Episode 10: Conversation with Jeff Hawkins – On the Thalamus

Jeff:	00:00	One of the things we knew is that sequences in the brain have to be able to do is you have to be able to speed them up, slow them down.
Matt:	00:04	Right. Yeah.
Jeff:	00:05	Like I can play a melody back faster. I can recognize it faster. I can speak faster and slower. So there's all these -
Matt:	00:09	And it's not different patterns. It's the same pattern.
Jeff:	00:11	Yeah. It's the same pattern. But you can speed up and slow it down and so, there had to be a mechanism for that in the brain and if you think about it, that mechanism has to apply not to one column in the cortex, it would apply to like all the columns that are doing, that are doing speech, something like that.
		Music playing
Christy:	00:35	You're listening to Numenta On Intelligence, our podcast series on how intelligence works in the brain and how to implement it in non-biological systems. In this episode, we're going to take you back to where the podcast started – a conversation with our co-founder Jeff Hawkins. In fact, for the next few episodes, we're going to try something a little different than the previous few episodes, which featured Interviews with Neuroscientists. Matt Taylor, our Open Source Community manager, will be bringing you conversations with Jeff Hawkins, or Subutai

		Ahmad, our VP of Research, on a variety of topics. These could include anything from Jeff's latest research developments that haven't yet been documented, to Subutai's updates on applying our theories to today's machine learning systems. These will be casual conversations, the kind that happen every day here at Numenta, and we want to share them with you, our listeners. Some of them may get pretty technical, but we'll provide links to resources for further reading. I hope you enjoy these conversation from Numenta On Intelligence.
Matt:	01:34	So I'm here with Jeff Hawkins in his office. It's early in the morning here at Numenta. There's just me and you and we're going to talk about some speculative thoughts and thinking you have about the thalamus, right?
Jeff:	01:45	Yeah. Yeah. So, uh, we chosen, I've chosen, uh, to talk about the Thalamus now. I'll tell you what it is and why we think it's important. And then some new ideas we have about what it might be doing.
Matt:	01:57	I think people will be interested cause we, we voted, we usually just talk about neocortex. So it's a little refreshing to go to somewhere else in the brain.
Jeff:	02:04	Yeah. So let's just paint a picture in your mind. You know, the neocortex is, is like a big sheet, like a big napkin wrinkled up on top of your brain. And it's only a couple of millimeters thick. The thalamus, it's right in the center of the brain and it's two parts, like everything in the brain. And there's like maybe like the shape of two eggs, two small eggs.
Matt:	02:22	Right. One on either end, either hemisphere. Right?
Jeff:	02:24	So we, you know, that's everything in the brain has got two parts. We don't usually focus on that, but they're doing the same thing, just divided in half. So the thalamus is right in the middle and um, it has a very, uh, unique relationship to the neocortex. In fact, myself and some other people studying the thalamus really don't think you could separate them. Um, and the reason is, is that when information goes to the neocortex, from your eyes, your skin or your, or your ears, it always goes through the thalamus, always.
Matt:	02:53	Sensory information...
Jeff:	02:53	All sensory information, pretty much, pretty much almost any sensory information. And so the object nerve, it doesn't go from

		the back of the retina, it doesn't go straight to the cortex. It goes to the thalamus and the thalamus then goes to the cortex.
Matt:	03:05	Right.
Jeff:	03:06	And when two regions in the neocortex project to each other, you know, region A and region B or v1, v2, there's they primarily do that through the thalamus again. So v1 projects to the thalamus and then the thalamus predicts to v2 that there are direct connections between these cortical regions, but there's always one that goes through the thalamus. And since all information goes through the thalamus, it used to be thought that the thalamus is like the gateway to the cortex. Like when you get through this gateway, you're in. But now it's believed that everything that goes between cortical region, the cortical region goes through the Thalamus. And that way you could think of it as a part of the neocortex. I kind of think of it like an extra layer of cells or extra set of tissue that has been, that's been consolidated down the center of the brain. But it's almost, it's so intimately connected with the neocortex. You can't really separate them out.
Matt:	03:58	But it is an older part of the brain, right?
Jeff:	04:01	Ah, I don't know that's true actually, Matt. I, you know, it's in the sense that it's not neocortex. We often tend to think about everything that's not the neocortex is the older part of the brain. I don't know if the thalamus existed prior to the neocortex. I don't know that. Yeah. So, um, it probably did in some form, but really I think we, if you really want to understand how the neocortex works, ultimately you have to understand how the, what the thalamus is doing.
Matt:	04:25	There are no mammals that we can find that just have a thalamus and no neocortex.
Jeff:	04:29	No mammals, all mammals have a neocortex of the question is, or the non mammals that have a thalamus that don't have an neocortex. I don't know the answer that one, but we can, we can pretty much say right now the neocortex is intimate and required, and the thalamus, is required to have a neocortex. So you can't really separate the two out.
Matt:	04:48	Well definitely the projections show that
Jeff:	04:50	That's right. The projections show that, physically it's separated. But the projections are very intimate and um, and so we've

always known that any theory of neocortex is going to have to explain what the thalamus is doing. Um, and the thalamus itself is not super complicated, but it's not super simple either. And I'm going to break it into two broad categories. There's one broad category we've just been talking about, which are called relay cells

Matt:	[05:16]()	Relay cells.
Jeff:	[05:17]()	Yeah, so like an axon comes from your eyeball and
Matt:	[05:20]()	Oh it's synapses in the thalamus...
Jeff:	[05:22]()	It makes a connection to one of these relay cells in the thalamus and the relay cells in the thalamus goes to the neocortex and it literally looks like one to one.
Matt:	[05:30]()	Wow. So just one, one stop and then
Jeff:	[05:32]()	That's right and not only one stop. It's, there's very little con-, there's no convergence in the thalamus. It's like it's literally like you took a long wire and you cut it and cut it in half and then connect it back together.
Matt:	[05:44]()	So why do it?
Jeff:	[05:44]()	That's right. Right. That's a good question. So the call of the relay is a little bit misleading because we know it must be, there's no reason you're not going to have this to do nothing. Right. But that's kind of what it looks like. They can say, this will show in many situations, it's one to one correspondence. A spike comes in and spike comes out and there's a, the topology of the arrangement of the cells in the retina are preserved in the Thalamus and they project to the cortex and they're preserved in the cortex. So, one thing is why are there relay cells? The second thing, there's a whole bunch of other cells and by the way it was a relay cells, a group of relay cells that go between the retina and V1 - that's called LGN lateral geniculate nucleus. That's just a bunch of cells in the thalamus and the separate ones that go between all the other regions. So these are dedicated cells for these units.
Matt:	[06:26]()	Right. They're localized to
Jeff:	[06:29]()	to whatever that projection is. There's another set of cells in the thalamus which are much more diffuse. They project to the cortex and they project very diffusely. So these cells, uh, they go

		by different names. I prefer the one that sometimes they're called matrix cells. I'm not referring to the movie, but referring to the, uh, the fact that they're sort of interstitial to these other, they're sort of in the matrix of the thalamus.
Matt:	06:53	When you say diffuse, just to define that term and the connection is diffuse that means it’s not like a direct...
Jeff:	06:58	Yeah. So let's say a relay cell from the thalamus representing the eye goes to two v1 and it only goes a very small part of v1. It connects to a few columns and that's it. But these, a diffuse one would go to like all of v1. It just, it goes up in the cortex and it just spreads like a big, you know, bearing tree or something like that.
Matt:	07:21	It distributes it across the whole thing
Jeff:	07:21	So it's not, it can't be sending something very specific because it goes everywhere. Now the, the, the clever thing about these relays, these matrix cells, they, um, they, they look like, uh, you know, they'll, they'll be a bunch of them and that bunch will project to like all of these individual regions and there's another bunch that projects to all the different auditory regions. So that's a second type of cell. And then there's a third thing that goes on in the thalamus, which is the thalamus sets up these rhythms or cycles, like a frequency between the cortex and the thalamus called gamma frequency. So what the hell is going on here?
Matt:	07:59	This is an oscillation, right?
Jeff:	08:02	It's oscillation I'm sorry, I should use that word: oscillation. So, um, we've been wondering about all these things and also as we studied the Neocortex, we have certain functional things we need to get done. We know, oh, we need to learn sequences, we have to make predictions, we have to do motor behavior and so on, whatever. And we know that some of that's going to be going on in the thalamus. So we have like, but we don't know which part. So we said, okay, we've got these functional and requirements, we're trying to match them to the neuroscience. We've got this crazy thing called the thalamus, which has, you know, unknown properties, unknown functions, and, but we know it's going to be important. And by the way, you know, if you, if you don't have a thalamus, your vegetable basically, literally you're just a vegetable. So it's an essential organ. Yeah. Um, and um, and so we've been struggling for a long time to figure out what to do with these things. Now, I had a theory for one of these components a long time ago and I still stick to it.

The matrix cells. And if, if you're long time Numenta follower you might know that I brought this up in both on the forum and I've talked about in various places, um, I've been talking about this for many years now, that I had, when we came up with the sequence memory algorithm or even before that and before we figured it out, one of the things we knew, that sequences in the brain have to be able to do is you have to be able to speed them up and slow them down, right? Like I could play melody back faster, I could recognize it faster. I could speak faster and slower. So there's all these

Matt:	09:22	Yeah, and it's not different patterns. It's the same pattern.
Jeff:	09:24	It's the same time, but you can speed up or slow it down. And so, there had to be a mechanism for that in the brain and if you think about it, that mechanism has to apply not to one column in the cortex. It would apply to like all the columns that are doing, that are doing speech, something like that. So you would want a broad, timing signal and, and so the system would have to have some way of sort of setting a time or a time rate for a large area of the cortex. And there aren't too many places I could do this, right? So the matrix cells, um, uh, were very suggestive, their anatomy.
Matt:	10:02	Because they're diffuse.
Jeff:	10:03	They're diffuse and because they're not diffuse everywhere, it's not like it was over the whole neocortex. It'd be over, like auditory, visual or tactile would be separate sets of matrix cells. There are cells that go over the entire cortex that might be for really seeing a neuro modulators
Matt:	10:19	From the thalamus?
Jeff:	10:20	No, from other places. You know, like if you were feeling certain emotions, well that can be everywhere, right? But, but this was very specific it, but it's broad, but it's also specific to modality and also what happens, is it all parts of the neocortex project to the thalamus. These are not, they will project to the Thalamus and then there's thalamus projects back. So it's as if all the parts of the cortex could say, I need to tell you how fast to go or slow to go and everyone, we all have to go at the same speed. So I have speculated numerous over, over probably 15 years or 20 years that perhaps these matrix cells are involved in timing and, and every time I go to a conference and I speak to someone who knows something about the thalamus and the matrix cells and not that many people who do this, I run this idea by them. And so far I've been encouraged that this is the people have

said, yeah, that's a reasonable hypothesis. Or, here's a piece of data which supports it. Uh, for example, on certain animals, every time they start a movement, there's a pulse of activity in these matrix cells. So that would be like starting, the way I think it works this timing works, is that you, you start like a clock every time you have a note in the melody and you can say, okay, from this note, how long do I have to wait till the next one? And then I started the next one. Now the next one and things like that. So there's some indications that's right. Um, I think you're going to talk to Subutai later about some theories we have about the relay cells.

Matt: 11:42 I will. And that'll probably be the next podcast after this one, so I will talk to him about that.

Jeff: 11:47 We have, we are now developing a theory of what the relay cells are doing, so now we've had two set of theories. One is like what the relay cells are doing as sort of a remapping of these, of these relay cells. And we have a theory about what the matrix cells are doing, which is timing. These are speculative, but we, there's some reasons to believe that might be true. And now I'm going to talk to you about a third one. And this has to do again with sort of timing, but it has to do with those oscillations.

Matt: 12:16 Okay. Okay. The gamma frequency oscillations.

Jeff: 12:19 Yeah. Right. Now we're going to dig a little bit here. If you've been following our work, you know that we think there are grid cells or grid cell like cells in the neocortex, everywhere. And they are, this is like a huge discovery I think. And it's like, to explain how the cortex models the world, and basically creates reference frames for everything. And grid cells of course exist in an old part of the brain. That's where they were first discovered in the, in the entorhinal cortex. And that's for learning maps of the world. Like when you're walking around like where am I in this office? But then we think the grid cells in the cortex are being used to map things like my coffee cup and you know, and spaces around my body and things like that. So that's a big theory. We published papers on this and um, now we propose that there are these cells throughout everywhere in the neocortex, every cortical column there are grid cells, cortical grid cells. How do grid cells work? Well, that's still a little bit of a mystery. We know a lot. We as in the broader general neuroscience community knows a lot about uh, how they behave and how they make maps of the world and so on. There's a tremendous amount of literature on, on grid cells, but the exact details of how they do what they do is still uncertain. And one of the leading theories is that grid cells work on oscillations. So, um, if I want to move in the world and the grid cells are representing my position. So what that means is a bunch of cells and some of them active. And as long as I don't move those cell, say active for minutes, they're saying like right now I can close my eyes and say, Oh, I know in my office I know where am I and where I am in my office. And if I slide my, you know, my chair to the right, now I'm, I'm in a different place, right? So those are grid cells. And um, how do they know to change their activity when I move? Well one of the leading theories is that there's an oscillation and the grid cells, and um, if you speed the oscillation up, it's like movement. It moves, it moves a bump of activity of cells. So there's an oscillation going on. And when you change, there's two actually oscillations. And when you change the relative frequency, it is equivalent to moving. So when you move, this theory says that when you move, how do the grid cells change the activity in this very clever way they do it? The way they do it is they have these two oscillations and they speed one up and slow it down. It's like a relative frequency. It's like it's, if you know music, it's like your two notes, two notes are in tune. And then one gets a little flat, one gets a little sharp and you hear this beating frequency.

Matt:	14:42	Right. But that just gives you an up or a down.
Jeff:	14:45	Yeah. But it's more complicated than that. There's also an orientation and it tells you which way you're going. But let's not try to understand this theory about grid cells because it's really complicated and it's, it's hard to describe. But anyway, there's a general, there's a lot of clues that say grid cells are dependent on oscillating frequencies, and that the change in those frequencies indicates you're moving. The change in two frequencies, indicates you're moving, and it can tell you which direction you're moving. So this is an ongoing area of research in the entorhinal cortex. All right? Now we're going back now to grid cells in the neocortex. Okay. Um, and what if they work on the same principles? They work on the same principles, the oscillations. Well, there's an oscillation frequency set up between the thalamus and, um, then the neocortex, it's what they call gamma frequencies and no one knows what they're for. They seem to be related to attention. So when you attend to something like, Oh, I'm not just looking at you and now I'm looking at your nose, or I'm looking at your ear, you know, zooming in on something. And the thalamus has long been implicated and attention and the other, and then what you're going to talk to Subutai about is also about attention.
Matt:	15:55	It seems to be in a good location.

Jeff:	15:57	It is a good location. It's sorta like if there was somebody in control of like, you know, where are you going to look now? It would be the thalamus. Okay. So, um, so, uh, one of the things we, I was, I was going through some of our cortical theories recently and, well, you know, we talked about like, imagine we talked about the coffee cup and we talked about touching the coffee cup. Yes. And uh, that's what we described in our paper last December. And now what if I gave you a coffee cup that was smaller? A lot smaller half the size. It's just a little child's coffee cup, tea set.
Matt:	16:33	Shot Glass.
Jeff:	16:34	Well, let's make it a coffee cup still. Okay. So I want it to be the same. Maybe shot glass size.
Matt:	16:40	Shot glass size.
Jeff:	16:40	Okay. Yes. We don't want little kids drinking shots. But imagine it's the same coffee cup, but it's just shrunk down. Honey, I shrunk the coffee cup and you'd look at that. You'd see it's a Numenta coffee cup and you could, you could pick it up and use it.
Matt:	16:55	I could.
Jeff:	16:56	Right, and you could make predictions about it. Now, that's a different object, but you see it as the same object, but now think about it as you manipulate that object as you, as you grab the handle or move the finger to the other side, you don't have to move your fingers much. Right? If I want to make - everything is like shrunk down, all my movements would be shrunk down. Even when I'm looking at it, if I'm moving my eyes to look for different parts of the coffee cup, I move my eyes less because they're going - it's half as big. I have to move half as much. If I want to move my finger from the lip of the coffee cup to the handle, I have to move it half as much. Yet, I don't have a problem doing that. It's like I have a model of the coffee cup and I bottle it says, Hey, I know what this coffee cup is, but today I've shrunken the coffee cup and everything has to be scaled.
Matt:	17:40	Yeah. Yeah.
Jeff:	17:41	Okay. How do you do that? I mean the way we think about grid cells, we don't really think that's possible. So, um, so the idea is the following. This is the idea I had. I said what if part of the

		attention, part of what the thalamus does is establishes these frequencies between the cortex and the thalamus, and what if it could change those frequencies based on scale?
Matt:	[18:03]	Right.
Jeff:	[18:05]	So it's scaling movements. It's scaling space.
Matt:	[18:08]	So it's scaling objects, too.
Jeff:	[18:10]	Yes. So, so yes. So this is, so the idea I had before is that thalamus matrix cells would be scaling time and in this case they'd be scaling sort of space. Like, like how far, if I move my finger as I typically do from the coffee cup handle to the lid - Today, I want to move it, but I only want it to go half as far because everything is shrunk.
Matt:	[18:34]	That's a lightbulb. That makes sense to me because movement is space. That's how we learn space is through movement.
Jeff:	[18:41]	Yes. Well the whole, exactly. So everything, the whole theory that we've got here is that the Cortex is this, you know, basically modeling space using grid cells and place cells and so on, and you learn movements through those spaces.
Matt:	[18:53]	Exactly.
Jeff:	[18:53]	Um, and in fact, um, um, I just wrote the chapter in my new book about this when I was talking about how moving through spaces, that's what you do when you think. You know, when you're actually moving through a space. Yeah. I think you and I may have talked about that once.
Matt:	[19:09]	We have, yeah. It's a great - Absolutely. That's the way I think.
Jeff:	[19:13]	So anyway, so now this, this is the idea. So now that's as far as I've gone with the idea. I have a couple of papers sitting in front of me that, um, that we got from a colleague at MIT who studies the thalamus about gamma frequencies.
Matt:	[19:27]	Do you want to mention them?
Jeff:	[19:28]	No, I haven't even read them yet. I don't want to go there yet. This is very speculative, this whole thing. You know I wouldn't be surprised if six months I said, you know Matt, that was a great idea, but it was wrong. Yeah. So, um, but the more I've been thinking about it, the more I think it's probably right or in

some sense right that uh, we, there was a functional need for scaling. I've sort of identified that. Somehow our models of the world have to be able to, you'd have to build a scale them under different situation. You have to be able to deform them. Part of that is, is the movement you use to interact with those things. And so you have to scale your movements and the size of things and the movements are all based on grid cells and grid cells are based on oscillations. And so if you can change the oscillating frequencies, you would basically in one fell swoop change the scale of everything. And now you have this thing in the middle of the brain, the thalamus, which makes these projections, sets up these oscillations between different parts of the - broadly. These were not, these were again, broad oscillations between visual system, between the auditory system and so on. And therefore you have a, a system, a set of neural tissue, the thalamus, which is in a great position to change oscillations, which would change the scale of grid cells throughout that whole area. So now that I can just very quickly scale my thinking about any particular object in the same way I could scale my time in the melody. So, so it could be like, oh, right, what's the thalamus doing? Well the thalamus might be doing three things that we've identified so far. One is scaling time, speed things up and slow them down at time. Like a melody or like my speech, I could talk slower. It might be easier if I talk slower. I'm saying the same words. I can talk really fast, too and I could scale, um, uh, the, um, my movement. I'll give you another example of scaling movements. Like if you write, uh, with a pen. Here, I see you're writing something with a pen and, and you're signing your name or something like that. Well, um, I can sign my name bigger. I can just make more grandiose movements and I get the same signature.

Matt: 21:36 Yeah, yeah.

Jeff: 21:36 Um, it's like the same motor command being played back, but I'm just paying it back with more movement, more scale. So we have these three things going on. We think, we think that the matrix cells might be a modifier basically scaling time. Uh, we have these oscillations that are established between the thalamus and the neocortex could be scaling space and movements in those spaces. It's really the same thing. And then, um, Subutai's going to talk about later that the relays tells we think are a way of sort of routing information and uh, it might also be related to scaling. Um, but uh, I don't know what he's going to say about that.

Matt:	22:15	This is fascinating because it really connects time and space. Like right there in the thalamus. It connects time and space through movement.
Jeff:	22:25	I know you like time and space.
Matt:	22:26	It's just fascinating.
Jeff:	22:26	I know you love time and space.
Matt:	22:27	I love time and space!
Jeff:	22:28	I know you do, Matt. And it's great. I do too. But I know you're really fascinated, but it's, I never thought about that as like, yeah, it's a, you know, you can think of the thalamus as the space time coordinator, you know, it's like, or space, space, time warping system.
Matt:	22:41	Well, there's a lot. Yeah, exactly.
Jeff:	22:44	It's a time warp.
Matt:	22:45	I've read a lot of people think that if we're experiencing, you know, I always, I hate to use this term, but a qualia, a sensation, like the sense of now being present, that it's probably in the thalamus where that sort of originates.
Jeff:	22:57	Well, I wouldn't go there, but you might want to go to there. I think. I think equalia has a different meaning than you just said that, but it's a very debated term. So we can leave that for a future.
Matt:	23:06	Let's leave that for a future podcast. That sounds good.
Jeff:	23:08	I don't know if it's true about that. I mean, I think that the risk of something like that we all, we, people tend to want to think about, oh, where am I in the brain. Right. And, um, and that's a very slippery slope because then you end up thinking like, well, there's a little, you know, the old humunculus and there's some little person that I'm looking at.
Matt:	23:26	I never go there.
Jeff:	23:28	I know but if you're trying to isolate where you are...

Matt:	[23:30]	You have to realize without the neocortex, the thalamus wouldn't work. Right. I mean, so you can't say that just what you need.
Jeff:	[23:36]	I just put it this way. I don't think, I'm not sure there's a location for those things you're thinking about. But it is true that the, and the way I think about it now, the thalamus, I actually think the thalamus is part of the neocortex. That's how I think about it. I mean physically it's not. Physically, it's connected massively, but it's not physically the same tissue.
Matt:	[23:54]	We have to understand it to understand the cortical circuit, right?
Jeff:	[23:56]	Yeah. I just, I, it's, it's almost as if, um, there was another layer of cells in the neocortex, but normally that would be spread over this big area. And we wanted this layer cells to be all brought together in one spot so that we can, we can have, we can act on that layer all at once. Where if it was on the bottom of the necortex, there's no, there's no connections that go all over the place, but bringing all those cells into one spot, now I can say, okay, together we're going to speed up. Together, we're going to stretch time. Together we're gonna stretch -
Matt:	[24:26]	Space. Same thing.
Jeff:	[24:26]	Yeah. And so that's just a metaphor for the way to think about it.
Matt:	[24:32]	So like time warping is similar to space warping in that aspect.
Jeff:	[24:35]	It's almost, yeah. You know, and of course we know time and space are the same really, some might say so. So yeah. Um, but here I think they, if these theories are correct and there are separate cells that do the time warping and the space warping and, and um, and then there's the relay cells. So that's, um, I think, you know, one of my, I think I almost 40 years I've been bothered by the thalamus because it's one of the first things I, you know, if you start studying the anatomy of the brain, you realize that it's an, it's a structure you can't ignore. And it's been a mystery, uh, what it does, and there have been numerous teams over the years who've written about the thalamus - huge. I have some monstrous books about the pharmacists, thousands, probably thousands of papers, at least hundreds of papers about the thalamus, and yet almost nothing about what it actually does and how it might function. And so there's a lot of speculative theories that suggest it's related to attentional

		mechanisms, but you know, it was very little data on that. So anyway, I feel excited that this is all of a sudden as you, just as you were expressing it for this very recently in the last few months. Um, I mean that it's maybe all coming together. Yeah. I've known about the matrix sales for a long time, but, uh, what the relay cells are doing, which Subutai'll talk to you about and what the oscillations might be doing. These are all speculative, but now all of a sudden there's a sort of a cohesive theory about, yeah, it is a tension, but it's also scaling and it's also, um, uh, scaling space and time and that was necessary and it allows us to take what we know about the world and shrink it and expand and kinda speed up and slow it down to fit the current situation.
Matt:	[26:12]()	Yeah. It's functions we have to be doing somehow.
Jeff:	[26:14]()	Yeah. Yeah. It's just as simple as just listening to someone speak, you know, there's a model of what a word is and some people speak faster and some people speak slower and that model has to be stretched. And so once I started listening to you at a certain rate, then I might be working at that rate for a while and maybe speed up and quickly adjust. You can think of just like a melody, right? If you are listening to a melody, um, you learned it at one tempo and now you're hearing it in a new tempo, very quickly you can catch onto it. Um, but, uh, but if you, if you, if every note has its own tempo, then you've lost the melody because then basically the rhythm is lost.
Matt:	[26:51]()	You can't find the intervals.
Jeff:	[26:52]()	Yeah, that's right. So, so you kind of have to, it has to last for awhile, you know, and then, but you're going to get, as you're going along, if someone wants us to, you know, change the tempo in the middle of the song they can do that. And you go, oh, it's like a surprise. Oh, look at that.
Matt:	[27:06]()	It can be pleasant.
Jeff:	[27:06]()	It is pleasant. And it's the same as changing the key. Key shifts. You can do a temporal shift in the middle of the song. What's that song? A little bit slower now? A little bit slower now. So, yeah. So that's basically, um, uh, the topic that I was going to talk about today.
Matt:	[27:21]()	Well, you mentioned a book you're writing. Did you want to say something else about that?

Jeff:	27:24	Uh, I'm just writing another book. Um, and I want to say too much about it at this point in time. We could do a whole talk. We can do a whole podcast about that.
Matt:	27:32	Maybe later then.
Jeff:	27:33	Uh, yeah, it, it's basically a, it's, it's, it's sort of a follow-on to On intelligence, but with all the stuff we've learned now about how the cortex works, so it's On Intelligence was more of a call to like, we should solve how the brain works, we should solve how the neocortex works. It's going to be important for AI, it's gonna be important for a lot of things. And here's some ideas about how it might work. Now it's like, oh, we figured out a lot of it. And, um, and let me tell you what it is. And let me sort of go into depth about it. And that's half the book. And the other half of the book is implications of, um, what we've learned, the implications for society.
Matt:	28:06	Well, I know a lot of people are looking forward to it, so I'm excited that you're doing it.
Jeff:	28:10	Yeah. Well, it just doesn't remind you that writing a book takes a long time. So it may be, it easily could be a year before this book surfaces, even though I'm working on it every day.
Matt:	28:20	Right. Well, hopefully we can do more of these chats as we go on.
Jeff:	28:24	Yeah. If this works, we'll find out if it works.
Matt:	28:26	We'll find out.
Jeff:	28:27	Um, there's lots of speculative topics like this. This is what we do here every day.
Matt:	28:31	All right, well if you want to hear more about it, then make sure and contact us. Leave a comment on our podcast or email me at matt@numenta.org even. I'd be happy to hear your feedback.
Jeff:	28:41	All right.
Matt:	28:41	Thanks, Jeff.
Jeff:	28:41	That was fun.
Matt:	28:42	This has been a pleasure. Yeah.