THE TRANSMITTER | BRAIN INSPIRED

David Robbe challenges conventional notions of time and memory

Inspired by his own behavioral neuroscience research and the philosophy of Henri Bergson, Robbe makes the case that we don't have clocks in our brains but instead perceive time by way of our interactions with the world.

29 JANUARY 2025 | by PAUL MIDDLEBROOKS

This transcript has been lightly edited for clarity; it may contain errors due to the transcription process.

David Robbe
How do we measure time? We measure time because while we have those things changing in us, there is also regular things outside. Those regular things, they leave traces that we can use to measure time. That's where it's a little bit funny to think that there could be internal representation of time, or internal measurement of time. What would that mean? We don't know what it means, an internal measurement of time, because measurement by definition has to be somehow related to an external, or observable standard. That's why I think people are interested in Bergson now, is because this *durée* is really something that is not in our computer or that is not in AI.

[music]

Paul Middlebrooks
This is "Brain Inspired," powered by *The Transmitter*. When you play hide and seek, as you do on a regular basis, I'm sure, and you count to 10 before shouting, ready or not, here I come, how do you keep track of time while you're counting? Is it a clock in your brain, as many neuroscientists assume and therefore search for in their research, or is it something else? Maybe the rhythm of your vocalization, as you say, 1-1000, 2-1000. Even if you're silently counting, could it be that you're imagining the movements of speaking aloud, and tracking those virtual actions?

My guest today, neuroscientist David Robbe, sorry about my French, David Robbe or Robby. David believes that we don't rely on clocks in our brains, or measure time internally, or really that we measure time at all. Rather, our estimation of time emerges through our interactions with the world around us and/or the world within us as we behave.

David is group leader of the Cortical Basal Ganglia Circuits and Behavior Lab at the Institute of Mediterranean Neurobiology. His perspective on how organisms measure time or duration is the result of his own behavioral experiments with rodents, and by revisiting one of his favorite philosophers, Henri Bergson. Henry Bergson, the Americanized version. In this episode, we discuss how all of this came about, how neuroscientists have long searched for brain activity that measures or keeps track of time in brain regions like the basal ganglia, which is the brain region that David focuses on in his research. How the rodents that he studies behave in surprising ways when he asks them to estimate time intervals or durations, and how Bergson introduced the world to the notion of *durée*, our lived experience and feeling of time.

This conversation is particularly fun for me in that I have a philosophical bent, not a philosopher, but as a scientist, I often struggle and do so aloud on this podcast. I struggle with how philosophy can influence in a practical way my own science, and science more broadly. David's recent past is a good case study in that very phenomenon. Click below for the show notes where I link to the paper in which David really fleshes out everything that we discuss. That paper is called "Lost in Time, Relocating the Perception of Duration Outside the Brain." If you value "Brain Inspired," consider supporting it on Patreon to get full episodes, access the full archive of episodes, join our Discord community, or just express your appreciation.

Thank you to all my patrons and to *The Transmitter* for their support, and their community work in neuroscience at thetransmitter.org. Here's David.

[transition]

Paul Middlebrooks
What's your name for me so I get it right when I do the intro?

David Robbe
In French, I would say David Robbe.

Paul Middlebrooks
Robbe, okay.

David Robbe
Robbe. If you say Robby, it's fine. Many people say Robby, and that's fine, too.

Paul Middlebrooks
Okay. I'm probably going to say Henry Bergson instead of Henri Bergson.

[laughter]

Actually, I'm going to start here. We were just talking offline and we'll come back to it about basal ganglia because that's a lot of what I'm doing these days. That's what you do in, what, historically, your day job, in your real job, perhaps. Although what we're going to talk about maybe is coming a little bit more into that because they're related, essentially.

David Robbe
Oh, yes. Totally. This is where it got me started in the time in. In the time business was all those stories in the mid-90s saying that there were potentially internal clock in the striatum that were providing internal representation of time. That's what got me started. From the beginning, I had a problem with this idea. That's where it started.

Paul Middlebrooks
Oh, from the beginning. All right, let's get to that. First, I want to say because we were talking about what I'm doing, and I'm in Eric Yttri's lab, I reached out to Eric and I was like, "Hey, you know what, anything you want me to ask?" First of all, he said-- by the way, I need to ask you, how's the tennis game, semi-pro? How's your tennis game coming along?

David Robbe
It's going a bit down. I have to admit that those last two years, I've been playing less. I play less, I still do from time to time local competition in Marseille. I need to go back to that more seriously, but I have to admit that I like, I went a little bit down in my tennis. It's still something that I enjoy a lot.

Paul Middlebrooks
Sorry, this is a total aside already. I'm terrible at doing this. Did your sports and tennis in particular, perhaps, did that lead you to interest in behavior and/or timing?

David Robbe
I think it's interesting you're asking that. I think at the end, as a teenager, I was a lot into sports, tennis and football, soccer. I went in neuroscience, and it's interesting how I'm converging more and more back to behavior. I think it has something related to my passion for sport and movement. It's interesting that I started by doing slice electrophysiology, and I went to do a postdoc in György's lab with in vivo, in behavior recording. Now I'm doing less and less physiology, and more and more behavior.

Paul Middlebrooks
Why is that? For me, I've become more interested in behavior. Really, what I'm interested in is, the connection between neuroactivity and behavior. The more I learn, the more I know how little we know about even the neural side of it. Then I guess my framework for thinking about these things has changed, and behavior itself is an open question. Neuroactivity is an open question. Of course, I'm just preaching to the modern neurobehavior choir that you have to study these things. We're embodied, and you have to study them in conjunction.

David Robbe
I think it's a combination of things. It's true that my experience has been that it's really important. Behavior can explain so many things just by itself in the way when you do electrophysiology in vivo. If your behavior changes, your neural activities change. That's the first thing I learned with György Buzsáki. That was really great. I really enjoyed actually watching rats running in a maze, and seeing actually how you could almost anticipate what it was going to do right or wrong just by looking at the way rats were running. I got really into behavior.

Then I read and I had the chance to meet another one of the regular guests from this podcast, John Krakauer, who really also, pushed me, and kept telling me, "Actually, you have to go, you have to be very careful with behavior." Also, some personal experience, how it is easy to actually-- when you do IFS in behaving animal, it's so easy to basically have a sort of bias that is going to make you interpret the data the way you want to interpret them.

I realized a couple of times in my career that I was very close to make mistakes. Then I thought, the key is we need to understand really well what the animal is doing. Otherwise, we can tell basically almost whatever we want, especially when you're recording a place like the striatum in which you have a very heterogeneous type of response. That has been the trajectory on those years, really trying to understand well behavior, also practically, chronic electrophysiology in behaving mice is really, really hard if you want to do it right.

In France, it's tricky. The funding is limited. The PhD duration is short, so it's tricky to have a project that you manage to go through a PhD in which you do good behavior, good electrophys, good data analysis. It's just impossible. I hope to do more electrophysiology soon again, but I ended up doing a lot of behavior also because it's already a lot of work, but you can make a story in like three, four years if you do good behavior, and a bit of perpetuation, I think.

Paul Middlebrooks
I was going to say, be careful because we come in with, I guess, the technical term would be biased, but we have a story about what we're looking for, and by God we're going to find it, or something related to it.

David Robbe
Exactly.

Paul Middlebrooks
Who is I'm going to say, Henri Bergson. You say the name again.

David Robbe
Henri Bergson.

Paul Middlebrooks
There you go. I'm just going to butcher it the whole time. Who is this historical philosopher/scientist/mathematician, and why are you so obsessed with this person and his ideas?

David Robbe
He's not a scientist, he's really a philosopher. I think he was born in 1859 or something like this, and he died in 1941, I think.

Paul Middlebrooks
I think it's '41.

David Robbe
He's a French philosopher that was actually extremely famous at some point, he wrote a couple of important books.

Paul Middlebrooks
He was a celebrity in his day.

David Robbe
He was a celebrity. Right now, he's a lot in the light after being in the shadow for a while. He's been more recently a lot in light. There's a recent biography in English that has been published by Emily Herring.

Paul Middlebrooks
I just want to stop you, because I can never tell these days, especially with the algorithms that feed you, what you have been searching for, and you get in that silo. Is he making a comeback-

David Robbe
I think he is, yes.

Paul Middlebrooks
- in academics, or is it just me that I'm seeing more of it?

David Robbe
He is making a comeback, but is not just like since last year or two years ago. I think it's more like something, let's say, that has started growing, maybe 10, 15 years ago. First, it was more something local, also evidently a lot in France, but now, I think he is becoming bigger. I think you could define him as really a philosopher of the living. He was really about understanding the difference between what's so special about living organism, versus other non-living things, or the movement of non-living things. That was his big things.

He tackled this question at different level, the level of the perception of time, then of memory, and then evolution. His big famous book is *Creative Evolution,* 1907 for which he got the Nobel Prize of literature, which is a book that has-- he's been very misunderstood, Bergson, because he's a philosopher that tends to say, "Well, there is some limits to science." Scientists didn't like so much this idea.

He's famous also for a famous debate with Einstein. He challenged some of the ideas of Darwin, in terms of the mechanism behind evolution. He was a true believer in evolution, but he was not sure about the mechanism that allows species to evolve, and because he had this view that was not mechanistic, he got some strong pushback when all the genetics movement came strong in the middle of the century. He got a little bit pushed aside.

Also, he had a very special way of doing philosophy. He didn't really build the school, so he got quickly forgotten, but the truth is that if you read his book is really deep. I think what is nice is to see how somebody at some moment can be forgotten, and then come back and sound so modern. When you read Bergson, that's really what strike me is how in so many instances, it's like he's just talking about the stuff we're dealing now. That's really cool.

Paul Middlebrooks
Why is that that's always the case? Sometimes I think that an academic's job, it seems, whatever, history, philosophy, science, is just to point out who had that idea beforehand. [chuckles] Like Buzsáki says, there's nothing new under the sun. It's all of these ideas have been well-traversed by sometimes forgotten people.

David Robbe
Yes, it's true. I have debates with some friends, I feel like Bergson did something very new, but it's difficult because he was building. Now that I'm starting to think a little bit more and I get some help from some philosopher friends, I have realized that he himself also was influenced by even lesser known people. It's very interesting to see this dynamic.

Paul Middlebrooks
The other comment that I was going to make is I was recently at a gathering at Carnegie Mellon University in Pitt. For someone who was a mentor of mine and many of us who just recently passed, and I asked the question at our little gathering. The thing is, super sharp guy, very careful science, wasn't concerned with glossy journals, just concerned mostly with just asking the right questions, pursuing it the right way, and he's got a great publication record.

I asked, "What do you think his legacy is going to be?" It's an interesting thing. What I imagine is 40 years from now, people are going to look back on some of these papers and dig them up again, and in the meantime, he might be kind of forgotten. It's hard to tell.

David Robbe
Maybe also the people that he talked to actually, he will probably have affected the life of a significant amount of people that are going to do science in a different way because of working with him. Like Bergson, even he was forgotten, he was still very influential, but just people didn't want to mention his name because he was persona non grata, but he was still very influencing people.

Paul Middlebrooks
From what I understand, too, that he is maybe at least popularly most well-known for losing that famous debate with Einstein, but then a lot of careful historians have looked back, and it's a lot more nuanced. He didn't just lose a debate, they misunderstood each other, they called each other out in their misunderstandings. It's not clear who "won or lost."

David Robbe
I know. Clearly, he was he was perceived as the loser. He was tough not to lose again, Einstein, no? Now I remember, when I was a student, I had the poster of Einstein in my room in the university. I had no clue, and no understanding about the theory of relativity.

Paul Middlebrooks
Of course not. He's just a figure, an idol, right?

David Robbe
There was something so big about him, nobody could really win against this guy. It's true, you're right, a couple of people have done some work. Jimena Canales, I think is the one that wrote this book, *The Philosopher and The*--

Paul Middlebrooks
The Physicist and the Philosopher Scientist, I think that's right.

David Robbe
Yes, exactly, in which she shows that there was actually no real debate. They misunderstood, you said it right. Another French philosopher, I think there's a book that is going to come out soon about it. I think actually, I would side with Bergson in the sense that, you have to read-- He wrote a book--

Paul Middlebrooks
Wait, but you should say what the debate was about, what you're going to side.

David Robbe
The debate was like an implication. The theory of relativity was that maybe there would be some multiple temporality. There was no more this unitary Newtonian time was basically gone. Bergson said, "Your finding is basically about things that move extremely faster, very close to the speed of light, but we can still wonder if in terms of our experience of time, if we should completely challenge this idea that we, more or less all of us, you and me right now, are living on the same tempo." That was the debate.

What's impressive, he wrote a book about it, which was called *Duration and Simultaneity.* If you open the book, the beginning of the book is him actually rewriting the equation of the theory of relativity, and saying that he entirely agreed with the theory. He was a guy that was able to actually redo the math, which me I'm not able. People say it's not that complicated, but he did this effort. He did a huge effort, and actually he called himself really, that he's more Einsteinian than Einstein.

His question was, can we make a conclusion about our experience of time based on a theory that is applied to things that move at the speed of light, or very near the speed of light? That was his question. To the discredit of Einstein, Einstein did not make a lot of efforts. If you would balance the two, if one guy had made a lot of effort to understand the theory, it was more-- but the problem is that Bergson, he's not always easy to understand, so his weakness is that he didn't manage to make himself understood to Einstein, and Einstein was not very patient.

Paul Middlebrooks
He also, Bergson, back in the day, and this is the story that is now becoming overturned, is that, he wasn't good at understanding the science, but he actually was good at understanding the science. Everything that you said.

David Robbe
Oh yes, he was good. He was very good. He was an extremely bright guy. He had like one, lots of prizes in mathematics when he was 18, 19, 20, and his teacher were extremely disappointed that he decided to do philosophy. They were like, "Come on, you should be a bright mathematician, and you're going to end up just like a philosopher." There's a saying like this that goes in the legend of Henri Bergson.

Paul Middlebrooks
Oh, poor philosophy. Why does it have such a bad rap? Because I was going to ask how you got wrapped up in all this, because I have a philosophical bent, and then there's something behind me always saying like, 'oh, you should stick to the science. People, they're all going to make fun of you, but don't waste your breath on philosophy."

David Robbe
Me, I think I always liked philosophy, even if I'm not sure I was really good at it, and I was very interested. Almost everyone that does neuroscience is interested in the relationship between mind and body, and when I was-

Paul Middlebrooks
Which was philosophy for a long time, and still is.

David Robbe
Yes, but I was studying biology, and I was starting to study neuroscience, and I felt like neuroscience was really the key. As a student, I was like, "Neuroscience is explaining all this, it's great." One day I was in a library, and really by chance, I saw a book of Bergson, which is called *Matter and Memory*, and the subtitle of the book is an essay about the relationship between *l'esprit et la matière*, the spirit, and the mind, and the matter, or in the body, something like this. I was like, "Oh, wow, this is exactly what I'm trying to understand with this neuroscience stuff." I took the book, and I started reading, and it was a shock, I didn't understand anything that guy was saying.

He was basically saying, on every topic, the opposite that what I was thinking.

[laughter]

You could see that the guy had thought a lot about it, and he was very confident, and he was like, "It's impossible that the brain is an organ that generates representation," and I was like, "What are you talking about?" It doesn't make any sense to think that the brain stores memory, and I was like, "What? The guy, he's totally nuts." I didn't go through the entire book, but I got one thing at that time, which is in the first chapter of this book, is that perception is a beginning of action. That's the first part of that book, and I found that even if it took me a long time to understand this idea, at the end, I was like, "Yes, it's true, we only perceive things we're going to be able to act on." That's not a bad point.

He had this really, this loop, the fact that we're not information processing machine, but what we see around us is basically already like adapted to our motor system. A perception is basically a question asked to my motor system. I found this idea very nice. The rest of the book, I couldn't deal with it. It was too hard.

Paul Middlebrooks
This is pre-ecological psychology, right? Gibsonian.

David Robbe
Yes, this is pre-ecological psychology, which is something that then got me into ecological psychology later on, and I was like, but how come they never site Bergson? I was very surprised.

Paul Middlebrooks
I was about to ask you that.

David Robbe
Why is that? It's very surprising.

Paul Middlebrooks
There are trails.

David Robbe
Because Bergson was, I think, labelled with this idea of *élan vital*, which came later, he was labelled as some like esoteric romantic guy.

Paul Middlebrooks
What is *élan vital* for the listeners?

David Robbe
The *élan vital* is a sort of metaphor that Bergson brings in his third book, which is *Creative Evolution*, and you really have to understand it as a metaphor. It's the idea that he's trying to think, so he's basically persuaded that living, there's something different between living and non-living matter, and that there should be some kind of original impulse. He's not believing in some like fluid, so he's not a vitalist.

Paul Middlebrooks
That's what it got labeled as, is there's some sort of magic fairy dust.

David Robbe
Exactly, but he's not. He's a scientist. He believes that the body is driven by electricity, chemistry, et cetera. That at the beginning of life, there is some kind of like impulse, impetus, that is like force that is pushing leading to thrive, and survive, and also transform itself, et cetera.

Paul Middlebrooks
Create. Yes, transform itself and create.

David Robbe
Create, and create against matter. That's the big thing, it's a form of creation while matters is like trying to kill you, or oppress you.

Paul Middlebrooks
Yes, going against entropy, despite matter you're able to create.

David Robbe
Exactly. We had this metaphor of *élan vital*, and that got him smashed by scientists. Also, other philosopher, Bertrand Russell, was really against him. That's a bit the story. That got me into Bergson. Then I was reading from time to time article of him, but I never actually, at that moment, I never understood the concept of *durée.*

Paul Middlebrooks
That's what you're onto with this paper that we're going to frame our discussion around. When did you pick up the concept of *durée*? Was it after your neuroscience beginnings?

David Robbe
Yes, that was way after. Actually, what happened is that, we were interested in the lab. There was a lot of those hypotheses saying that they were really time representation in the striatum. Everybody knows also that the striatum is really important in motor control. I had this idea and others too, that probably if the striatum had a role in time estimation, it was because it had a role in motor control.

Paul Middlebrooks
We should say, this idea of there being time represented internally, it's been applied to many parts of the brain. It can be decoded from many parts of the brain. It's been ascribed to-- the assumption is because we're good at timing things, we must have these internal clocks that our brain produces that we can then read out as organisms to do things, right?

David Robbe
Exactly. At the time where I started working on this, the striatum was one of the big like-- there were a striatum and prefrontal cortex, and cerebellum were the three hotspot for time at different timescales. My idea was that actually the role of the striatum in timing was related to movement, and that it's because it changed animal move that animal changed their performance in time estimation tasks. It was actually my first postdoc, we designed this crazy experiment, Pavel Rueda-Roscoe, who's now in Mexico, we designed a task on a treadmill. We knew another thing that everybody knows, but nobody speaks too much, is that if you do a time estimation task in which you request the animal to really respect a time interval, otherwise you will get no reward or a punishment, then animal develop those weird superstitious behavior. This was something that was known.

This was the problem that we had also, is that we know that the striatum responds to movement, to sensory stimuli. The trick is that how do you make an experiment in which you can dissociate time, movement, and sensory response? Knowing that on top of that, the animals are going to tend to develop some motor routine, superstitious behavior. We decided to do a time estimation while rats would be running on a treadmill.

The idea would be to clamp the animal into a state in which he cannot really escape. What we wanted to do is that we wanted to change the speed of the treadmill. Our expectation would be that if the treadmill goes faster, maybe the animal maybe pounce with his toe. Then he would have the impression that time is passing faster, something like this. This was our intuition.

Then we got this very weird behavior. The task was we had a treadmill, and at the front of the treadmill, there was a reward area that was clearly salient. The task was the animal has to go there seven seconds after the trial started and the treadmill start pushing the animal away from this reward area.

Paul Middlebrooks
If the animal still, it starts moving back on the treadmill, but what you guys thought was that it would just keep running right next to the reward port for seven seconds?

David Robbe
Exactly. They didn't do that. All the rats started doing this strategy in which they-- First they struggled, because they would go too early. They would go too early. They would go too early, get beep, a sound, then we are like instead the rat ran for an extra time. They did a lot of error trials, because the impulse of a rat, like us, is if he's thirsty and there's a reward in front of him, he goes there straight. He does that over and over until he gets bored. Then a new trial starts. The treadmill pushes the animal away, and then at the end, the animal bumps into the rear wall, and then runs, and then he gets the reward. We had a time of seven seconds. Seven seconds has elapsed, and he gets the reward. Then the animal understands that to get the reward, they have to go to the back, and then--

Paul Middlebrooks
That's what their superstition understands?

David Robbe
Exactly. We were really disappointed, because this is not what we wanted. We tried a bunch of stuff, and it never worked. We said, this is great, we have a nice stereotype behavior. We can do recording in the striatum, which is supposed to be important in stereotype behavior. We did still a very nice paper on this with Pavel. Then we had the visit of John in the lab, and John told us, "You guys need to understand better this task, what the animal is doing, et cetera," so we did a lot of experiments. We realized that, really, the animals were unable to do this task if they were not allowed to use what we call a motor routine.

Paul Middlebrooks
Did they all develop slightly different routines, or was it--?

David Robbe
In our case, 80% of the rats developed this routine, but I think it's because of the setup. We had some rats that were doing other stuff, but they were still doing some stereotype stuff.

Paul Middlebrooks
Still stereotyped, but it wasn't always just hit the back wall and then go?

David Robbe
This is the easiest one, basically. I think this is why many rats stumble onto this one.

Paul Middlebrooks
Wait, let me just pause here and just say, because this experimental setup is sort of in between the hyper-reduced experimental setup that had become dominant in neuroscience, and that's my PhD work was, fix everything as still as possible. The organism needs to move only its eyes to perform this task. Of course, the animal wasn't completely still. Of course, they were moving their arm, even if their head was fixed or whatever. Your point in the paper, also, is that all of these hyper-reduced experiments, people don't control for these little movement routines that the animal could be undergoing to help time behaviors in these time tasks, for example?

David Robbe
Yes.

Paul Middlebrooks
Yours is in between, that's the hyper-reduced, and now we have these super freely behaving, and I guess yours, those rats were freely behaving on the treadmill.

David Robbe
Yes, it was freely moving, yes.

Paul Middlebrooks
They're still in the behavioral, they're in an apparatus, that they're behaving within that context?

David Robbe
Our idea was to somehow try to clamp this motor activity, and we failed.

Paul Middlebrooks
Clamp it while they're behaving freely?

David Robbe
Exactly. We did a nice purely behavioral study in which we did a bunch of manipulation to see that it was really the routine that the animal had no clue, really, about time. They really managed to do this task by developing a motor sequence, and if you perturb this motor sequence, then the accuracy goes down. We were wondering, and we had the debate, why is this this way? Is there other condition in which the animal could do a time estimation task? Is this just a failure to basically be understood by the animal, et cetera.?

This is where I stumbled, again, by chance on Bergson. Actually, it was just at the beginning of the COVID--

Paul Middlebrooks
Oh, when you're going through your old books and saying, what shall I do now?

David Robbe
No, actually, more luckily, there was a podcast in France about *Matter and Memory*. There is this really cool philosophy podcast that does not exist anymore, called *Les Chemins de la philosophie*, the Road of the Philosophy, and they had a podcast in four episodes, the four chapters of *Matter and Memory*. I'm like, I have time now, I'm going to listen to that.

The first podcast, the speaker is one of the most famous scholar of Bergson in France, **[unintelligible 00:35:10]** his name. He says, "We have to understand that the Matter and Memory in the book is the problem, comes from actually the first book of Bergson we see, which is, *Time and Free Will* in English. In that book, Bergson says that we misunderstand time because instead of living it, we spatialize it.

Then what was very interesting for me is that the conclusion of our papers, a paper that we published in PNI in 2020 was that rats were developing a spatial routine to be proficient into a time estimation task. That was the conclusion that they were spatializing time. I was like, "What? It's exactly what our rats are doing."

Paul Middlebrooks
Wait, you wrote this before you came across the--?

David Robbe
Yes. The 2020 paper was written, I hadn't been back to Bergson. Then I was like, "Oh, I need to read this first book." Then it was really like a deep eureka moment.

Paul Middlebrooks
That is the best when you revisit, although you weren't revisiting in this case, but you were revisiting Bergson, but you weren't revisiting. My point is, when you read something even that you've read before, but you're coming at it from a different framework, all of a sudden it expands, and you have this eureka moment. It's so beautiful.

David Robbe
Yes. It was like, "Wow." He's explaining us exactly why animals do that, and why they actually can't do a time estimation task. I felt very like-[crosstalk]

Paul Middlebrooks
Right, they can

David Robbe
They can't do it internally. Actually, what they're doing is just they're getting rewards. They're not really measuring time. They're just doing what we want us to do, which is-[crosstalk]

Paul Middlebrooks
[crosstalk] Utility comes in that they're actually basing their-[crosstalk]

David Robbe
Yes, that came a little bit later, but also with a bit thanks to Bergson, because he has some idea about time being a cost and actually, there is a huge field in neuroscience about this idea about time being seen as a cost. Yes, this was my moment in which-- it was great because this was the COVID lockdown. I read this book, then I understood better *Matter and Memory*. I read *Matter and Memory*. I basically read like in circle these three main books. Then I decided to write this long piece, and it was great. It was fun.

Paul Middlebrooks
With his concepts, then you were able to reinterpret your own data, your own studies. I don't want to lose the listener, you should talk about what *durée* is in Bergsonian terms. Right?

David Robbe
The idea of *durée* is simply that, when we experience time, when we live, because we have memory, our memory constantly prolongs the past into the present. That's the way that we manage to have a conversation together, is that we are constantly remembering a little bit of the past into the present.

Paul Middlebrooks
Every present moment is inundated with at least some of our past memories?

David Robbe
Exactly.

Paul Middlebrooks
The entirety of our past, but maybe subjectively, some of our memories. Every given moment is created anew, and is unique in that sense.

David Robbe
Exactly. His point is it's a continuous, heterogeneous new thing that is created at every moment, so it's indivisible. You cannot divide it. You can divide it artificially, but the *durée,* the experience- [crosstalk]

Paul Middlebrooks
Time itself is- [crosstalk]

David Robbe
That experience, it doesn't make any sense to divide. The example I like to use is when you grow impatient. Think about whatever occasion in which you grow impatient, it's something that accumulates, but you cannot really tell at which moment you are impatient. It's a process, it grows, and you cannot switch time. To be very impatient, and mad, and ready to yell at somebody, you needed to go through the process of waiting, but you cannot go from mad to super--

Paul Middlebrooks
Some people can. Some very special people seem to be able to. I take your point, but how is that concept then related to externalizing time?

David Robbe
His point is that, this experience, basically, experiencing time, being in time, because you cannot divide it, you cannot measure it directly. Then, how do we measure time? We measure time because while we have those things changing in us, there is also regular things outside, and those regular things, they leave traces that we can use them to measure time.

For instance, the movement of a clock while I'm talking, it's moving, then it arrives there, and then the distance travelled from the moment I started talking or moving to the end, that gives me a proxy from time. Actually, measured time is not about time, it's about space. That is his big discovery, is to say, "Hey, there is two aspect of time. One that is lived in which because of memory, it's a continuous melting pot of the past, of the present, and you cannot be divided. You cannot measure it because one moment it's here, and then after that it's gone." There's no possibility of measurement because measurement is about superposition.

Paul Middlebrooks
In that case, isn't there no time because it's always just present?

David Robbe
It's not exactly just present because you remember.

Paul Middlebrooks
Yes, but that's part of the present, right? It hinges on your present subject-

David Robbe
It's growing in you. Otherwise, you wouldn't become impatient. Something has to stay and accumulate for you to become impatient.

Paul Middlebrooks
It's ever-changing. That's how you measure it, is because it's ever-changing in the present moment.

David Robbe
That it's ever-changing with this communication of the past into the present, and that's really the key. Some people mistake the philosophy, the *durée* of Bergson with the say of Heraclitus that says, everything is changing, you never step twice. That's not the same idea.

Paul Middlebrooks
I'll say Heraclitus for our American fans.

David Robbe
Sorry.

Paul Middlebrooks
That's okay. Just want to make sure.

David Robbe
Exactly. That's not the same idea because for him, for Heraclitus, it's continuous change all the time, but there is no memory effect. That's the key thing of Bergson. He's saying that each new moment is totally new. It's not just different, it cannot repeat. In the sense of Heraclitus is more of a eternalist philosophy. It's changing all the time, but it's the same in the change. While for Bergson, it's actually new, it's really new.

Right now we're different. You can't measure it. It's not something like this. You cannot measure it directly.

Paul Middlebrooks
I love this idea because as a scientist, and you've become a reductionist, and then you view everything in those terms, and then you think, "How does anything move? How is anything new?" I love this account of everything is always new, and it is an act of creation, which is a wonderful thing.

David Robbe
The point is that to be able to measure, you need to somehow relate to something external that you can leave fixed traces. That's why the change of light is a good cue for knowing how much time is passing, et cetera. This is why we keep saying all the time, "Oh, this movie was too long," or, "The time passed too quickly."

Paul Middlebrooks
It's spatialized time.

David Robbe
We have no way to actually not measure time in reference to space and movement. That's where it's a little bit funny to think that there could be internal representation of time. Internal measurement of time, what would that mean? We don't know what it means, an internal measurement of time because measurement by definition has to be somehow related to an external, or observable standard.

Paul Middlebrooks
It's a relational relation. [chuckles] You have to measure it. In other words, you have to read it out. People like Dean Buonomano, who was on my podcast a long time ago, and lots of other people just continue to try to find this internal representation of time, be it in the recurrent dynamics of recurrent neural networks, be it in the timing of nested oscillations in the brain where you could read these things out, either accumulation models, all sorts of ways that you could represent time internally.

David Robbe
You can use them to represent time for you. You plot your firing rate changes, and then gives you to you a representation of time because it's a change. It doesn't mean that the animal use it as a representation of time. This was the point in which I agree with actually György Buzsáki had a very similar idea, that it's not because you have a change in your brain, and then you relate it to something that it means that this is a correlate of this thing. It doesn't have to be that way.

Paul Middlebrooks
Since you mentioned György, and you did a postdoc with him, in your paper, I'll just go ahead and ask this now, even though it's a bit of an aside. There's just one or two lines, and they almost seem like extra thrown in where you say, "Well, this is where Buzsáki got it wrong in his inside out view," and this comes at the end of the paper, right? You've all built up all these ideas, and then it's like you're reflecting a little bit. At the time, I didn't know that you had been a postdoc in his lab when I read the paper.

David Robbe
First I want to say that I'm a huge fan of György.

Paul Middlebrooks
Sure.

David Robbe
It was the best time of my life in his lab. He's fantastic. What a fantastic person, human person, and a fantastic scientist. György has his view, very like a internal model.

Paul Middlebrooks
I'll summarize György's view real quick, the inside out approach. The very shortened version is that, he thinks that we've gotten it wrong, we have these really old psychological terms that were invented by psychologists to describe what we were doing. Then we've been looking for neural activity, and processes to map onto those terms and concepts. What he proposes is instead, let's look at the way the brain is actually processing signals, information, the past, the capacities, the structures, et cetera, what the brain is doing, and then use those to build up our psychological

constructs. Throw away the old psychological terms, maybe come up with new ones, or understand them in a different way. That's his "inside out approach," saying that we haven't gotten very far with this outside in approach. I just wanted to make sure we explained what his view was.

David Robbe
That's exactly right, and that's exactly the point in which I like disagree with him. I think it's a false problem to say that the psychological terms are old fashioned, and they don't reflect anything right. Again, if you think about an experience of time, I'll take an analogy to try to convey what I want to say. You went to a movie, you had a great time, you were very entertained. Then, the movie finishes, you realize it lasted two hours and a half, and you say, you didn't see the time passing. When you say you didn't see time passing, it's a very approximate description of what you experienced during the movie. It's good for communication purpose. That allows to convey to your friend, wife, partner, that you enjoyed the movie, and that you didn't see time passing. That's it. It's an approximate label for the entire experience.

Paul Middlebrooks
It's a condensed abstract version of what you went through.

David Robbe
Exactly, but you already lost a lot of information there. There is no way you're going to be able to recreate all this information, even if you're recording all your brain activity during the entire movie.

Paul Middlebrooks
Right. You wouldn't say at this, at this point, it was fanning in and fanning out from my retina through the thalamus. Then it really fanned in. Then there was a lot of gain from the basal ganglia. You wouldn't go through all the brain activity.

David Robbe
The point I'm just making is that, yes, we're never going to be able to explain some aspect of our psychology because we're always limited by, let's say, language, and that's fine. That language is inaccurate because that's not the purpose. The purpose is not it to be perfectly accurate. It allows just to communicate enough.

I think it's a lost because to try to find the perfect description of whatever brain cognitive stuff is going on in your brain with neuronal activity. I think at the end, this was the point because you invited the John to ask question. No?

Paul Middlebrooks
I think John asked the question. It was György and David Poeppel on the--

David Robbe
I think maybe David asked that question, or John, or whatever. One of them asked György, "You're still going to need, at some point, a word to describe the thing that relates to this neuronal activity that you found was important. There's still going to be a gap, so you can't just bank everything on the inside. There's always going to be an inside and an outside. I think [crosstalk] that's the way I understood that it--

Paul Middlebrooks
I get behind that, but I've become a radical pluralist man. It's not about the word itself, it's about refining the concepts that the word is attached to and stands in for. György's point, I don't want to speak for him, is that the folk psychological terms that we use are attached. The way we understand them might be highly inaccurate relative to the actual processes going on. It's not about whether you have a word or don't, it's just about refining the concepts, but I don't know if he would say that at all.

David Robbe
My point would be that whatever concept will come out will always be somehow insufficient for two reason, because this is just something that is fixed. It's going to be a fixed label, and our brain state is constantly changing all the time. There will always be a distance between the two and that's fine. It doesn't mean that they're not related. It doesn't mean that science doesn't do a good job at approximating attention, depression, feeling warm, cold or-

Paul Middlebrooks
Impatient.

David Robbe
-impatient, et cetera. It doesn't mean that science cannot do stuff on that, but there's always going to be a little gap and I think it's a good news.

Paul Middlebrooks
It's weird when-- Neuroscientists do this all the time. I'm sorry, I want to come back to the main topic here, but using a term like-- In decision-making sciences and in neuroeconomics, which you write about and study, let's say you're making a decision, and then you use the term "urgency" but then you define it neuronally, you have an operational definition. Actually, sometimes you don't, so for urgency-- Then you ask, "What would urgency look like in neuronal signals?"

The other way to do it is to say, "Here's a neuronal signal, what concept could we ascribe to that neuronal signal?" Then it's something like what we think of as urgency, so it's coming from the bottom up. I don't want to-- Anyway. [crosstalk]

David Robbe
You could also try to define it behaviorally.

Paul Middlebrooks
Sure.

David Robbe
Then manipulate urgency, even if it's not a perfect term. Once you decide what is urgency, which I think you can operationalize the definition, manipulate the parameters, and see if it correlates with something more or less in the brain.

Paul Middlebrooks
As long as you attach it with that operational definition, because what happens is that then just the term urgency starts getting used to not be attached to the operational definition, but with our common conception of urgency, and all the subjective baggage that comes with it.

David Robbe
Yes. The issue would also be that you would reduce urgency to the neuronal activity, which there is no reason to do that because if your definition of urgency is about a certain type of behavioral attitude in certain circumstances, then it's really-- urgency is these all complex things. It doesn't have to be--

Paul Middlebrooks
The neurons aren't feeling urgency.

David Robbe
Exactly. I think the big issue comes with when you want to really localize thing in the brain, like if you want to say procedural memory is in the striatum, whatever other form of emotional memory is in the amygdala, then you get in all kind of trouble. I think it's also a bit in reaction to this reductionism that theory also-- I'm not sure is right to start from the brain. I think there is no reason to do that. I think we can do both.

Paul Middlebrooks
I think you hit the hammer on the nail with the both. I think it's so healthy to have someone like György and have people like David Poeppel and John Krakauer. Everyone's saying they've got it wrong when everyone's right and it's both, and it's all in some sense. Bring us back to the reason that you felt-- not the reason you felt obliged to, but what you were keying in on when you mentioned Yuri's inside-out view with respect to the conception of durée and the way that you think of time related to brains and bodies and movements.

David Robbe
Why did I bring him in the--

Paul Middlebrooks
Yes, what was it? What is it specifically about that approach? I think you mentioned it earlier, but maybe just restate it [crosstalk].

David Robbe
It's just that basically the point of Bergson is to really realize that our mental state, our life is constantly-- we're beings in becoming. We're constantly transforming ourself. Having some fixed label is great. I'm called David, you're called Paul, and that's very convenient. It's fixed label, also we are constantly changing. I think there is nothing wrong on that. What I was calling into question is that, it's not a big deal that we use fixed label as long as we are aware that they are just labels.

The problem is that if we think that those labels are becoming real things that we can find traces in the brain, then that doesn't make any sense. I don't know if I'm clear. It's like, now if you think attention is one thing, you're going to want to find attention in the brain. That's ridiculous because attention is a dynamical process. It's not going to be a thing that you're going to find in the brain. It's good to name something attention for communication purposes, as we know what we're talking about.

Of course, it's a label. Especially in psychology, there's always going to be a gap between the labels that we use to speak, to communicate about science, and actually the real stuff going on, which is constantly changing. Attention is a dynamical thing.

Paul Middlebrooks
Why are humans, myself very much included, so prone to make that leap and say, "Oh, attention, it's a thing, therefore it's in the brain and I'm going to find attention in the brain." Why does that feel like such a natural way to think? It's embarrassing how easy it is to do that.

David Robbe
I think the case of time is really a nice-- it's very easy to speak about this tendency we have because we have this experience of time and we speak a

lot about it all the time. We say, "Time went by quickly, slowly. A movie is too long. A trip is too short," whatever. We constantly have those fixed label that we need to use on top of our experience that is constantly changing. At the end, we end up confusing the two. We end up basically having the feeling that we can slice, divide what's going on in our brain.

If we take a clock, we see the clock moving and we have the feeling that it divides our life. We get confused. I think at the end, because of language, we get confused, but then we feel things from the inside, and so we said, "Okay, there is something going on inside. Why am I sometimes feeling time passing fast and sometimes passing slow?" Then it's obvious that we want to attribute that to our brain. Basically, we localize something that is dynamic first through the language. Then because we feel something inside of us is changing, then we think, "Okay, well, we need to explain it with neuron."

I think that it's quite straightforward. It's typically what in paper about time. A paper about time perception in neuroscience start by a sentence saying, "Time passes fast when we have fun and slowly when we bored."

Paul Middlebrooks
Then it says, "The neural mechanisms underlying this sensation are poorly understood."

David Robbe
Exactly, because it's this subjective thing, you feel like then it has to become from your brain. The problem is that you attributed fast and slow, which are something that are about actually movement, to something that was very actually not movement. It was a temporal things. It was like your experience, your memory, et cetera. I think it makes sense that you think that it's something that is related to your brain activity, and in a sense it is.

Paul Middlebrooks
It is. It has to be.

David Robbe
It has to be.

Paul Middlebrooks
Make that connection for us then. You have rats, you have this task where they're on a treadmill and they have to do these timing experiments. They develop these stereotyped motor sequences, basically to help them keep track of when to go back to the port, when seven seconds in one case has elapsed so that they can get back to the port right just after seven seconds to maximize their reward.

They go through these stereotyped behaviors between trials to do that and areas like the basal ganglia are doing things that are coordinating there. Maybe this is where-- of course it's also in the brain because you're actuating these movements through this continuous perception action cycle, but it's the movements themselves that get honed over time and that you use as your clock. You're using your own movements as a clock.

David Robbe
Exactly. The tricky stuff here that's very subtle is that we're always tempted to say animals use their body and their movement to measure time, but they're not really aware that they have to measure time.

Paul Middlebrooks
Yes, I know.

David Robbe
I think the key here is to think that we humans have this ability to feel time. The fact that if I stop talking now, something uncomfortable is going to grow and I'm going to say, "Okay, what's going on?" We're able to do that. At the same time, we're able to watch a clock move and really relate our internal experience of change with this regular movement. That allow us to measure. The question is that, do the animals are able to do that? Are they able to do this comparison?

No, I don't think so. I think rats, they are really just in time. They're in time. They're not comparing with something and saying, "No." No, they're just in time. They cannot measure. They're just like, "Look." They're just like, "Okay, I got to get my reward." They cannot step back from time and compare what they've done with something regular. They're just living time. That's why they can do those tasks. That's why you can do whatever you want. That's my bet.

Paul Middlebrooks
Humans, again, are special in this particular way that they can reflect on their experienced living time with some machines ticking.

David Robbe
Exactly. First was the sun, the rotation of the earth. That's how it started. Then they developed tools to do that very accurately. It's exactly that. I think there is something special in the ability of human cognition to be able to co-register their own internal change with external change. I don't think rats are able to do it. Who knows? Maybe there could be some condition in which they could do it. Primates might be able to do it in certain conditions, but I don't think they can do it.

The key thing is that we do that because we relax. I don't know. Imagine a rat's actually thirsty and wanting to get reward. He's going to be in time a lot.

Paul Middlebrooks
To your point, we are embodied. Reading your paper, I sat quietly, tried to sit very still, and just time something in my head, just match the seconds, but of course, I found myself barely nodding my head or internally vocalizing the seconds. It's always related to some sort of movement, even if that movement-- Here's what I want to ask you, even if that movement is just on internal models or representations. Do you think of cognition as internalized movement? This is terrible because we're using language and we were just talking about how--

David Robbe
It's great that you're saying that because I'm trying to write a new, shorter paper on the subject. It's really about exactly that. It's that cognition is a form of-- It's really close to movement and a form of internalized movement, but can it be entirely internalized? That's the tricky question. As you've said, when you have to time in your head, you're making those small moves. Recently I participated to online experiment on time perception and the instruction were, you're going to see a square and you have to say how long did the square appear, but you should not count.

You should not nod. What was it? You shouldn't use round numbers. There's all kinds of weird instruction. I was thinking about, "No, but what they should say is that you should stop breathing. You should stop blinking." It's an impossible experiment. When you have an impossible experiment, maybe this should give you a hint that something is wrong. I think that's the same with the rats. If you see that you have to struggle so much to have a rat learn something is maybe the question is not the right question.

I'm saying that being a guy that has actually trained and designed experiments to do that. Now I'm not doing this anymore and I'm quite happy. Time is still a very important things, but you don't need to put it into this setup of measurement. Actually John was one-- I think he disagreed with many things I say.

Paul Middlebrooks
No.

David Robbe
Yes, because he doesn't like when you go too much into cognition and movement.

Paul Middlebrooks
Oh, I know.

David Robbe
He said to me, "David, find me an example of an animal in nature that would do a time estimation task." It was true that I realized when we wrote the 2020 paper, and I wanted to find an example for the first line of introduction, I was really struggling to find what is the right example. It's actually extremely rare, even for human, extremely rare to have a pure time estimation experiment.

Paul Middlebrooks
That fits exactly with your modern conception.

David Robbe
Exactly. That fits a lot with what Bergson was saying. I needed this guy actually assuming all the way in that the experience of time is something different than measuring time. That's what we're doing in neuroscience is that we take the experience of time of an animal and we would like him to measure and say, "Long, short."

Paul Middlebrooks
We're like, "I'm measuring it. You measure it too."

David Robbe
Exactly. That's great. I think it's great also if there's ideas that you push. What I found really nice is how the animals were telling us, "You guys, this is wrong." Actually, when I talk to people, I go visit labs, a lot of people that are doing this kind of experiment, they tell me, "Oh, we've seen it too." What's very interesting is why nobody speak about it.

Also that you have to do an experiment in which, "Okay, now that we see that the animals are moving during time experiment, you have to think about a way in which the animal is not moving because otherwise, you won't be able to do a *Nature Neuroscience* paper that would be purely about a cognitive things because movement is not the right stuff." It's nuts.

Paul Middlebrooks
It is. I appreciate that more and more how arbitrary it is to try to untether our behavior from our minds because it's just a continuous cycle.

David Robbe
Exactly.

Paul Middlebrooks
Analog continuous and it's never divorced. Even John Krakauer would argue, "Well, actually we do have these internal representations that are divorced and that's pretty special." I don't know where the line is. He doesn't either. No one does, because even if you have this internal representation, it is still continuously connected with another layer, with another layer, with another layer. Out into the environment. Embodied and in the environment.

I know I'm preaching to the choir here. We're not going to get into a free will debate, but as you were talking about looking at a clock and measuring, it reminded me of the Libet experiments, where you're looking at a clock and then you note where the clock is when you, volitionally, whenever you want to, tap your finger and then you note it. The famous experiment, and there's been a lot to debunk these things, is that your brain reads out what you're going to do before you know you're going to do it, before you report that you have subjective awareness that you're going to do it, therefore we have no free will.

There's been a lot of reasons why that experimental setup is perhaps not the best, has holes in it. Is there a road into free will with your conception now of--

David Robbe
Oh yes. Remember the title of the first book of Bergson in French is called *Essai sur les données immédiates de la conscience*. An essay about the immediate data and consciousness. It was translated in English as *Time and Free Will*. That's the title of the book. Actually, if you read the book, the translation is not great, but it's okay.

Paul Middlebrooks
You should learn French and read it in French?

David Robbe
What's crazy is that now that I'm talking to philosophers and I've been talking recently to Japanese philosophers, people that study Bergson, they speak French. I found that so amazing that philosophers that study German philosophers, they actually learn German. That's a very different world than our world. If you look at the book, the foreword of Bergson is that actually the problem he wants to attack with this question of time is the problem of free will, of freedom.

His point is that the problem of the free will is just like a very badly framed problem due to a mechanistic approach. He basically says. Once you've understood *durée*, the problem of free will totally vanishes.

Paul Middlebrooks
Oh, how's that?

David Robbe
If every moment is new, at every moment of our life is a new moment--

Paul Middlebrooks
Then we're not bound.

David Robbe
We're not bound to anything. It's like we're actually creating ourselves at each moment. That's it.

Paul Middlebrooks
This could really make us go another few hours.

David Robbe
It's very interesting on how he says the problem of the way we think about free will is because we're thinking retrospectively. We see something that happened and then after it's been done, we think, "Oh, yes, I can't understand why David decided to jump out of the rock at 10 meters high." Actually, when I went to do that jump 10 meters high in the sea, I'm hesitating, but nobody knows what I'm going to do because this is a new moment for my life.

Even me, I have no internal model of this because I'm a new person doing something new. Actually, this new thing is going to define me. If I jump it, I'll be like, "Oh, yes, I did it." I'll be a new person. If I don't do it, I'll go down the rock, my son will be looking at me and say, "Hey, Dad, you didn't jump."

Paul Middlebrooks
Can't have that.

David Robbe
You see what I mean? Retrospectively, of course, we can justify, we can explain things. The question is that, when you do something entirely new, how can you explain something that never happened?

Paul Middlebrooks
It's a liberating idea then that everything is new in every passing moment. You can always jump off the rock.

David Robbe
Exactly, it's very liberating.

Paul Middlebrooks
Then why do I have the same stupid habits that I've had for a long time? Why is it so hard to change things? Why am I so predictable in so many respects if I'm creating myself anew in every instance?

David Robbe
Yes, because we have this fight between-- It's a balance between surviving in which we need to somehow take advantage of regularities that are beneficial to us.

Paul Middlebrooks
Not jump off the rock.

David Robbe
Yes, for instance. It can be advantageous in some cases, if this is to impress somebody, like you want to impress your son. We'll be able to take advantage of some regularities to be able to live, find food, strive in the world. There is this competition between some kind of habit in which we take advantage of the world for things, but also we're changing. At some point, the bad habit will break or not, but it will change anyway, or you'll get more and more frustrated with your bad habit.

There's a word that Bergson uses that if I have free will, I can understand why I need some kind of determinism to take advantage of the regularities of the things that happens all the time that I cannot use.

Paul Middlebrooks
Oh yes.

David Robbe
Cause and effect. If I have this free will, it's really important that I'm also able to take-- but if I was entirely determinist, why do I have this feeling of free will? It's very--

Paul Middlebrooks
It's counterintuitive and it uses the argument against free will for an argument for free will. "If things are deterministic enough, I can actually make use of that." I have to make us switch gears here because this podcast, although less and less so, is ostensibly about the natural and artificial intelligence and sciences. What does this mean for artificial intelligence? A robot could just actually keep an internal Casio watch clock. Why would this conception or implementation or way to approach time make any difference for an artificial intelligence?

David Robbe
I think it makes-- I'm not an expert in the intelligent artificial.

Paul Middlebrooks
I wouldn't want my computer to subjectively become bored or to go faster sometimes and slower sometimes. I want it to be--

David Robbe
Yes, constant. That's the big difference I think and that's why I think people are interested in Bergson now is because this way-- This *durée* is really something that is not in our computer or that is not in AI. I don't know exactly how it works, the AI algorithm, but we can imagine that it's not-- In the computers, there's clocks that--

Paul Middlebrooks
It has to be precise.

David Robbe
It has to be precise and it pauses time regularly and one beam is separated from the other one. Then basically you stop the computer, you turn it on again an hour later and you can go back to where you were before. That's exactly not how we-- *durée* is actually the opposite of that. *Durée* is the fact that you cannot beam. Is this continuous merging that makes that if you stop doing something, you become impatient or uneasy, et cetera. I

don't think AI yet-- If you are interacting with ChatGPT and asking him question about French philosopher and all of a sudden you stop asking, he's not going to tell you, "Hey, what's going on?" or even shut down.

It's not built like that from this accumulation and merging from the past to the present. Things are very discretized I think in this system. I think this is what is interesting is it's a very different-- There's no time. Basically time doesn't matter anymore in AI. No, there's no time. It's just sequence of things.

Paul Middlebrooks
Dynamics matter, but time-- Would you want an AI to have this same Bergsonian *durée*? There's obviously an advantage-- No, no, there's not obviously an advantage for us actually. I was about to say it's obviously--

David Robbe
I don't think if it's-- Is it possible? I don't think we can do that. I think that's really--

Paul Middlebrooks
It's dependent on being a living system, you think?

David Robbe
I would think so, but I haven't really thought how you could somehow-- Because the idea is that we're constantly transforming ourselves. You would say, "Okay, an AI system is also constantly growing."

Paul Middlebrooks
Updating its weights-

David Robbe
Updating.

Paul Middlebrooks
-all the time.

David Robbe
I don't feel like that would give-- You wouldn't say it's getting old. No.

Paul Middlebrooks
My computer's getting old right now [chuckles] in a different way.

David Robbe
Yes. You see what I mean? For an AI that is like, "Okay, now it's--" How could you include impatience in an-- A true impatience because the true impatience doesn't have to be played repetitively, because I'm impatient. Now I go out, I take my car, the red light is too long. It's going to be different if I do it tomorrow. It doesn't have to be an impatient that is replayed all the time. It's got to be new every time. That's not possible. The AI system, it's got to be very regular. When I ask him, "What's the birth date of Bergson?" he's going to gimme the birth date each time.

If you keep asking me, maybe I'll be bothered by your question and I'll tell you something stupid. I don't know if this can come into an AI. I don't think they're designed for that.

Paul Middlebrooks
One of the advantages for us having this sense is, let's say the hawk is coming down on the mouse, and the mouse needs to hurry the hell up and get in the hole, and so time is going to go very slowly because it needs to move very fast. That it's *durée* in that moment is changed for it subjectively. Our sense of timing is dependent on motions and the needs of our demands from the environment and to survive, et cetera. Take the example of self-driving car. You would want it to-- I don't know. If the boulder is--

Let's say David has jumped off a rock 10 meters high, thinking that the highway was actually the sea, and you detect David falling through the air, and you don't want to contribute to his demise by hitting him with the car also. You'd want your car to be able to slow down. I don't think you would actually need *durée* to do that. You could still just use clock time if you're the car.

David Robbe
Yes.

Paul Middlebrooks
Are we just constrained because we are not-- Because we don't have an internal clock, we can't use clock time. We have to use this *durée*. Is that one way to phrase it?

David Robbe
Yes. *Durée* is making itself in us whatever we do. It's imposed to us. We're changing right now. We're growing some reflection about our discussion and then-- It's like we cannot escape it. It's a force of change, in a sense. We're not going to stay immobile or-- Something is going to happen with time for sure for us, which I don't think is the case for an AI. If we stop it now, it's not going to say, "Hey, guys, take care of me or whatever." No, because we have those metabolic needs that we need to-- We are in perpetual disequilibrium. Time is actually important for us.

Paul Middlebrooks
Is it in that sense that Bergson also conceives of time essentially as a force upon us?

David Robbe
Exactly. It's like it's going to do something on you. It's an active thing. That's what you see a lot and that's what's great is actually when you do those time experiments where you ask animal estimates, you're constantly surprised that why do the animals always go too early? Because time is acting on us. Actually, for the small story with this time experiment we designed with Pavel, at the beginning, we wanted the rats to wait 10 seconds because we thought, like this, we would get a lot of good units, like a good stable chunk of units for 10 seconds.

Then we were really pleased because the rats when they started doing this task, they were 9.5 all the time.

Paul Middlebrooks
You were too impatient.

David Robbe
Yes. We said, "Okay, let's move down to nine." Then they moved on immediately, 8.5. We kept moving down, and then at some point we realized that they would just want-- [chuckles] This is true in like if you look at a lot of different papers, like the work of Ben Seoliefsky. If you look at the data, the animals, they really struggle to wait. In that sense, that's where you can see that they're active by time. They want their reward as soon as possible. Time is important for them and for us too.

Paul Middlebrooks
Then just to wrap up our little AI segment here. Not only can you not imagine why AI engineers would want to figure out how to implement or program in this sense, but you can't imagine that it's possible in a machine. It has to be a living being?

David Robbe
It has to be a living being for which time matters.

Paul Middlebrooks
For which time matters. Are there living beings for which time doesn't matter?

David Robbe
No. I guess maybe for plants it's a little bit different.

Paul Middlebrooks
No, because they're having to create themselves all the time as well.

David Robbe
They're just in the place in which actually they get their food for free.

Paul Middlebrooks
No, their roots have to go down. They have to bend toward the sun. They still have to configure, but that's a plant cognition conversation.

David Robbe
Yes. You see what I mean. I guess what you would have to design is something like if you were putting an AI under pressure, then maybe. Maybe I shouldn't say that. We don't want to go there.

[laughter]

Paul Middlebrooks
No. Also, I don't want an AI to be impatient with me. "Come on. Hurry up. Ask a better question. Come on."

David Robbe
Yes, exactly. That would be the reason why. Is time matters for AI? No, it doesn't. No, but for us, time matters.

Paul Middlebrooks
Another thing you mention in your paper is a-- again, I see it as a recent trend among people like you and more increasingly me, of saying, "Oh,

doing this--" From my perspective, there's this recent "Rah-rah, science needs humanities" movement. I always question that, thinking, "Well, does it really, or does a certain segment of scientists need humanities, and those can be the people who connect it?" That was thrown in there also, and I'm curious what your take is. Why are we hearing this more and more that the science need humanities and how you got from this idea that time is not in the brain to humanities is important?

David Robbe
The idea, if we stay on the time topics, is that impatience-- This way we are changing in time, all the time because it's changing all the time, it's basically unreachable by science. We're always going to be a little bit behind. We're going to lag behind all the time in this description. We'll do a description of the living that is actually a mechanical description.

Paul Middlebrooks
Because it's the best approximation we can do in the given moment.

David Robbe
Exactly. There will always be a gap between the mechanical stuff and the real changing, creative process that is life. If there is a gap, then there might be other way to address this. For instance, you can learn a lot about perception with visual artists because they're going to do you some experiments and you won't be able to actually-- There's no point of putting electrodes while you're watching stuff, or et cetera. No. It's a different experience because it's just focusing on the experience itself.

Because it's a new experience, to do science you need to repeat an experience. Let's say it like this. Very simple. If you want to do a science something, you need to repeat. How would you repeat somebody watching a piece of art? It won't be the same. Once you've seen it, the second time will be, by definition, different. It will not be the same. You won't be able to do science. Actually, I think it's an under-appreciated phenomenon in neuroscience.

We try to have the animal doing the same trial over and over and over, and they don't actually. It's not true. We would like them to behave like robots, but they don't. My point with the art stuff is that there will be a limit because of this novelty stuff, and so then we can just talk about it in literature. Literature will give you a sense of what's happening in the mind of an artist creating or a character watching a piece of art. That will be much more valuable in the form of knowledge of humanity than knowing what's going on in his brain.

Paul Middlebrooks
Then that's separate from what I think of as science, which is where you want to be able to reliably reproduce results. That's its own thing. That's not science using humanities. It's almost not science. It's just a different description, a different story of experience.

David Robbe
Exactly, and it's a valuable one. It's not sure that it's failing more than science, in the sense that science is great and it's approximating a lot of things. There's no question about the benefit of sciences, but it's because it's always lagging behind, then let's not discard other forms of approach to reality. Arts is one of them. Literature is one of them.

Paul Middlebrooks
This is different than bringing-- I'll just say humanities to encompass all of them, bringing humanities into the science. It sounds more like appreciating the humanities as a different perspective.

David Robbe
Yes, you're right. That was my original point. Now the only maybe little twitch that I could say is that, for instance, there is often the tendency to think that neuroscience is going to help philosophy. I feel like my re-encounter with Bergson was the opposite. It's like basically, Bergson, for me-- It's still a debate, but for me, he's solving a problem in science.

Paul Middlebrooks
It changed your perspective. It changed the way that you approach the problem, right?

David Robbe
Yes. There's an entire committee that is struggling with trying to have rats doing time estimation experiment, and there's a guy that say, "Hey, maybe it's because you're confusing time and space." That's cool. I think that's great. I think it's interesting. It's not to think that every experiment is a good one. Maybe there's experiments that are just-- I think your guest, Paul Cisek was there.

Paul Middlebrooks
Paul Cisek, yes.

David Robbe
He has a very nice paper, I think, or at some point where it's the introduction of one of his papers saying that the toughest part in science is actually to find the right question. I think it's really true. Sometimes we ask questions that are some kind of very quick superficial psychology. Then we apply it to animals and then it fails. I think that's the case. In my case with Bergson, I felt like-- I think people should read him and actually take into

account his-- Maybe it redirects science so much. This was something else with-- What I liked a lot with Bergson is that actually, all his philosophical work is very tight to science, very.

Paul Middlebrooks
See, that's what I was about to say is I have my own internal dialogue sometimes like, "Oh, is what I'm interested really philosophy, or am I interested in science?" Really what I'm interested in is just knowing stuff and I'm curious about stuff. Once you start opening that door to philosophy, then it's easy to get hung up because you get immediately into the debates and the semantics around the concepts. Then you can just get lost there.

Having your perspective where you had already this scientific data set and viewpoint and questions, and then you visited, revisited in your case, Bergson, who you revisited in the light of your specific set of questions and problems, that was effective. That's where philosophy can be effective, I think, because everyone says, "Oh, philosophy needs to be like the humanities. People need to read philosophy," but you can't just go read philosophy. You have to go with your set of problems.

David Robbe
I think the key here is to interact with people when you do-- The risk is sometimes I feel like it's a little bit too much a closed society.

Paul Middlebrooks
Philosophy?

David Robbe
Maybe both philosophy and neuroscience, they tend maybe to be a little bit too in their thing. I think the mix is great. What is very interesting is that Bergson was actually saying philosophy should be much more like science. Despite the fact that a lot of scientists were really pissed at him and were calling him really a rubbish, but he had this idea that what was lacking philosophy was the precision of science.

Paul Middlebrooks
That's funny because he got flack because he's very fond of using metaphors.

David Robbe
Exactly, because he's not a scientist. He was trying to find actually good metaphor. I think his metaphors are really-- I love reading him. He's very precise, very sharp.

Paul Middlebrooks
That's how we think as metaphorers. George Lakoff.

David Robbe
Yes.

Paul Middlebrooks
Oh, yes. I had this thought before we spoke. I was walking my dog and I was thinking about philosophy and science. I remembered a recent conversation we were having in my lab, actually. The topic of whether pineapple is good on pizza came up. Of course, we all had our opinions on this, and we were debating it. Then one of my colleagues, Mark, said, "I don't understand why people are so adamant about their opinions about this stuff." I thought, "That's the way I feel about scientists and their opinions of philosophy. Why do you have to have an opinion on whether someone is interested in and uses philosophical inquiry to aid their own science?

You think it's useless. Other people find it useful. Who cares if there's pineapple on the pizza? The person eating the pizza likes the pineapple." There you go. There's a metaphor. There's an analogy.

David Robbe
That's a nice one. Do you really think that people think that philosophy is useless in neuroscience?

Paul Middlebrooks
Oh, yes. Of course.

David Robbe
Oh, yes?

Paul Middlebrooks
There's tons of historical examples of scientists talking about how useless philosophy is.

David Robbe
That big names. [laughs] My impression, I was extremely surprised by each time I gave a talk about this stuff how people were really engaging. I feel

people are actually hungry for doing meaningful stuff. If you do an experiment, and you wonder why does it take you so long to train your rats? It's cool also to have this perspective of philosophy of people also that think about science. I feel people are hungry about that and students a lot. I think that's really great, that's positive.

Paul Middlebrooks
David, hopefully, I have not taken you over your personal *durée*, but I've taken you over clock time, so I've-

David Robbe
A little bit, but it's okay.

Paul Middlebrooks
Yes. Okay.

David Robbe
It's so fun.

Paul Middlebrooks
My final question, is pineapple on pizza, yay or nay?

David Robbe
No.

Paul Middlebrooks
Spoken like a true-

David Robbe
Sorry. [laughs]

Paul Middlebrooks
-French person. You're okay with other people having pineapple on pizza, right?

David Robbe
Oh, yes. Totally.

Paul Middlebrooks
All right. Thank you for your *durée*.

David Robbe
Thanks, Paul. It was really fun.

[music]

Paul Middlebrooks
"Brain Inspired" is powered by *The Transmitter*, an online publication that aims to deliver useful information, insights, and tools to build bridges across neuroscience and advance research. Visit thetransmitter.org to explore the latest neuroscience news and perspectives written by journalists and scientists. If you value "Brain Inspired," support it through Patreon. To access full-length episodes, join our Discord community, and even influence why invite to the podcast. Go to braininspired.co to learn more. The music you're hearing is *Little Wing*, performed by Kyle Donovan. Thank you for your support. See you next time.

[music]
