamine is saying that's over and now you're in a new phase of your life. Even if it's very short, right? So if I get up in the morning, I really need to cup a coffee as you probably all know, I wait 90 minutes to 120 minutes before I drink my coffee, but then I get my coffee and surely there's a dopamine hit there. I promise you, I actually am starting to carve up my day according to dopamine hits. I am with consciously or subconsciously, I'm actually carving up my experience according to when I'm getting dopamine throughout my day. This governance over our perception of time that dopamine has points to a very clear, very actionable and very powerful tool. And that is a tool that many people have talked about before, which are habits. People have discussed habits in a variety of contexts, but in the context of dopamine reward and time perception, what this means is that placing specific habitual routines at particular intervals throughout your day is a very not just convenient, but a very good way to incorporate the dopamine system so that you divide your day into a series of what I would call functional units. What would this look like? It would mean waking up and having one specific habit that you always engage in that causes a release of dopamine. You could say, well, great, that'll make me feel good and I would agree, dopamine release generally makes us feel motivated, but it would have an additional effect of marking that time of day as the beginning of a particular time been. Then inserting another habit, perhaps the beginning of your breakfast or something, but recognizing that that's a habit and being fairly habitual, you don't have to be obsessively precise about the timing, but that regular sequencing of things is going to lead not just to dopamine release as it relates to reward and motivation and feeling good, but it actually becomes the way in which we carve up our entire experience of our day. This is almost a circular argument. You could say, well, of course, I do one thing, then I do the next, then I do the next, and that's how I perceive my day. That's my day. It's my list. It's my to-do list, et cetera. What I'm saying is that on the basis of this study, I should mention the first author, his last name is Antony, his Antony at all, it was published in 2020, the study on basketball viewing. What it points to is that by engaging in specific habits that we know we can perform well, we are actually setting the frame rate on our day. I think there will soon come a time where human beings are not just thinking of, okay, my morning routine and my afternoon routine. I think that can be useful, and in fact, I used or mentioned a structure of that sort earlier in the episode, but rather thinking about what's actually going on at the level of our biology, which is that dopamine is marking time. Habits are a very clear way in which we can invoke dopamine release and therefore provide time markers. What this means is that, for instance, during your morning, you might insert habit one and habit two at, say, I don't know, 8 a.m. and 10 a.m. and in doing that, that marks an epoch, a little batch of time in your morning routine that's distinct from the second half of your morning. In other words, habits serve as flankers or markers for the passage of your day. Now if that seems kind of hyper neurotic or why would I want to structure my life like that, I would say that many people would do well to structure their life like that and to utilize habits, not just for sake of what you do during the habit, but because of the fact that the habits serve as a marker because of the way they can evoke dopamine release. In doing that, you are able to segment your day into a bunch of smaller, if you want them to be smaller, or larger functional units. If anyone wants to experiment with this, the Hubertman Lab podcast puts out a newsletter called the Neural Network newsletter. You can sign up for it at HubertmanLab.com. We put it out each month. You can see the previous newsletters. There's zero cost. We have our privacy statement there. We don't share your email or anything. There, you'll find that 12 steps to improving sleep was the first one. There's another. The second newsletter was all about neuroplasticity and using scientific literature to improve learning and teaching. In the next newsletter, I intend to include an example protocol of how one could use habits and the relationship between habits and dopamine, dopamine and time perception to structure your day according to performance of particular types of tasks. May we cover a lot about time perception? We certainly didn't cover everything about time perception, but we covered things like in training, the role of dopamine, habits and various routines that can adjust your sense of time for sake of particular goals. If you're interested in learning more about time perception, I'd like to point you to a really excellent book called Your Brain is a Time Machine, The Neuroscience and Physics of Time. The book was written by Professor Dr. Dean Bonemanno, who's a professor at UCLA and a world expert in the neuroscience and physics of time. I do hope to get Dean on the podcast in the not too distant future. If you're learning from and or enjoying this podcast, please subscribe to our podcast channel on YouTube. It's simply Huberman Lab on YouTube. And there you can also leave us suggestions for future guests and topics and questions about the podcast episodes in the comment section on YouTube. In addition, please subscribe to our podcast on Apple and or Spotify. And on Apple, you have the opportunity to leave us up to a five star review. You can also follow us on Instagram. On Instagram, I do short neuroscience tutorials and tools and protocols, I cover recent papers. Many of which are not included on the podcast. We also have a Patreon. It's patreon.com slash Andrew Huberman. And there you can support the podcast at any level that you like. Not so much today, but on many previous episodes of the Huberman Lab podcast, we discuss supplements. And while supplements aren't necessary for everybody, many people drive great benefit from supplements for sleep, focus, and so forth. One issue with supplements, however, is that what's listed on the bottle of various supplements isn't always what's included in the bottle and the quality of ingredients varies tremendously across different supplement manufacturers. For that reason, we've partnered with Thor and that's THOR and E because Thor and supplements have the highest levels of stringency of any supplement company out there that we are aware of. Look with all the major sports teams, they work with the Mayo Clinic and so we're delighted that we partnered with them. If you'd like to see the supplements that I take, you can go to Thor and that's THOR any.com slash the letter U slash Huberman to see the supplements that I take and you can get 20% off any of those supplements. If you enter the Thor and site through that portal, you can also get 20% off any of the supplements that Thor makes. Thank you for your time and attention today and last, but certainly not least, thank you for your interest in science.