THE TRANSMITTER | BRAIN INSPIRED

Gabriele Scheler reflects on the interplay between language, thought and AI

She discusses how verbal thought shapes cognition, why inner speech is foundational to human intelligence and what current artificial-intelligene models get wrong about language.

26 MARCH 2025 | by PAUL MIDDLEBROOKS

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

[music]

Gabriele Scheler
There is this still unexplained, in current neuroscience, enormous increase of cortical capacity in humans. The obvious explanation would be a language. We don't even understand how the neurons work together to create grammatical sentences. This is something that we can find out, and this is important, but that doesn't mean that we now can build an automaton which does exactly the same thing, and that this automaton is then the same as us, so to speak. If you have the building blocks from the brain, if you can build it like a brain, then we should at least be able to get away from these absolutely huge and wasteful, essentially dumb, huge models.

[music]

Paul Middlebrooks
This is "Brain Inspired," powered by *The Transmitter*. Hi, everyone. It's Paul. Welcome to "Brain Inspired." Gabriele Scheler co-founded the Carl Correns Foundation for Mathematical Biology. In fact, Carl Correns was her great-grandfather. Great, great. Great. I can't remember. You'll hear from her. He was one of the early pioneers in genetics.

Gabriele is a computational neuroscientist whose goal is to build models of cellular computation, and much of her focus is on neurons. When we discuss her theoretical work, building a new single neuron model, so she, like Dmitri Chklovskii a few episodes ago, believes that we've been stuck with essentially the same family of models for a neuron for a long time, despite minor variations on those models.

The model Gabriele is working on, for example, respects the computations going on not only externally via spiking, which is the traditional way models are built and the only game in town forever, but she also wants to respect the computations going on within the cell itself, within the cell membrane, and then even down within the nucleus.

This is in line with previous guests on "Brain Inspired," like Randy Gallistel, David Glanzman and Hessam Akhlaghpour, who argue that we need to pay attention to how neurons are computing various things internally and how that affects our cognition. Gabriele also believes the new neuron model she's developing will improve AI, drastically simplifying the models by providing them with smarter neurons, essentially.

We eventually get to talking about that work on the single neuron, but we also discuss things like the importance of neuromodulation, her interest in wanting to understand how we think via our internal verbal monologue, so connecting the language that we hear essentially in our minds with the process of thinking. We talk about her lifelong interest in language in general, what she thinks about large language models, why she decided to start her own foundation to fund her science, and what that experience has been like so far.

Gabriele has been working on these topics for many years, and as you'll hear in a moment, she was there when computational neuroscience was just starting to pop up in a few places when it was a nascent field, unlike its current ubiquity in neuroscience. You can find the links to Gabriele's work in the show notes at braininspired.co/podcast/208. By the way, you may be listening to this in Montreal right now. If you're at COSYNE, I wish I was there with you. However, my name is on a poster there. You should swing by and say hi to Aden and Eric, my colleagues in crime, and check out our research. I hope you're having a good time at Cosign.

I hope that you are well, and I hope you enjoy my discussion with Gabriele.

[transition]

I vaguely remember when I became interested in the neurosciences, the cognitive sciences, like many people, I wanted to understand consciousness, subjective experience, but you have a slightly different interest that drove you into it. You wanted to understand how we think and how we speak. Is that correct?

Gabriele Scheler
That's right. I wanted to understand how we think and the sense of this verbal thought in a monologue or so that some people produce more or less of, I produced a lot of it. I was very introspective and I wondered what is going on in my brain to that I have these sort of conversations with myself.

Paul Middlebrooks
You don't equate thinking with that internal monologue. That's just the facet of thinking that you're interested in.

Gabriele Scheler
Exactly. I wouldn't say there's no other way of thinking. There's certainly preverbal thought. It's very important. Some people suggest that they actually think very explicitly in visual images. It plays a role, but so there are differences, but there's no doubt that all of us at times use internal speech or in a monologues. Certainly, also when we speak, we all speak and explain something that is going on in our head.

Paul Middlebrooks
I don't want to just get into sex differences right off the bat, but is it true? Are there more proportionately males who think visually and females who think in language? Do we have these there?

Gabriele Scheler
I have no idea.

Paul Middlebrooks
You have a high rate of internal thinking, but you used preverbal to categorize other thought. Is there post-verbal?

Gabriele Scheler
No, I think it is more that, when we speak or when we require the ability for in a monologues at some point in our lives, often only around the age of six or so, even though we can usually speak by the age of three. That is also a process where we start to internalizing it, but we use it for thinking. We use it in trying to solve a problem. We begin to speak and say, "Oh, I should probably do this or something." I think verbal thought is really very important and very central for our experience as humans. It is not some additional extra that you can leave out.

I had a small conversation with Yahn Lecun about it because he thought cats are fine as a model. They're not, if artificial intelligence, as I would define it, is an attempt at modern human intelligence, then no way, because it is really the case that children, who in the past, who could not hear, when you don't stimulate him sufficiently early about language, they really have a deficiency in the intellect in some way. That's why people have learned to do this very early.

It is important, I think, for our internal organization of our thoughts, the ability to resort to symbols and then do symbol manipulation, which is why I think there's also-- I think Piaget and Vygotsky and people like that have found this, that you need object manipulation skills in order to learn grammatical sentences, because that is what you are doing. You are manipulating symbols, attaching them together, doing them apart, building an actual sentence, like you would build something out of stones. All these abilities come together there. I don't think it's so mysterious anymore.

You asked me about this upfront, whether I think that we could understand human language. From my perspective, yes, I would say we can get close. We can understand it pretty well. It's not much more difficult than odor recognition. For instance, flies can do, they get all these odorants. Then that we understand in their brain how it goes to the different neural areas, like antenna lobe, and the mushroom, bodies where you have these sparse coding.

We can understand how out of this odorant environment, they build sort of their own world of odors, so to speak, which then influences their behavior. Of course, language is more complicated, but it has this mechanical aspect.

Paul Middlebrooks
Do you ever have this experience, though? I have this experience over and over where I will be thinking about something, and a sentence about that thing will pop into my head, and I will think, "That is so stupid that I'm using language to think about this. It doesn't buy me anything." In fact, sometimes it gets in the way.

Gabriele Scheler
You feel restricted by it.

Paul Middlebrooks
I'm restricted by it. Do you ever have that experience?

Gabriele Scheler
Actually, it's interesting. For me, language has been very-- I've used it differently. It's more empowering, I would say. It leads me sometimes from one thought to the next, or a thought pops up, which I cannot name, but as I think about it, I can begin to put it into words for myself. Plus, the good idea is once I have articulated it in words, I don't even know how many people have this, I can better remember it.

Paul Middlebrooks
Oh, yes, sure. It's almost like collapsing the wave function, right? It's not a real thought until you put it into words. Then because of that symbolic abstract nature of it, then you can, from afar, look at it anew in a new light. I guess that's why when people say writing things down helps them think about it because it concretizes some idea that you had that was vague. Then that can, I think, even change your own thinking.

Gabriele Scheler
Yes, it helps with your memory. It helps with your memory, also your internal memory. That was the point I was making, that I believe, as humans, we have organized our brains, especially our cortex, very much according to language and symbolic principles, and that is probably very different. There is this still unexplained in current neuroscience, an enormous increase of cortical capacity in humans.

The obvious explanation would be a language because that's what we developed. As we developed language, our cortices got bigger and bigger and bigger, as if we suddenly can use all that memory, which you cannot use. You have to access it. In order to access it, it's probably structured and ordered, I think, with the help of symbols. It's like a hash table or so into your memory. That's, of course, since you had the topic, current AI doesn't do that.

Paul Middlebrooks
What do you mean? Elaborate on that.

Gabriele Scheler
Current AI does not build a structure, build off symbols which references into complex theories or thoughts.

Paul Middlebrooks
Okay. We'll come back to the AI because-- yes. We'll come back to the AI and large language models, which I know you're interested in. One more random thought about language. I was asking, my son is 10, my daughter is 12, and we were driving around, and I'm frequently bothered when I see advertisements, for example. What is the name of this phenomenon where you cannot not read something when you see it? It's like language capture. What is the name of that?

Gabriele Scheler
Sorry, I don't know the word either. I only know that it's interesting for bilinguals like me. I cannot shut this off in German, but I can shut it off in English.

Paul Middlebrooks
Oh. What do you mean?

Gabriele Scheler
I can actually watch an English movie and decide not to listen, not to understand the words, just listen to the sounds.

Paul Middlebrooks
Oh. That's verbal. I was thinking visual, but you're saying it happens verbally, too.

Gabriele Scheler
As people speak, I can decide, just let them speak and not listening into what they are saying.

Paul Middlebrooks
That's like the entirety of my listening experience in any language. Come on. [laughs]

Gabriele Scheler
Yes, I can choose to understand or simply listen to the sounds. I cannot do this in German. It's probably too deeply ingrained probably.

Paul Middlebrooks
Okay. You had that early interest in understanding how we think, specifically in our language capacity. Have you kept the same worldview? What I wanted to ask you is, what is thinking? Because my conception of thinking has changed over time. Have you kept the same conception about how to go about thinking about thinking?

Gabriele Scheler
Yes. Actually, no. My original idea was simply I want to understand it from a scientific point of view, and to me, that is mechanical and mathematical. What has changed a bit is, after a couple of years, in my 30s or so, I wondered about the spiritual side of human experience. That was already the time when the machine translation was on the horizon. Of course, you could use a synthesizer to create a violin, and all this artificial was already in the air. People asked themselves, me too.

I came to the conclusion that even though we can rebuild all these experiences, and we can mechanically analyze it, and that is also very useful for us in many ways, especially in medicine, we do not capture the essence of what is going on, something else. I said you can link it to subatomic

physics or whatever it is. It certainly is against-- a mechanical account from a physical point of view, that's the term. That is really a 17th century. In terms of, as I said, in language and the thought, we don't even have that. We don't even have a mechanical, Newtonian account of what's going on.

Now, I think it's two different things. If we have it, that's fine. That is a scientific point of view. If somebody has an illness, if something is broken, if somebody has an aphasia or a dementia or whatever, that is important. It is not the essence of who we are, how we communicate. All these spiritual sort of extra is, I think that is not all, so to speak. When I was younger, I wasn't even thinking about whether there could be a dichotomy between this. Once you've explained it in a scientific way, that's what it is. There's nothing else.

Paul Middlebrooks
That has not really changed your approach necessarily, just how you think about it.

Gabriele Scheler
Exactly. For the science, I think it makes no difference. It makes no difference, as I said, because we are so far behind. We don't even understand how the neurons work together to create grammatical sentences and so on. This is something that we can find out, and this is important, but that doesn't mean that we now can build an automaton, which does exactly the same thing, and that this automaton is then the same as us, so to speak.

It will remain an automaton which is mimicking certain aspects of our thought process. That is the difference. You see? That's the difference. As I said, this is in contrast to Hinton on people like that who seem to think once they have an automaton, once they have a mechanical device, which produces pretty much what a human produces, then the human is not different from this device.

Paul Middlebrooks
Yes. I came across Hinton the other day saying that it's already conscious and, oh, come on, guy.

Gabriele Scheler
Yes, but what is understandable to me is when you go very deeply into it, I already had said, depersonalization effect, I think it's called in psychology. When you suddenly have the idea that everybody around you is some kind of automaton, so to speak. I think Hinton must have that problem. If you can explain everything, then you don't understand that other people are actually still people and not, let's say, an AI also. I think it is a psychological problem if you mix these things up.

Paul Middlebrooks
I like that you maintain that distinction because we live-- our modern scientific world is very mechanistic. It is like the machine metaphor. As soon as we've explained it in those mechanistic scientific terms, that's all there is. You go beyond that. It's just you're content with the idea that that is the best way to explain it scientifically.

Gabriele Scheler
Exactly.

Paul Middlebrooks
It leaves out--

Gabriele Scheler
Science is not everything, so to speak. Exactly. Science can be very, very useful and helpful in many ways. No questions. Much better to know mechanically what is going on than to simply know nothing at all.

Paul Middlebrooks
All right. I was going to bring this up later, but let's go ahead and talk about it because you have taken an alternative kind of path thus far. Maybe it didn't start off alternative, but at some point, would you say that you're out of it? Did you leave academia? I don't know how to phrase this exactly.

Gabriele Scheler
I see it as an academic nonprofit institution, but I was in a way more or less trying to recreate what I understood by academia. Also, I would say how it started with me personally, because I think the world has changed in that respect. When I was a student, there was a lot more freedom and independence.

Paul Middlebrooks
When was this? Tell the listeners when this was and where it was.

Gabriele Scheler
That was in Munich. Actually, I had, by chance, obtained a job at a computer science company, Digital Equipment. They don't exist anymore. At the time, they had money. I got a freelance position trying to do natural language processing. The guy who hired me was, himself, a linguist. We understood each other well. For a year and a half, they would just give me a computer and Lisp and Prolog and do something with it.

At some point, he actually showed it to his boss because he thought what I had achieved was quite good. Yes, he's very nice, but he never came back to me. With that experience, I then went to the old professor in logic, and he was actually a physicist whom I liked very much and asked him what I could do I was in a dissertation on this, because up to that point, I hadn't used a computer. They gave me a computer, and I taught myself Lisp and Prolog and also some language Prolog, and then I pieced things together.

Paul Middlebrooks
What year was that?

Gabriele Scheler
It was a very nice experience. I was actually paid for that.

Paul Middlebrooks
[laughs] About what year was this?

Gabriele Scheler
Oh, that was between 1986 and 1989.

Paul Middlebrooks
Okay, so computers were still pretty early on.

Gabriele Scheler
It was early on, and I was happy about it. I can actually say something in terms of feminism at this point because I really loved the computer experience. I had also this experience as a young woman at that time in Munich, in logic, in the math classes, that people wouldn't listen to me. I would say something and then nobody listened. Then some guy, some man said the same thing, "Oh, yes, that's very interesting." It annoyed me. I had this computer, and I thought, "I have a computer. This computer doesn't care." [laughs] A computer has no conception of what I'm telling him, what I'm trying to make him do. It comes from a female or male. It was very liberating.

Paul Middlebrooks
Eventually, then, you went to the United States. What we're eventually going to get to, and that's interesting that you just said that your mom had a PhD in biology because I wanted to ask about her approach, because you have this, it's mechanisms in science, but the old biologists were accused of just stamp collecting, just collecting the data without a theoretical background. It made me curious if maybe your mom--

Gabriele Scheler
There's, of course, the Carl Correns aspect, which is my great grandfather, who's also a biologist. I used him then for this foundation, and I asked the others what they thought, and it's okay because it's just a family relation. Then it occurred to me, it's not just a family relation. There's something else. At the time when the Mendel's Laws were set up, and my grandfather wrote this paper when he actually added a law that was never Mendel's Law, so he really pushed it along.

Paul Middlebrooks
This is Carl Correns.

Gabriele Scheler
Carl Correns, yes. He was much attacked, that said, mother from the Bergson people. There was this Henri Bergson, and they had this life force. Biology is different from physics because there's a life force, and because of the life force, everything's different. It's not the--

Paul Middlebrooks
The *élan vital* that was much maligned eventually. It's a little bit misunderstood from Bergson's point of view. You said the Bergson people who did take it on.

Gabriele Scheler
Exactly. Often happens, like with Marxists or Freudians or so, they take certain aspects and make them very big. One of these was that biology is separate from the material world, from physics, and also from mathematics. You can't use mathematics for biology because it's messy, it has a life force, it is a living organism, and so on. You have to study it completely differently, and it is not part of science in the same way. He took a lot of flack from these people because genetics, as it was then, only appeared as a discipline, and it was the first, you could say, mathematical discipline in biology.

My great grandfather had a different outlook on that. Of course, he studied plants. We could say, in a way, he loved plants, but he took them very seriously as objects, as physical objects. It's physical objects which could be understood in a rational way. You didn't have to appeal to some supernatural forces or so to understand how, for instance, he was, I think, the first who pointed out that the chloroplasts, which do the photosynthesis, probably were earlier bacteria which were incorporated.

Paul Middlebrooks
Oh, he posited that theory?

Gabriele Scheler
It's actually true, I think. You see, things like that. That was just an outflow from this mechanical, physical approach to plants. From this aspect, I thought it was good for the name of the Foundation for Mathematics.

Paul Middlebrooks
Yes. You have this linguistics background, and you're into the computer science and the math. What was the turn into neuroscience?

Gabriele Scheler
Yes, that was exactly the point. I did all this high-level thing. Anyway, linguistics, as I said, was degrading into natural language processing. At the time, I thought, Google would take it all. I have no interest in the segment.

Paul Middlebrooks
What does that mean, degrading into--

Gabriele Scheler
Natural language processing is the question of how to do information processing in a natural language on a machine. My question has always been, how do we do language in a human brain?

Paul Middlebrooks
You don't think we can learn about the human brain by building machines?

Gabriele Scheler
Yes. That's one of the best ways, yes.

Paul Middlebrooks
Then what's the problem with natural language?

Gabriele Scheler
No, they wanted to use language to communicate and deal with machines. That is not what language is made for. You have to change it. You have to use a stupid kind of language for it. You have to take many things out, all the jokes, all the fun, all the poetry. The machine won't understand it, and therefore, it's not a topic anymore. For us, humans, it's all a part of it.

Paul Middlebrooks
Yes, and confabulation and lying, and anything creative, essentially.

Gabriele Scheler
Yes.

Paul Middlebrooks
This is a total aside, but do large language models generate neologisms? Because the nature of language, it's always evolving and changing. A word, it's called semantic drift. I don't know what it's called, but the meaning of a word changes over time because people elect to use it differently or to use it in a funny way. Then sometimes that catches on, sometimes it doesn't, so it's always changing. I was curious. I was talking with a friend the other day about whether large language models can or will, what effect they'll have on that drift? It almost seems like they will crystallize language into one thing.

Gabriele Scheler
I think what happens is you have an exchange between brains, and this exchange uses this root of language. You don't need a chip in your head in order to show the content of your brain to somebody else. You can use language. If you do this, and if this happens between different people over time, then you will always have access to different experience that these people do have extra-linguistic, that they have in other areas of their lives. As you use this communication method, the substrate which interprets it.

My substrate interprets what you are saying, and yours tries to interpret what I'm saying to match it to your own thought patterns. This happens all the time between people. I think this is the explanation why semantics changes, and also why it's such an interesting, and also, I think that's a joyful topic. It's very, very interesting. Now, if you have a machine, let's say an ELISA machine or any kind of QA machine in between, you can, of course, communicate to this machine.

Actually, if you know it's a neural network sitting there and there's certain things, it may also have changes to the communication process. That's what many people are not very concerned about, that if we have lots of AI-generated linguistic content that younger generations are exposed to without understanding that this may affect their thought processes in negative ways. I think that's quite true.

I personally think it's-- to use language for communication with a machine, from my point of view, is something I never wanted. People I know, of course, computational linguistics, I was a computational linguist myself for three years in Heidelberg Institute for Computational Linguistics. That

was one of the goals. People say, "I want a microphone, I want to talk into it, and the machine should give me everything that I want to say." I always thought, no.

Paul Middlebrooks
What's the danger there?

Gabriele Scheler
Also because it's not suitable. Language is suitable to human brains. It's produced by human brains, it's understood by them, and so on. Many communicative issues shape our language. Now, if I communicate with a machine, then I have a-- it's almost as if you have-- of course, it's different, but you have a child and you have an adult, and you talk to a child and you talk to the adult, you have to adjust yourself. You have to talk differently to the child and to them. Now you have a machine and you have to adjust yourself to the machine, because you have to assume the machine has, again, a very different level of understanding.

Paul Middlebrooks
I worry, and I don't know if this is related to what you're saying, but it doesn't matter how we treat the machine, because it's just a machine, and because you speak differently in different contexts, when I'm talking to a machine, if I say, "Please," I think it's ridiculous. I'm not going to be polite necessarily, as polite to a machine. I worry that then affects, especially with younger people growing up, how they then could translate that style of communication to the real world, like social media.

Gabriele Scheler
There are many such aspects. I always get angry at these things very quickly. That's why I don't use them anymore, because you have to have a lot of patience explaining something to them. Since I know it's a machine, I don't have patience because I'm not friendly. I think we have programming languages which are made for machines. They're not very made for humans, but they're very well made for machines. That's how we can communicate.

Paul Middlebrooks
Okay, well, let's go back then to-- eventually, you're going to start this Carl Correns Foundation. What I want to know is why you did that and how you did it and how I could do it if I wanted to.

Gabriele Scheler
The reason I did it was I had this biocorp at Stanford for about 10 years. This meant that it was actually started by a student, and then she went away. Did somebody want to go on? She said, "I'm ready to go on with it." I invited people to give talks in the Bay Area, doctoral students or postdocs. They usually came and gave a talk, and some of them were very excellent.

I read the paper up front. Somebody actually asked them, "How do you manage to get such wonderful lectures?" I said, "Well, I read the papers. I read the papers, and when I like the paper, then I invite the person." We had really wonderful people there giving talks and very interesting research. When I asked them, "Yes, how is it going on with basic science, academia?" No, no, pretty much always. Nobody wanted to do academia. Nobody wanted to do basic science. Everyone was going out.

As I said, this occurred to me. Imagine this, say, Paul Dirac, Emmy Noether, Werner Heisenberg, they give their talks on physics. If you're asking, how are you going to go on? Oh, well, we're going to do a startup and rent out garages or so. They might be a success. They were smart people. It's a waste, right?

Paul Middlebrooks
Well, depending on your goals.

Gabriele Scheler
Of course, on their goals. I'm talking about society at large.

Paul Middlebrooks
I don't know. I'm not sure. A lot of people who go and do a startup have the intentions to change the world.

Gabriele Scheler
Yes, but what I meant was that academia and basic science was simply not a valid alternative for them. I could understand them, and I would not even have contradicted them.

Paul Middlebrooks
They were getting their PhDs, et cetera, in order to move to industry.

Gabriele Scheler
Then sort of never go back to this place again because they had their experiences. That's what I mean. It used to be in the earlier world, okay, academia, you don't make as much money, but you have your freedom. You have your joy. You enjoy your work. If, for half a year, nothing comes to your mind, then you do nothing.

Paul Middlebrooks
That doesn't exist anymore.

Gabriele Scheler
That was academia. Then you write a wonderful paper, maybe. That was academia, and nobody bothers you.

Paul Middlebrooks
You had time to reflect and think and work things out.

Gabriele Scheler
Yes.

Paul Middlebrooks
Is that different these days, you would say?

Gabriele Scheler
Oh, of course. Yes. It's very different. There's always this run for funding. You can't do anything without any funding. That was the second observation. Then I talked to the people who actually were professors at Stanford. You might think, oh, they're on top of their profession or something. What would they do if they could? Pretty much everybody said the kind of stuff they're doing now, they wouldn't do. They would do something else, but they can't get funding for that.

Paul Middlebrooks
Right. You have to pretend to be.

Gabriele Scheler
From their own research, what they do, they would go in a different direction now in order to advance, in order to make an impact or something. They can't because they can't get funding for that. They get funding for something else. They have to do something else. As I said, the older they were, the more cynical they had become about the value of all this. That was also sad. This was not some tiny place in Romania where people are very sad that they cannot do what they want to do. This was a place where we would expect them to be able to actually do the science which they believe in and which they want.

Paul Middlebrooks
You were feeling that also in your own career?

Gabriele Scheler
I felt it all the time, but I thought it was just me.

Paul Middlebrooks
Oh, no. It's everybody. It's 99%.

Gabriele Scheler
Yes, that's the part that shocked me. When I was in Munich, I thought it's because I'm in Munich. Then I come to Stanford, and it's still like that.

Paul Middlebrooks
It's universal. That's when I thought, "This is something wrong." As I said, if you go to, I don't know, the University of Banja Luka in Bosnia, they don't have that much money. You expect, if you talk to somebody, "Oh, once I get to Harvard, then I will be able to do what I want," it's not the case.

Paul Middlebrooks
Yes, actually, I was just telling a student in the lab the other day, I said, "You're not going to like this. It's going to be obnoxious, but it's true that there is no destination. You never get there, because you're always moving." Similar lines, someone in my lab the other day asked me about my research, "Oh, well, what are you going to publish from this?" I just sort of bristled because that shouldn't be the question. The question is, what are you finding that's interesting? Not like, you have to think about when you're doing your research, well, what is publishable? What can I publish from this instead of what can I do to further advance my understanding of this?

Gabriele Scheler
I know what you mean. That's often the problem. I've thought, coming from you, it's even worse because-- or even maybe that's actually a good thing. It's one thing to have results, but it's a different thing to go deeply enough in order to be able to publish them. In that process, sometimes you learn something, of course. That is a good thing. I simply use a blog that I have and some gray literature for things which are not ready to be published.

Paul Middlebrooks
I don't think I heard that term before, gray literature. Is that like preprints, you mean?

Gabriele Scheler
Yes, exactly. Preprints and, for instance, on ResearchGate, you can just put in a paper and you get a DOI. Then maybe four years later, you think, "This thing I can now use for an actual publication," it's still there.

Paul Middlebrooks
Oh, so you can-- there's no hoops and hurdles to jump through to put it up on ResearchGate?

Gabriele Scheler
No.

Paul Middlebrooks
You can do whatever, put up whatever you want?

Gabriele Scheler
More or less, yes. I wrote a piece on language, on the biology of language, simply because I wanted to put it together for myself. I put it on ResearchGate, and I have no idea whether I ever will publish it. When the LLMs came out, I thought it was very necessary to remind myself all the many things we know about language in the brain. We know many, many things, and this LLM was in the process of sweeping it all aside. I thought I need to write a-- need to put this together in just 10 days, sit down and put together, looked at the current literature and so on about-- we have this N400, for instance, I don't know, event-related potentials. If you are familiar with them, that's--

Paul Middlebrooks
It's when you take EEG signals.

Gabriele Scheler
Exactly.

Paul Middlebrooks
Then over many, many trials, you can align those signals to an event, and then you average them. Then the waveform, the shape of the waveform, different shapes get different names, relative to when it happens relative to the event.

Gabriele Scheler
There are actually not so many. Yes.

Paul Middlebrooks
Yes, not so many. Yes, there's a handful.

Gabriele Scheler
Yes, the N400 is up to 400 milliseconds. It's a negative. You get it with all kinds of language effects. You get it when you make a joke, because something doesn't align and you laugh.

Paul Middlebrooks
Oh, is that the unexpected? Yes, surprise, error, mismatch.

Gabriele Scheler
That's also for garden path sentences. A sentence which starts off grammatically, but doesn't end grammatically. Whoosh, goes like this, right? That's large. To generate this EEG signal, this means that essentially your whole brain is involved in interpreting this ungrammatical sentence, which is interesting because sometimes people think it's very localized.

Paul Middlebrooks
Right.

Gabriele Scheler
It's not. It's actually very profound.

Paul Middlebrooks
Yes. It doesn't have to be whole brain, but it has to be more than 10 neurons to be there.

Gabriele Scheler
Yes, exactly. A large part of the cortex may be more focused.

Paul Middlebrooks
Yes. Why did you mention the N400? Why that would be important in terms of understanding?

Gabriele Scheler
This is a sign of how we interpret language and what we do with ungrammatical sentences. Ungrammatical sentences have a very strong effect on us.

Paul Middlebrooks
Yes. They can be funny.

Gabriele Scheler
Yes, that's true. The N400, I just read it. You can also use this for prices. If somebody quotes you a very high price, N400 goes up. It works as unexpected, right?

Paul Middlebrooks
What would you take from that? Because you write over and over in your papers, well, it depends on the level of abstraction that's important, right? You don't think like, "Well, I think we need to build a system that has an N400 for language."

Gabriele Scheler
In a way, yes. When we build a language model, which interprets, for instance, feature landscapes by terms of symbols and so on, and now we give it an unexpected series of symbols or a series which first makes sense, and then some symbol that doesn't make sense at all. I do want in my model to see what is happening here, which could cause this N400. An LLM doesn't do that because it doesn't even model a brain.

Paul Middlebrooks
There might be some readout of expected versus unexpected because it's based on probabilities, right? Then eventually collapses and the word with the highest probability or the token gets placed next.

Gabriele Scheler
Yes, but that's different. This is what they use in order to build sentences here. I really mean a violation of an expectation. Of course, the LLM produces it all the time. If it gives you useful answers and then counts the number of Rs in strawberry faults, you should get an N400, but the LLM doesn't. It should, but it doesn't.

Paul Middlebrooks
That also just speaks to the lack of any dynamics, right, in a model in general.

Gabriele Scheler
Of course, somebody could argue that these signals in the brain are irrelevant or don't mean anything. We can build artificial intelligence in a completely different way and still be very happy with the results that is engineering, but it's okay. For my perspective, somebody wants to engineer a language machine. I have nothing against it, but it doesn't interest me.

Paul Middlebrooks
You think that there are better ways to do it, to engineer artificial intelligence, and that's why you're--

Gabriele Scheler
Well, there's two things. First of all, I have nothing against people engineering it. It's just something that doesn't interest me because I see myself as a natural scientist, as somebody who's looking at the natural world, and a natural language is part of a human natural world.

Paul Middlebrooks
One of the thoughts that I have recurringly about artificial intelligence is like, okay, that's fine. First of all, it's an unfortunate name. The originator of that name thought it was an unfortunate name also. I think John McCarthy, I think, coined it and then hated it or I don't know. It's always been contentious from the earliest days.

I just think like, okay, that's fine. It's engineering. It's not really what I think of as intelligence or I need to re-jigger what I think of as intelligence. They're sort of, all of a sudden, people are claiming that they're working on intelligence when I think of that's actually missing the mark of what maybe I'm interested in. I don't know how to really articulate it, but it's something different. It's not what I'm interested in understanding as far as intelligence.

Gabriele Scheler
Yes, well, look, I was also distant from that for considerable time for the same reason. You see, it occurred to me that, of course, it can help us focus when we do computational neuroscience models. We do many of them and they capture different functionalities, different ideas. Wouldn't it be useful from time to time to say, let's see whether we can build a functional model, which actually do some task or so on the basis of our knowledge about the brain? Let's not just do simulation models, which do use experiments and then show in the model how you can explain the experiment. Let's try to build a functional model on a higher level and see whether we can use this to achieve some goal, to let them do some task that's useful. Why shouldn't we do this on the basis of our computational neuroscience experience?

Paul Middlebrooks
Because we're so far behind in computational neuroscience.

Gabriele Scheler
That's actually the contention. That is exactly the idea why I had this idea about the spin-off. I think the time is right.

Paul Middlebrooks
Okay. Let's go back to the Carl Correns because there's a lot of science that I want to talk to you about also. The things that you have worked on, and so let's get to the spin-off that you're developing or have developed, but go back to-- I want to know how to start a Carl Correns.

Gabriele Scheler
I asked friends and colleagues whether they wanted to be on the board. I set up a non-profit foundation, California Law, tax deductible, took some time, took a little bit of money, mostly time.

Paul Middlebrooks
Then you had to make the decision to step out of academia too, right?

Gabriele Scheler
Yes. I still see it as a part of academia. There's so many-- look, by the way, I almost ended up at OpenAI at the time because that was a non-profit. As I was doing this, people told me, "You know about OpenAI? That's a non-profit too. That's just like your idea to do exactly the same thing. Why don't you work with them?"

I looked at them and I already then had the idea that somehow I don't really trust them. I think that their legal structure seemed a bit strange because-- so I missed out. I admit it. That would have been nice, but knowing me, I probably would have left way too early and so on. Besides, I really don't like their approach, but I could-- of course, we have a small endowment for the Carl Correns Foundation from our family. Of course, it could have been larger, right? I could have siphoned off some money, siphoned off some money from the OpenAI in terms of my own work or in terms of how you call it, a stock or so. The idea was right. There are people like that. There's the Allen Institute. Of course, they all have much larger endowments, much larger.

Paul Middlebrooks
How do you keep going though? Do people donate? Because there's the fundraising aspect to it, which would be--

Gabriele Scheler
We have the endowment that generates a bit of money and some people donate. We have essentially just one scholar per year.

Paul Middlebrooks
What is that? You pay as like an intern almost?

Gabriele Scheler
Yes, well, you could say that, something like that. It depends. We had different people. We had a master's student. This year, I hope there's a PhD student who's doing work on cortical microcolumns and he wants to contribute to our work and so on. The possibilities are there. If there's more money, we can either put it in the endowment if we don't know what to do with it right away. This year, I would finance another scholar because we have two things for the spin-off. One is the cortical microcolumn, making it useful for language. The other thing is a neuron model that we are building. I could use another one. I haven't got done the second one yet.

Paul Middlebrooks
If I'm a PhD student and I'm whatever, it's my second or third year or something at my institution and I come across the Carl Correns Foundation, what do I-- is that sort of a separate thing that I apply to and then you send me money to do my work related to what you're wanting? How does that work?

Gabriele Scheler
Yes, usually-- because we have so little, we don't have calls or anything. I also always think the best system for grant funding-- Let's put it this way. There are different possibilities for grant funding. I think it's good if several exist next to each other. One is what the DARPA use, and I think there is this McKnight or something, some genius grant thing.

Paul Middlebrooks
MacArthur? Is it MacArthur?

Gabriele Scheler
Oh, yes. Probably, yes. What they do is they look for people who are already doing work which they like, and then they give them extra money.

Paul Middlebrooks
Okay.

Gabriele Scheler
No grant funding, no competition, and so on. I don't even think it's more-- The other model is more democratic, but it's not unjust or something, because not everybody gets money who has to apply for it. The people who apply and don't get it, they have unpaid work, quite a lot of it. That's why I think this second model about democratic spreading it to everybody is way too much. There's way too much of it, and there's way too little of the money.

Of course, it sometimes happens. I remember somebody from Stanford, she went to Harvard, and some rich family approached her and gave her money. That's, of course, also nice. I think it's best if there are all these different possibilities next to each other.

Paul Middlebrooks
You guys--

Gabriele Scheler
From our perspective so far, we have asked people whether they want to--

Paul Middlebrooks
Oh. Do you search for people then, or do you--

Gabriele Scheler
Yes.

Paul Middlebrooks
Okay. So they don't come to you, you go to them?

Gabriele Scheler
Yes.

Paul Middlebrooks
Yes, okay.

Gabriele Scheler
We're not making any calls for grants or so, because it would be ridiculous with the little money we have.

Paul Middlebrooks
That's why you're creating this spin-off, right, to generate more--

Gabriele Scheler
It's the hope that we could generate more money and build our endowment. That's my hope at the present time. If the endowment grows, then we have a regular income for the foundation, and that puts us on a safe basis, and we don't always have to hope that some donation comes in.

Paul Middlebrooks
Are you also seeking money from angel investors and stuff?

Gabriele Scheler
Sure, yes.

Paul Middlebrooks
Yes, okay. Okay. It just seems like a lot of--

Gabriele Scheler
For the start-up, clearly. I already have this problem. I have two developers that I will be talking to next week, and they both make a very good impression on me, but they're both people who cannot or would not work for free, so we have to see whether one of them may want to join the company.

Paul Middlebrooks
What do you have, like a pitch deck or something when you--

Gabriele Scheler
Yes, they're always asking for the pitch. I have something similar, but not really, because I don't do this VC thing. This is not really very-- It doesn't fit with my approach--

Paul Middlebrooks
Right, but you're in this situation where you almost have to adapt and--

Gabriele Scheler
Yes. Now, the goal is actually to come up with a platform also for a simple version of the platform in the near future.

Paul Middlebrooks
What do you mean? What's the platform?

Gabriele Scheler
The platform will offer algorithms, tools from the computational neuroscience world in order to build practical-- solve practical problems. It will come with one or two demos.

Paul Middlebrooks
Do you feel like you need to--

Gabriele Scheler
Then I want to see what traction we get.

Paul Middlebrooks
Are you going to be competing against benchmarks in current AI, that sort of thing?

Gabriele Scheler
No, it's more like when you look what AI is built on, then you will find that essentially everything is from the early '90s.

Paul Middlebrooks
[chuckles] Yes.

Gabriele Scheler
In that time, there was a lot of creativity around, a lot of different ideas and so on. That dried up. People did other things. What came later, deep learning, the transformer architecture, then this was called adversarial training and these-

Paul Middlebrooks
Generative Adversarial Networks.

Gabriele Scheler
- that were very derivative. Now, these things are not a novel. I think when you and I, we understand some parts of how the brain works-- Some of these observations could be put in a platform for people to use outside of our community. Inside the software developer AI community, see whether people become creative with it, or there's something with it.

Of course, I have more ideas which would happen if we had more money, but I've decided the best thing is to gain some traction with a platform before then again addressing. So far, the problem was with angel investors. They proclaim they don't understand it. That may be me.

Paul Middlebrooks
[laughs] Sure.

Gabriele Scheler
They have their minds full of this AI thing.

Paul Middlebrooks
Right. Yes. You need to work on that pitch deck.

Gabriele Scheler
Yes, but I said this is not-- What they now call AI, the reason it's interesting, it's because huge amounts of data. I think the reason why everybody put money on that, because this data is power. It won't be restricted to public data, or the problem of copywriting data. It will certainly be private data, data that maybe they shouldn't have, but they have collected, Google, Meta, and so on.

It gets to the point where they will use health data. Of course, they will say it's not individualized, but that is also a hard sell. They may have your health data. This is something I feel strongly about, because I know that at least German health insurance companies sell our data to pharmaceutical industry. Of course not identifiable, they say, but still they make money this way. You pay your insurance, and your insurance takes your data and sells them to the pharmaceutical company.

I had a person here in Munich, and she wanted to give a talk about it because they make these conclusions to death. They can tell you at a point when you are going to die on the basis of how often you went to the doctor or something.

Paul Middlebrooks
Oh my God.

Gabriele Scheler
They are pretty good. You think they can't. They cannot individually, but overall they're pretty good.

Paul Middlebrooks
Yes, I don't like that.

[laughter]

Gabriele Scheler
All these questions about data analysis rolled up into this AI. I don't mind the AI, but I do mind the data. What we do is something entirely different. It will, in the future, use the data that you want it to use.

Paul Middlebrooks
What does that mean?

Gabriele Scheler
Oh, the user will provide the data. When you use an LLM, all the data is already in there.

Paul Middlebrooks
Right, but as a user, I might not know which data to put in.

Gabriele Scheler
Yes, it depends on your problem, so one has to see how much. I admit it goes too far because I'd rather have the basics ready, the algorithms and so on, before discussing all the practical problems. It's not there yet. Since you asked for the Carl Correns Foundation, then I can tell you, yes, we didn't have enough donations to grow. I think we have to earn them with our own work.

Paul Middlebrooks
Fun. [clears throat] Okay. One of the reasons why I wanted to have you on, Gabriele, is because your interests-- You come at it from a very theoretical standpoint. I know that you saw some experimental work and thought maybe that's not for you. Because you're coming at it from a theoretical standpoint, you remind me of people like Steve Grossberg, who basically dabbles in a lot of different things, always coming from that theoretical approach. You have done a variety of questions that you approached. I want to talk a little bit.

For example, we won't talk in depth about your work on this, but you highlight that neuromodulators have been basically ignored in computational neuroscience forever.

Gabriele Scheler
That's right, yes.

Paul Middlebrooks
You have ideas about those. One of the things that I do want to discuss more in depth, because it crosses paths with a lot of previous guests I've had on the podcast, people like Randy Gallistel, David Glanzman, Hessam Akhlaghpour, which for a different reason that I'll bring up later. This idea that it's a single-neuron model that you're working on. The people that I've mentioned have made the argument that our memories, that we need something more permanent to store our memories. Memories are not stored in the synaptic clefts, for example, that we need like internal cellular processes, something more stable-- That's the word for it-- to allow storage essentially.

You have this model. You've taken that on, right? I can ask you this in a second, but you seem to more or less agree that the synapse is not where it's at with regard. You posit this model of a neuron where there are external processes, internal processes, and then core processes in the nucleus. Tell me a little bit. Presumably, is this what one of the things that's going to be available in the spin-off as well?

Gabriele Scheler
Yes, exactly.

Paul Middlebrooks
Okay.

Gabriele Scheler
We will have conventional neural models. That's exactly what we're working on right now. We want to have one of these novel models. The reason why I believe these are important, again, the good thing is why do we need such a model? The answer is in computer science. If you have complex blocks, then the system as such can be much simpler.

Paul Middlebrooks
Okay. What does that-- Elaborate on that, yes.

Gabriele Scheler
Yes. If I take a neuron, which is nothing but an activation function, and synapses which can change the weights, it is no surprise that I end up with neural networks the size of a city, because each element is so smallish and has so little possibility. I gave as an example already, deep learning imposes a structure on a normal neural network with a hidden layer. By imposing the structure, certain, a lot of problems become manageable, which mathematically you could express it with just one hidden layer. That would work.

The deep layer is more restricted. If you try to train a three layer network on the problems that they could solve with deep layer networks, you probably can't do it because it's a much, much larger, larger network that you would get. This is already a step away from the universality of the network towards a more special structure. This more special structure makes many problems easier to solve because the structure is smaller. Now, I believe when you take, instead of the neuron as an activation function, the neuron as a more complex building block with storage inside, which has the possibility of internal memory.

As such is-- Then when I begin to stack or combine these models, I will probably be able to have useful functionality with much smaller systems than I have now, even though I lose in generality, in universality. This is why it's tricky because we already know in the brain it works, and so therefore it should work. It's tricky because you have to make the right abstractions. If you take a building block, which is no good, so to speak. They probably can't build a system at all. That's what I say. There's the joy, there's the fun of it, there's interest in it, which I probably wouldn't have if I would have to worry all the time who's going to fund me next.

This thing, they don't like it. How can I position it so that some funding agency feels compelled to give me money for this? Isn't it the danger that they say, "Wow. What does she want there all the time," and you don't want to hear it and so on. I work over my grant proposals all the time, and I shout at my family. [laughs] You know what I mean? That's not worth it.

Paul Middlebrooks
Yes. Well, all right. Neuroscience for a long time has agreed-- writ large-- on the idea that all the information is in the spiking, and we don't need to worry about the ion channels, right? When we're explaining how cognition works, all we need to do is explain the pattern of the spikes and the way that the populations dynamically unfold in a low-dimensional space, et cetera, all through the spiking. We don't want to worry about the details of all the stuff happening inside the neuron. All of that stuff is for homeostasis and staying alive, and maintaining the ability to spike. You see it more, all of that internal richness. You see it as computation. How do you see it?

Gabriele Scheler
I see it as the problem of finding the right abstraction. I could easily say I don't want neuromodulation because it makes it more complicated. I know that is neuromodulation, it's very important. I ask myself, "What is the indispensable function which this offers to my neuronal cell? Why has biology kept it, and kept it, and kept it? Because I can do some very cool and smart stuff with it, and I want to have this in my model because I want to use this particular thing.

For instance, neuromodulation, as everybody knows, by activating neuromodulators, you can change the ion channel composition of the neuron, essentially changing their open probabilities via the G-proteins and the internal signaling. You can alter the ion channel membrane expression, and therefore alter the function of the neuron, it's activation function, for instance, on a time basis of seconds to minutes. This is obvious.

There is the alternative, the horror on the other side. You remember Henry Markram and this IBM Blue Brain and so on. I remember when he first got the money, and I remember that people made remarks that he won't use it properly, and that they built huge neuronal cells with all the biophysical and biochemical detail they could think of, and then they didn't know what to do with it. That's the danger on the wall, that you build all this neuromodulation ion channels, internal signaling, and genetic-

Paul Middlebrooks
Turn it on.

Gabriele Scheler
- regulation and then you say, "What is this thing good for?"

Paul Middlebrooks
Right. Okay. Then your approach differs. I thought it was one of the interesting things, is in the paper that I read where you talk about this. You

posit, "Here's the level of abstraction, right?" You say, "All right, I'm going to call these unknown variables that are occurring internally in the cell. I'm going to call these parameters. Instead of modeling the number of vesicles and how the ligands bind and communicate, et cetera., instead of modeling all that detail, you're saying, "Well, that can come later." Right now, I'm going to call all those things parameters, and then figure out what those parameters need to be doing, what those variables need to be doing to--

Gabriele Scheler
Yes, there's this one way. As you know, I've written papers before that were purely about internal signaling, and they easily had some hundred or so proteins, but reality is we have some 15,000 or so which may play a role. There is always these decisions to be made. Where do I draw the line or so? This is correct. This is what I said. This would be the wrong approach.

When you say, "I have 15,000 relevant proteins," in order to understand internal signaling and get the parameters at the external membrane which I need, I need to build a dynamical system of 15,000 variables. At that point, maybe you get the money for it even, because the funding is always very crazy.

Paul Middlebrooks
Well, yes. In that case, you can point directly and say, "We know these exist, and therefore they're important, and I'm going to do something with those, which is different. What you're doing is much more abstract, saying it doesn't really matter what exists. There's a computation that has to occur, and we'll figure that out later.

Gabriele Scheler
Exactly. Yes, because I said the simple thing is, of course, to have an individual learning rate. You assume that internal signaling somehow figures out the level of plasticity that the cell undergoes. You could say that the cell has zero plasticity at some point, and then there is some internal signaling going on, and this raises the plasticity level of the cell. That would manifest then on the external membrane level as simply as a learning wave.

Paul Middlebrooks
I just had Mitya Chklovskii on the podcast, and he views every single neuron as a controller, using what's called data-driven dynamics. The cell is trying to match, see how its output affects its input, and then it changes what it's doing based on that mismatch. One of the things I'm curious about that I want to ask you is, how does the cell know when to be plastic? What is that internal reference signal that the cell is aiming for? How is it so smart? How does it know what to do?

Gabriele Scheler
Well, to a certain degree, I think there must be a lot of accumulation of evidence going on. Similar as in decisions, you have to accumulate evidence from several sources until you have a critical amount, which means that you're going to persist in more, for instance. When you mentioned Chklovskii, I think you were right. That was one of the few novel neuron models which I've seen in the past. I was very happy with somebody also. We said we have essentially just one type of model in all of computational neuroscience.

Paul Middlebrooks
Oh, the abstract point processes?

Gabriele Scheler
Point or not point, it is always the model of-- Essentially, we have a model which tries to explain when the neuron spikes.

Paul Middlebrooks
Yes, that's the thing to explain. Yes, that's funny actually. [chuckles]

Gabriele Scheler
As a matter of fact, we think that in our model, we want to have a rate model. We want to have a rate which changes over 100 milliseconds.

Paul Middlebrooks
The rate is just the average amount of spiking over some time.

Gabriele Scheler
Exactly. In that 100 milliseconds, it either spikes, or it spikes two times, or whatever. Within a second, it spikes 1 time or 10 times. It has its frequency because that is one of the earliest things I found about neurons having different intrinsic frequencies and sticking to them very much. This was back in 2006, at a time when people reported on neurons always in averages. Suddenly it occurred to me that this can't be right, and I tried to get the data from the experimentalists. They said, "No. Of course, they're not all alike. They're different." I look at it and I say, "Look, it's a lognormal. It's a power law."

Paul Middlebrooks
This is your lognormal working?

Gabriele Scheler
Yes. The experimentalists, they didn't care.

Paul Middlebrooks
Describe what that is, for the record.

Gabriele Scheler
Well, the thing is in theory, what people did is they initialized all neurons with the same way. You had homogeneous neurons. They were all initialized as if they were all alike.

Paul Middlebrooks
They were like integrating fire-type neurons?

Gabriele Scheler
Yes, and the parameters, they were all alike. For instance, they all had 10 hertz, for instance, all of them.

Paul Middlebrooks
On average? Okay. Yes. Sure.

Gabriele Scheler
Yes, and every single one was the same as every other.

Paul Middlebrooks
Then they would do cognition by modulating within some range of those recoveries.

Gabriele Scheler
Yes, it was an ideological thing about emergence from interaction of identical particles. Therefore, the neurons had to be all identical from the ideology. The experimentalists knew that but the theorists didn't care.

Paul Middlebrooks
What is lognormal, and why is it important?

Gabriele Scheler
Well, it turned out when I build a neural network with all these different kinds of frequencies, with the high-frequency neurons and low-frequency neurons and so on, then as a matter of fact, I have not mathematically been able to prove or show this, but I get all these effects like I did with the symbolic paper. I get the effect that the information content concentrates in only a few neurons, because the neurons which have the highest fire rate also have the most connections.

Paul Middlebrooks
Now, you're talking about your mutual information work as well, right?

Gabriele Scheler
Yes, that derived from that, because I have all these different neurons in my model.

Paul Middlebrooks
Okay. All right.

Gabriele Scheler
They are not initialized in the same way. They're initialized over a range. I have long models and I have many low firing neurons and a few high firing.

Paul Middlebrooks
Is that important because it allows the system to be scale-free? What is the importance of that distribution?

Gabriele Scheler
Good question. I can't really say too much about it, really. I always focused on the idea that what it means is that I have Hub-and-spoke neurons, that I have--

Paul Middlebrooks
Hub-and-smoke neurons.

Gabriele Scheler
Exactly. I have a structure of important and lesser important neurons.

Paul Middlebrooks
Small world connections.

Gabriele Scheler
Then it was my idea that the important neurons need to speak to each other without regard of the lower important neurons and such ideas. In this paper, I actually wrote this down that I hope somebody with more mathematics could prove just how many patterns you could really-

Paul Middlebrooks
Oh.

Gabriele Scheler
-store in such a network. I would like to know whether the storage capacity, for instance, is comparable to an associative memory network. It's not for me to calculate these things. It would be great if somebody did that because, at this point, I don't really know. I don't really know whether it's actually really much better in terms of the number of patterns you can store in a memory, or whether it's just comparable and really no improvement at all. I don't think it is worse because I've looked at the numbers, and they seem higher for associative networks. The usual thing is you take a vector, and you store the vector, and you store the next vector and the next vector.

If there are orthogonal or so, then you have so and so many vectors that you can store per size of the network. That has been done and has been calculated. I don't know how a man would calculate it in this case.

Paul Middlebrooks
What does vertical and horizontal functions mean in your single-neuron model?

Gabriele Scheler
I already wonder whether it was a good choice of words because the internal and external is in a way sufficient. It's much more intuitive. The idea was the neuron has its connections to other neurons, and there's calculations going on in a network. You could call it a horizontal network for calculating information. Then on the other hand, the neuron has, as I said, 15,000 or up to 70,000 different proteins. They interact with each other in an internal signal network. There is a lot of-- There is the metabolic network, of course, which overlaps with it.

There are many, many proteins, and they have certain rules of how they interact, and how they run as a dynamical system. It has any amount of complexity comparable to a neural network. Other people have same ideas. I saw a neuron model where somebody said, all this dendritic integration, we just throw a multi-layer perceptron into the neuron. Then the neuron gets inputs, does a multi-layer perceptron kind of thing, and gives the output. Here we have essentially a neural network inside the neuron. If I model the protein network as a neural network, then I have a neural network inside that would be the vertical.

Paul Middlebrooks
Wouldn't it be more like a graph neural network though? Maybe that's too technical because there's-

Gabriele Scheler
No idea-

Paul Middlebrooks
-no networks.

Gabriele Scheler
-but that would be the vertical. I have the neuron and I have the vertical. Yes, I have a whole complex signal network here, a dynamical system. I can model it with the help of ordinary differential equations, which is nice, but also, as you know, very complex because as soon as my concentrations are not very precise, then this network may give any information because they're too many.

Once it's more than three or four, it goes out of-- they become larger and larger. One could say that neural networks have a lot of success because they don't have these problems. They're not built from differential equations. As soon as you have a couple of wrong concentration in network, the result is completely not useful. Then the neuron interacts with 15,000, 100,000 of other neurons, making a computation, even though inside of itself, it has approximately the same complexity in terms of calculating its own activity, its needs, its metabolic needs, its ability to read out DNA information.

When do you need which DNA information? When do you want to have more AMPA receptors? When do I need additional dopamine receptors and so on? Always have to talk to the DNA.

Paul Middlebrooks
That's a lot to keep up with. Is that when epigenetics becomes important to the signaling at the nuclear timeline?

Gabriele Scheler
Yes, the epigenetics becomes very important for them. Exactly. It's almost between it. There's no loss of complexity in this vertical cellular environment. This is amazing.

Paul Middlebrooks
The thing is I don't want to keep track of the thousands and thousands of proteins, right? I want to just be able to say, okay, at some level, I'm just going to model this as a dynamical system. I think that's comforting to someone like me who I don't want to talk about the ion channels when I'm talking about working memory, or trying to explain working memory. I know that those things are important. If it is the case that we do need that internal cellular machinery, that it is essential for our cognitive process as part of that story. I want be able to model it at a level of abstraction that I'm comfortable with.

Gabriele Scheler
Exactly, that is the point. I personally am fascinated with this world, and I would love to go into details and read up on every single protein because every one of them is fascinating. I agree with you, and that's the advantage of trying to do something functional in computational science, that you have to tell yourself just by studying what BDNF does in all circumstances. It's not going to help the function of the model. As you said, we need then a proper amount of abstraction.

Paul Middlebrooks
Aren't you tempted though? Because you're opening that book, aren't you tempted to read all the words in the book then? Are you like me and you want to keep it somewhat at bay?

Gabriele Scheler
Unfortunately, no. I am that person. That's why I did linguistics in a way and even started to learn different languages, and so there's lots of details, information. I didn't mind that. Of course, my goal was to understand how languages operate, but I didn't mind learning a couple of languages.

Paul Middlebrooks
Yes, but that's the thing. We want to understand how languages operate, and now you're going to have to study the nucleus of a single neuron? It seems like a stretch.

Gabriele Scheler
That is really interesting. I had a conversation with a botanist who is actually a specialist on Mendel, and maybe we're doing an interview or so, but I don't know. He said, well, it sounds strange, but if you think of it, it's logical. If you want to understand how thinking works, you need to understand the nucleus of the cell, because-

Paul Middlebrooks
That's not obvious.

Gabriele Scheler
-that's what we use. That's what he said.

Paul Middlebrooks
Yes, but we also use atoms, and we don't have to understand atoms to understand thinking.

Gabriele Scheler
Our thinking uses exactly these things. The idea that the electrophysiological events are sufficient for the-- let's say, cognitive content of what's going on in the brain, that is already put at absurdum as soon as you, let's say, smoke some cannabis.

Paul Middlebrooks
Which we'll do together right after this interview.

Gabriele Scheler
Just as an example. It works in your brain, but it works on those CB receptors. It goes to the G-protein. The G-proteins affect your ion channels. It goes into the cell, all kinds of places, certain parts of the brain, and your processing is different. Don't tell me that a neural network with electrophysiology would be sufficient.

Paul Middlebrooks
Well, okay. Right. What I want to say, the way that you just described that, I want to re-describe it by saying that smoking the weed alters the shape of the manifold that I'm operating under. However that is, whatever those constituent parts that give rise to the emergent property of a manifold, I don't know, G-coupled receptors, cannabinoid receptors, fine, you can talk about that. At my level of wanting to understand these things, I can just talk about the dynamical system aspect of it.

Gabriele Scheler
I have my doubts about that. Think of something more drastic. If I call you names now, it could happen that your adrenaline goes up, and that's some way down in your kidney, right?

Paul Middlebrooks
Do it. Call me names. Let's do it.

Gabriele Scheler
No, it wouldn't work right now, because you're laughing, but I know what you mean. You can be in a situation when somebody talks to you in a very angry way, and your adrenaline goes up, and your whole body goes into fight or flight mode because of the tone of voice or just the words that you heard. If you just read them, that's not even clear. It's only blank.

Paul Middlebrooks
Now of your account on that, that's exactly what will go eventually into the media, and then we'll have the anger molecule, right? Dopamine, right, is the happy molecule or whatever it gets to--

Gabriele Scheler
No, adrenaline is very important. The brain is very similar to dopamine, and it certainly activates all kinds of neurons in your brain, and also change the ion channels on the operation. Yes.

Paul Middlebrooks
I think it'd be fun.

Gabriele Scheler
If you don't watch out for 20 minutes, 30 minutes afterwards, that your cognition changes, because you're still angry at the email somebody wrote you or something.

Paul Middlebrooks
[laughs] Yes, I had to give a talk.

Gabriele Scheler
I just want to make it clear that this talk about electrophysiology and some dimensions which change or so is too far away from the properties language really has, or what our brain really operates.

Paul Middlebrooks
How would this-- Let's say you are successful in your endeavors to model neurons this way, right? Some are important with high mutual information. You need these vertical and horizontal accounts, this internal machinery. How would that change Artificial Intelligence? Do you care?

Gabriele Scheler
Yes, that's what I'd say. Once we have complex building blocks, we can build simple systems, and with building blocks are adequate for the tasks that we want to use, namely human cognition. I make this different. I told you that I make this different with engineering and actually building the original idea of Artificial Intelligence with a small field of computer science. It was only building systems that are like human-like intelligence. They've changed the meaning all the time.

If you just build a system that does a certain task, that's engineering. These days, it's also called Artificial Intelligence. The original Artificial, which I stick to, was actually building human-like models.

Paul Middlebrooks
The old GoFi--

Gabriele Scheler
Yes. If you want to do that, and if you have the building blocks from the brain, if you can build it like a brain, then we should at least be able to get away from these absolutely huge, and wasteful, and essentially dumb, huge models.

Paul Middlebrooks
That's funny. The rote response, or the very typical response when I say often-- This podcast is called “Brain Inspired.” Often I point to the fact that modern AI doesn't pay any attention to brains, and what a shame that is and stuff. Often I have neuroscientists on and I say, "Well, what do you think of modern AI? Without fail, they have to say, "Well, of course, I'm very impressed with the abilities of modern language models and stuff.. I sense that if I asked you that, you would not begin."

Gabriele Scheler
No, I'm not impressed in the least. I know very well how they work. As I said, there's my friend who’s building something in Austria. Long before

the Chinese with DeepSeek, he already showed that you can shrink it enormously. Then these people came about and so on. It's pure engineering. Actually, language as such is not so complicated. The number of words we use.

Paul Middlebrooks
Thank you for saying that. I feel, yes, thank you for saying that.

Gabriele Scheler
As I said, the number of words we use in everyday discourses, that's like some 10,000, 20,000 words. We are able to communicate in spite of that and quite a lot. That's the interesting part. What interests me is not so much the tool of communication that we use, but what is behind it. With the simple words I use, I'm still able to cause you to come up with similar things and ideas that relate to it, which are interesting to me.

Paul Middlebrooks
Right.

Gabriele Scheler
Right? In spite of we have so few words, but in spite of that, because we have these complex memories and experiences and so on, that's a way to access it.

Paul Middlebrooks
You Germans, you have many more words than-- Actually, neologisms are perhaps the German languages--

Gabriele Scheler
Yes, full of them. That's true. Yes.

Paul Middlebrooks
Best example of that. Yes.

Gabriele Scheler
Everything is always a word. Yes. Every new expression, many new expressions can be used as a word, right?

Paul Middlebrooks
Okay. Then that's AI, right? Okay. What I originally asked you there was how this model would change AI and what would it just-- It would make everything more efficient, or your pro-symbolic approach to AI, I suppose.

Gabriele Scheler
Yes. Yes. Yes. There are also people. There's a whole movement, the neuro-symbolic, where they are trying to put these things together, but are already trained in horror because there was a lecture, "How to put logical reasoning into large language models."

Paul Middlebrooks
Okay. Gamble it in there.

Gabriele Scheler
I'm so, "Ooh, no, no, no, no." Just the other way around. How to employ Large Language Models to give you the information you need for your reasoning, that would be my type of question.

Paul Middlebrooks
Okay. Explain this to me more. You don't want to put reasoning ability into the model. You want to use the model to--

Gabriele Scheler
To give the knowledge that I need for my reasoning.

Paul Middlebrooks
Oh, okay. Just use it as a tool, you mean, not--

Gabriele Scheler
There's still the old problem of Reagan. This old problem in AI was, of course, always where do we get our common-sense information from? These people have made good progress. Then there was always the question, "How do I immediately know that I don't know something? There, the LLMs are not so great.

Paul Middlebrooks
Oh, okay. Yes. Well, they're not great. There's a cottage industry of showing what they're not great at.

Gabriele Scheler
Yes, they make it up then. They like to make it up when they don't know something.

Paul Middlebrooks
Do you use LLMs?

Gabriele Scheler
I don't know. I don't remember the examples, but I don't know whether it's a good example. It's like asking you, "Did you see Nixon or so?" and you immediately know, yes, you met him or no.

Paul Middlebrooks
Right. [chuckles]

Gabriele Scheler
Yes, because it's Nixon somehow. Let's say Reagan.

Paul Middlebrooks
Nixon, Reagan, these are old references, Gabriele.

Gabriele Scheler
Yes, okay. Look at them or maybe--

Paul Middlebrooks
Say Obama or something.

Gabriele Scheler
Exactly, or Clinton. If you ever meet Bill Clinton, you would probably be able to answer that. Yes.

Paul Middlebrooks
Yeah, Charlie Chaplin. You're going to-- [laughs]

Gabriele Scheler
Okay. Yes, I know. It's this ability to immediately be able to-- You don't have to think about it for a long time, whether you ever met him, you know the negative.

Paul Middlebrooks
Right.

Gabriele Scheler
The LLMs don't know their negatives.

Paul Middlebrooks
Okay.

Gabriele Scheler
Not very well.

Paul Middlebrooks
Add it to the list, yes. It seems like any criticism of AI, then it eventually gets fixed, right?

Gabriele Scheler
I know that's what they say, but you can't fix. Look, this is something simple. You cannot fix the fact that there are always a high percentage of errors in it, or that they have this hallucination, because if you train a neural network, and you train it perfectly, then you have over-fitted it, you've over-trained it, and you have no generalization. In order to get a generalization, you have to leave off, and even the training has to be below 100%.

Paul Middlebrooks
There's that-- After that dip on this is where big data comes in, right, and lots of training where generalization decreases eventually, but then it re-increases. That is like-- Uri Hasson talks about this phenomenon as direct fit, where you actually-- We are over-fitting, and that's how we generalize, because we're interpolating. We fit so much that it encompasses everything we need, and that we don't need to intentionally over-fit.

Gabriele Scheler
This is just in the areas where we believe we have no lack of data, but in very many areas we do have a lack of data, and always will. They automatically assume that you have tons of data, but you don't always have them.

Paul Middlebrooks
We don't have maybe the right data.

Gabriele Scheler
Yes, that too, but that also. In general, I would say, right now it's a low-hanging fruit. You see all the results from the areas where lots of data exist.

Paul Middlebrooks
Right, which is the stupid Internet.

Gabriele Scheler
I still remember teaching in the beginning, teaching the GPT tool about Saterlandish. That is a Frisian language in North Germany. I asked him about it. He didn't know it, and so I explained to him that it was an upper Bavarian dialect and so on. The system happily responded and told me, "Yes, now I know what it is. It is an upper Bavarian dialect and so on."

Paul Middlebrooks
Sure.

Gabriele Scheler
Yes, I don't know. It was not-- I don't like these systems. It was not-- One time it's fun, but the second time it's not fun anymore.

Paul Middlebrooks
[laughs] That's funny that you called the system him and he.

Gabriele Scheler
Yes, that's true. Yes, that's-- I should call it "it", but it is a German--

Paul Middlebrooks
Yes. Is there anything that we didn't discuss that you wanted to highlight? I'll point people to the Carl Correns Foundation website and to the work.

Gabriele Scheler
Certainly. If somebody directly asks us, sometimes something can be done, but of course, it's easier if they want to donate than if they want to do some work and get some funds for it. The second is always more difficult. In general, of course, we are open to all kinds of questions and collaborations.

Paul Middlebrooks
Great. Okay. Right after this, I'll go start my non-profit and see how far I can take it.

Gabriele Scheler
Yes, that would be great.

Paul Middlebrooks
Okay. Gabriele, thank you so much for joining me, and continued success with your work.

Gabriele Scheler
Yes, thank you.

[music]

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