

The Vitals—The Future of Brain Surgery transcript

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Genomics to Neural Code

Ben Rapoport: If you think back to that moment, the first human genome was sequenced, right? That was like a pivotal moment in, in genomics. And what happened after that, nobody, almost nobody would've predicted, right? Right. Nobody really, really knew what was gonna happen when we could sequence many human genomes and sequence them quickly.

Well, the neural code is another biological code. It's a different code. It's dynamic, it's two-dimensional or three-dimensional, but it's another biological code that we're now able to compute on.

Welcome and Big Picture

Leslie Schlachter: Hello, and welcome back to The Vitals, the Mount Sinai Health System's groundbreaking roundtable video podcast. I'm your host, Leslie Schlachter, a neurosurgery physician associate here at the Mount Sinai Hospital. On this episode, we're discussing something near and dear to my heart and my brain, and that's the state and future of brain surgery.

Every day, I see and speak with patients in need of some form of neurosurgical intervention, and [00:01:00] since I've started in this role, I've witnessed personally the incredible advancements made in this field. So what is the current state of neurosurgery, and what are the biggest advancements on the horizon, particularly related to artificial intelligence and BCI, which is brain-computer interface?

And we're really lucky to be here at the Mount Sinai Health System, where we are one of the world's leaders in brain-computer interface. So to walk us through these answers and to these questions, we're joined by three giants in the neurosurgery field, Chairman Dr. Joshua Bederson, Dr. Benjamin Rapoport, and Dr.

Shahram Majidi. Thank you so much for being here. Okay, so let's start with the big picture. What do you think the future of brain surgery is gonna be 10 or 20 years from now?

Josh Bedersen: Well, it's a rapidly evolving area. We're learning more about surgery and the functions of the brain on a, what I would think of as an almost weekly basis, and the technology's [00:02:00] evolving in a way that parallels what we're learning about the brain and how to access it.

My own practice over the past several decades has changed to something that I don't think I would even have barely recognized- Mm-hmm ... when I started. Uh, so I can't presume to know g- everything. Uh, but I do know the problems that we face now that seem very important at the moment, uh, that I believe we'll have solutions to.

Future OR Tech and Sensory Restoration

Josh Bedersen: And I could go on for several hours about what those problems are and what those solutions will be, but they'll include things like robotic assistance that would prevent me from hurting a patient, that might guide me through a very critical pathway deep inside the brain to get access to the patient's pathology.

Um, our sensors are becoming ever more sensitive and more precise, and we will be able to detect the signals of the brain and translate those into meaningful functions for patients Um, I'm just [00:03:00] barely scratching the surface there, but those are a couple of ideas that come to mind.

Leslie Schlachter: When I first started working with you, I thought of brain surgery as, like, you make incisions, you do what you gotta do into the brain, and you leave.

I didn't fully understand the technology that we use, even just the basics of navigation, which is like a Waze system for the brain. So the use of just technology, simulation, getting ready for surgery, and navigating surgery, that's kinda like the basics now. What do you think is gonna be, 10 years from now, the technology that we're gonna use actively in the operating room to help you with surgery versus the technology that we'll use once it's implanted out of the OR?

Josh Bedersen: Uh, well, that's a, you know, that's a complex question. Again, many possible answers. Uh, but I think things that are currently being

researched now. For example, the ability to stimulate parts of the brain to reproduce sensation, s- [00:04:00] sensation in your hand, the sense of sight- Mm-hmm ... the ability to hear or taste That's experimental now.

I think it's gonna be, in 10 years it's gonna be part of our almost daily armamentarium, that we will be replenishing, replacing, and enhancing senses that have been lost in patients through brain-computer interfaces such as the ones that, uh, Ben Rapoport and, uh, Shahram Majidi work on right now. Uh, I think that's gonna be routine.

I, I, I truly think it'll be part of our weekly effort to restore function.

Leslie Schlachter: Yeah. Can you tell our listeners about the project that you're working on? 'Cause it truly is BCI, but start, define BCI and then tell us about your project.

Ben Rapoport: Okay.

BCI Basics and Patient Impact

Ben Rapoport: Uh, well, brain computer- BCI stands for brain computer interface, and a brain computer interface is a system that, um, some people like say translates thought into action.

It, [00:05:00] um, allows, uh, it allows us to record from the electrical signals of the brain, which are the sort of physical manifestations of thought, and translate those electrical impulses into, um, a digital language that a computer can understand so that a person's thoughts can be translated into interaction, direct interaction, um, with a computer system or, uh, a robot, a robot, um, in a way, in a way that in real time allows somebody to have thought-based control of a digital ecosystem or a robot extension of a computer.

Leslie Schlachter: So what has that meant for our patients so far?

Ben Rapoport: Well, the, the origin of this technology and the goal is to enable people who have paralyzing injuries, uh, to regain lost function. So think of somebody- So

Leslie Schlachter: a movement.

Ben Rapoport: A movement or the equivalent of a movement. So think of somebody who has, uh, a spinal cord injury that leaves them paralyzed from the neck down.

Oftentimes, these are young people. Uh, think of a 30-year-old who may have a family, has a job, people [00:06:00] depend on them, gets into a tragic car accident and is still sound of mind, but unable to move, essentially from the neck down, unable to move their hands, unable to walk independently. That person's life is totally transformed even though they may, uh, be just as motivated, if not more so, to, um, to um, have a job and take care of their family and so on, um, and what prevents them from doing all the things they used to do, uh, at least in today's world, in 2026 is, um, seamless access to digital technology signi-significantly.

I mean, of course- Mm-hmm ... they wanna get up and walk and do all the things that they took for gran- that we all take for granted in the physical world. But going to work in 2026 and communicating with your loved ones is substantially a digital process. So the ability to convert thought and intention to, um, manipulating a, a computer interface takes a significant, um, fraction of all of our lives.

So enabling somebody who's paralyzed to go back to work in the [00:07:00] workplace, um, often means just enabling them to have control of a desktop computer. Uh, it doesn't necessarily mean that they need to move their arms or move their feet. And if you unlock that ability, um, it actually transforms an individual's life.

I know Shahram and I and our teams have spent a lot of time thinking about what does it take to move the needle for somebody who's, um, a quadriplegic or has, uh, you know, pr- significant paralysis from a stroke or from ALS to go back into society in a way that, um, you know, we kind of took for granted before the injury.

And to a significant extent, that means being able to operate seamlessly in the digital world because if you think about somebody who, for example Can't hold their job and has a, a, a spouse or a loved one who's come away from their work to take care of the individual with the condition. Um, even just the finances of that person's life, um, are transformed from enabling them to have seamless control of a desktop computer and go back to [00:08:00] work.

Leslie Schlachter: So how do you get there? That all made it sound like this was just flipping a switch. It is not.

Ben Rapoport: Right. Good point. What's

Leslie Schlachter: the logistics of actually doing this?

Ben Rapoport: Un- understanding how a brain computer interface works first requires understanding that the brain is an electrical system, and that means that the brain communicates with itself and with the outside world using electrical signals.

And we can record those signals, and now with 2026 technology, we can record them in real time at a very fine spatial resolution.

Leslie Schlachter: But this involves a brain surgery. Uh- You have to, like, get in there.

Ben Rapoport: Correct. Correct. Correct. So the recording of those brain signals requires, um, an electrode array, meaning a group of tiny little electrodes that touch the brain in some way to record the electrical signals.

Leslie Schlachter: Who's letting you do that to them?

Ben Rapoport: So, um, well, the, the target population, uh, are people who have paralyzing injuries. And, uh, and so some of the individuals involved in these studies are people who have had paralyzing injuries or who have had loved ones, uh, ha- have paralyzing injuries such as a stroke, and are they [00:09:00] themselves, um, going through another brain surgery, for example, to remove a brain tumor or to study an epi- you know, to study the root cause of their epilepsy or surgery for Parkinson's disease.

Uh, the s- the patients in our current studies, um, have-- are patients who are having brain surgery for a reason unrelated to a paralyzing injury. Shahram, I think, can speak to a different stage in the R&D pipeline, um, which relates to people who are themselves paralyzed and are, uh, the first recipients of this- Right

uh, technology.

Leslie Schlachter: Before this started, we were talking a little bit about why you think this is the most exciting time for BCI. Um, why is now the most exciting time?

Majidi: Yeah. I argue that this is the time. We are truly at the inflection point for BCI, and that's not just because of the neuroscience foundation of it, which isn't, isn't new.

It has been around for decades. But we can really take BCI outside the lab to the large population of the patient. And [00:10:00] I would argue that BCI is not about connecting brain to the computer anymore. We are at the point that we-- now we are connecting patients to the world, especially the one that-- who has lost the communication because of various, uh, disease processes.

Leslie Schlachter: So it's more like using technology and the computer to teach the brain how to manage itself. Or to connect with itself? Is that what you're trying to say?

Majidi: Uh, c- uh, connect the, connect with outside device

Josh Bedersen: To connect to the world. So the problem is the loss of connection between the brain and the world due to an injury, due to stroke, due to degenerative d- diseases like ALS, and that connection goes both from the brain to the world.

You're trying to operate a computer system or maybe a prosthesis, but it also goes from the world to the brain. Um, [00:11:00] it's, you know, many people in the audience will have tried to operate, uh, a joystick or a mouse, and you could see the cursor moving on the screen. You're interacting with the computer there, and you're moving a mouse, but it's, it's still a machine interface.

Leslie Schlachter: Right.

Josh Bedersen: The other part of this discussion that really interests me, and I know that my colleagues here are also interested, is the concept of taking information from the outside world and feeding it into a brain that has become disconnected from that world. In that scenario, when we reproduce those signals in the brain properly, and as we learn to do that, we could potentially feel the movement of a mouse. A joystick or a computer interface, a prosthesis- Mm-hmm

so that it wouldn't feel like operating a machine anymore. Pres- presumably would feel like operating your own hand. And likewise, the same is true with a visual prosthesis. The, the way the visual [00:12:00] cortex works is it's activated electrically by signals that originate in the eye. Instead of those originating in the eye, those will originate in a camera, um, and we feel we

should be able to reproduce those signals in the brain so that people can see what the camera is seeing.

So the, the concept here is not to connect the brain so it will teach itself what to do, but to connect the brain and the person, uh, whose brain that is, to the outside world to both manipulate and control the outside world, but also to live in it and to perceive it and to feel it better.

Ben Rapoport: Hmm. One really interesting question that I find our groups asking in one way or another is wh- what, what's the natural way for the brain to interact with the outside world?

When you think about typing on a keyboard or moving a mouse or using a joystick, these are kind of these artificial, in some ways, mechanical [00:13:00] interfaces with the digital world that we've come up with over the years for, um, how to get information into a computer. Right. Um, and they have to do with the fact that we have developed evolutionarily the ability to use our hands, use our voices, and figuring out how to use that as an intermediary to getting information into the digital world and so on.

But, um, we all have this intuition that we seamlessly interact with the world. Our thoughts don't exist in joystick or keyboard or mouse terms, and is there a way for us to decode what the brain is doing at the level of intention, uh, that goes one level higher than mouse movement, keyboard movement, all these things that we learn when we're learning how to interact with

Leslie Schlachter: a computer?

I mean, I want that. I want my thoughts of what I need to order from Instacart to go into my cart and then be delivered tomorrow with me doing nothing other than thinking.

Ben Rapoport: Exactly. So- That would be great. So, so this is a... That concept is actually a deep concept in modern artificial [00:14:00] intelligence, and it's something that we've been, um, really in practical terms trying to, uh, implement through the world of brain-computer interfaces.

So I think that's an interesting, um, thread there, and another one that, that I think we can talk more about is, you know, I think if you think about the stereotype of a neurosurgeon, um, you know, from 10 or 20 or 30 or 40 years ago, uh, as the kind of cowboy surgeon that, that some of us have, you know, in mind, that, that I think is not the...

There's no one archetype of a surgeon, let alone a neurosurgeon. But I think that, um, that, that there, there is maybe an archetypal neurosurgeon of the 2030s, 2040s, which looks very different from what the- Right ... you know, the Cushing, Harvey Cushing, you know, era neurosurgeon looked like, um, where a lot of what needed to happen in the operating room, you know, decades ago, um, happens outside of the operating room in today's world, whether that's [00:15:00] pre-planning or programming an interface because of, for example, modern imaging techniques or, you know, the ability to analyze data that is available to us before surgery.

Some of the, some of what used to be exploratory in the operating room where you would expose the brain, you would find something using anatomic landmarks, and then you would do something to that tissue based on what you saw, a lot of that is done in the planning stages before surgery. Um, and, and so we c- we are able to do things in a much more minimally invasive fashion.

And so the, um, kind of exploratory, uh, aspects of surgery have, uh, in certain respects been reduced. And so the nature of intervention has become more and more precise, um, whether that's endovascular or through, um, electrophysiologic means. And, uh, and also our ability to program after the fact, um, and, and tune what we have done in the operating room, that, that [00:16:00] is, uh, also a kinda a theme of, I think, modern neurosurgery.

We're talking about implantable devices that are electrical in nature, that have a software component also. And so what you do, the intervention that you do physically with the brain exposed in the operating room is only a piece of a larger puzzle- Right ... where, um, what happens afterwards is involves data gathering and personalization of the interface.

And the neurosurgeon of today and of the future is actually a part of all of, of that whole process, of the intake, the studying of the brain before the act of surgery, and the programming and tuning of the interface so that the therapeutic benefit is maximized even outside of the operating room. And so I think, like, what a neurosurgeon does in 20- 20- 2036 is gonna look very different from what, you know, was happening decades before.

Leslie Schlachter: So-

Majidi: To your point earlier- Yeah ... though, uh, Leslie, we are not literally, uh, reading your mind or thoughts with BCI. What we do, imagine you intend to move your hand or speak a word [00:17:00] or perform an action. Brain computer interface will capture that specific, uh, electrical activity from a

population of neurons in the brain, will decode that to a certain command, like computer, uh, moving the, uh, cursor or click and doing a different, uh, performing different task.

So not reading thoughts or mind at this point, but-

Leslie Schlachter: Well, that, I like that you say that, but a lot of people listening to this, I mean, this is the world that we live in so that we n- like, we know this is happening But other people are gonna look at this and be like, "Well, when-- what else could they do?" Right?

So the goal here is to get a body part moving, right, through thought. Um, potentially vision through thought or camera or whatever. But w- like, there's gotta be more to that, right? So we have deep brain stimulation for things like tremor, w- [00:18:00] OCD, depression. There's gotta be eventually a BCI for addiction. Um, people right now are taking shots.

Everyone's taking GLPs for weight loss. Why not a BCI for overeating or addiction or drinking? That doesn't sound so crazy.

Josh Bedersen: No, it doesn't. And some of the work that we're doing with, um, Dr. Rappaport's electrodes now are actually getting towards the decoding of emotions.

Leslie Schlachter: Right.

Josh Bedersen: Um, in fact, in two recent patients, we looked at What is the cortical signal, uh, th- that is different between when someone smiles-

Ben Rapoport: Mm-hmm

Josh Bedersen: and when someone sticks their tongue out. And, uh, even in the first two patients, it's possible to see a significant difference in the cortical activation of an emotional response from one that just activates facial muscles. So you're right. It's [00:19:00] moving in all kinds of directions beyond motor and sensation.

Um, it would be nice at some point if we could modulate and moderate destructive behaviors- Right ... and dangerous ones or things like depression. And as you know, there is a pivotal trial going in now- Mm-hmm ... for a brain-computer interface modulation of depression in the form of deep brain stimulation. Uh, but you're right.

It's, it's the possibilities for expansion are there.

Endovascular BCI and Epilepsy Interfaces

Leslie Schlachter: So in our, in our world of neurosurgery, we actually have a couple different types of doctors that work in our practice. We have our neurosurgeons who perform open neurosurgery, but we also have neurosurgeons that do endovascular. We have neurologists and radiologists that do endovascular.

So can you kinda just give us like a general overview of your world of endovascular, of what is currently being used that fits into like the BCI that [00:20:00] patients actually have access to, even if it's in research?

Majidi: Yeah. So the endovascular neurosurgery or neurointerventional surgery is a rapidly evolving field, uh, with a massive amount of technological advances in recent years.

Most of my time in clinical practice is, uh, dealing with vascular diseases in brain, whether it is brain aneurysm, arteriovenous malformation, fistula, things related to brain or, uh, stroke. However, now BCI is also coming in as a, uh, a subtype of, uh, at this point, research aspects of our field is rapidly evolving because now we found out that we can use the brain vessels as normal highways of the brain to reach the certain area of the brain without violating the brain anatomy.

It's really fascinating, and the re- uh, the past 10 years have shown us that [00:21:00] we can safely reach those targets and- Uh, record the brain, stimulate the brain, and perhaps, uh, do some neuromodulation. So, uh- Is

Leslie Schlachter: that the, the Synchron device that

Majidi: you're speaking about? So the Synchron device is one of the, uh, uh, endovascular BCI, uh, platform that, uh, is actually the most advanced one, uh, uh, in terms of their, uh, development, and they are now in the second stage of their clinical trial.

Mount Sinai has been the leading center at, uh, at that trial. Uh, in early phase, we, uh, demonstrated, uh, safety of, uh, endovascular implantation of Synchron device. Now we are f- uh, expanding that to a larger patient population. But we

should also remember that at some point, that we should start thinking about how we, uh, we are helping this patient.

We should define some measurable, [00:22:00] uh, outcome that we can define, okay, with yes, this is safe and very cool to, uh, perform this procedure, but how this is, uh, impacting the patient life by providing some level of independence- Mm-hmm ... and, and autonomy. So that's where the BCI field and minimally invasive BCI field is going with all this active discussion in the field in terms of defining measurable outcomes beyond patient safety.

Leslie Schlachter: So these devices not only need to be put in safely, they need to stay in safely and preferably work-

Majidi: Yeah. We

Leslie Schlachter: need- ... doing something that you could measure.

Majidi: Absolutely. We need- Are

Leslie Schlachter: they safe?

Majidi: At this point, based on the data that we have from multiple centers and al- also outside the United States, uh, there is a consensus that it is safe.

Mm-hmm. Um, uh, but now we are moving to show efficacy because we need to show that it is not only it is safe, it's durable, it's scalable, [00:23:00] uh, and it can be used, uh, in home environment, uh, outside the brain labs with a large number of patient population. That's really where the field is going.

Leslie Schlachter: And at this point, I've seen you put in, uh, a bunch of the precision electrodes.

Um, one of the concepts that I like to think about is, like, I feel really lucky to work at Mount Sinai. I work with a bunch of doctors who are outstanding at what they do. So when you say scalable, watching you do the procedures that you've done, that makes me nervous. There's all these other neurosurgeons across the country.

How long is it gonna take for them to get the skills to be able to do that?

Josh Bedersen: Hmm.

Leslie Schlachter: So that they can help even more people.

Josh Bedersen: Well, scaling is one of the critical parts of this.

Leslie Schlachter: Yeah.

Josh Bedersen: And I think that both Dr. Majidi and I, when we are doing the implantation procedures, are quite focused on the minutiae of technique that can be incrementally changed and improved to make it [00:24:00] accessible to just about anyone.

Ben Rapoport: Mm-hmm.

Josh Bedersen: And sometimes this involves a minor improvement of the technology. Let's say, for example, a technology that connects one part of an electrode to the next. Other times, it involves shrinking the whole prosthesis, if you call it. Uh, but there are a number of different things that we observe during these implantations that lead to sequential changes and evolution of the technology, because ultimately, as you've pointed out, it's either gonna be accessible to everyone with the disease, or it will be a niche effort that is not so applicable to- Right

to the masses and to the people who need it.

Leslie Schlachter: But the skills that you guys have in order to do these implantations, that's already part of your scope of practice. It's just a new device.

Josh Bedersen: That's right. That's right. I would say that it is an enhancement, uh, and a s- sub-specialization to evolve the techniques [00:25:00] such that the electrode placement gets better and easier as time passes.

Ben Rapoport: Mm-hmm.

Josh Bedersen: I was trained putting in larger electrodes With a different type of interface. And so this is just an- you could say just another type of electrode that I'm- Right ... putting in. And same with Dr. Majidi. He's trained in all the advanced techniques of both arterial and venous access to the brain. Um, I don't think that I would want anyone other than him doing it, though- Because-

Leslie Schlachter: At least right now.

Josh Bedersen: At least right now, because, you know, you want someone who has devoted their whole life to it before you're taking on another advancement of the technique.

Leslie Schlachter: So we were talking earlier that right now, I know we're still in research phase, but the indications for what we're doing right now are generally people with, like a spinal cord injury, a paralysis, something from the neck down to give them some movement.

There's a large population of people out there that had [00:26:00] traumatic brain injuries, whether it be from an accident or a stroke or a tumor or what have you. Are those people not included with these body improvements? Because there are people that with major brain injuries that maybe are hemiplegic, can't move a side of their body.

So is a damaged brain a contraindication to doing something like this?

Josh Bedersen: No. No, in fact, that's one of our target populations.

Leslie Schlachter: Okay.

Josh Bedersen: Um, and even for the Synchron trial of ALS, um, you know, those are frequently brain lesions.

Leslie Schlachter: Okay.

Josh Bedersen: Right? It's not just the spinal cord, but there are, there are people with neurodegenerative changes that occur throughout the whole entire neuro axis, as, as you might call it.

Leslie Schlachter: Mm-hmm.

Josh Bedersen: Um, but anything that disconnects a functional part of the brain from the rest of the body would be a candidate. For example, a hemorrhage deep in the brain that doesn't wipe out the cortex that controls [00:27:00] the, the neurons that move the body. However, the deep white matter contains the cabling, if you will, that connects that part of the cortex with the spinal cord.

So that type of intracerebral hemorrhage would be a, you know, very perfect patient to receive this type of implant.

Leslie Schlachter: So people who have injuries that are so severe that the cabling is not intact are not candidates?

Josh Bedersen: Are, are candidates. Are candidates. Are candidates. So think of the way the brain is, is wired.

Leslie Schlachter: Right.

Josh Bedersen: On, in the cortex, you have where you have the cells that are generating the electrical impulses that need to travel through the brain and out the spinal cord and into the periphery to move the arms and hands, and likewise, traveling backwards from the hands and arms and eyes and so on, ears, through the spinal and brainstem pathways, up through the white matter and to the cortex.

That conduction is done through white [00:28:00] matter tracts, and this is where brain computer interface is really ideally suited to replace that connection. So someone who's had a certain type of stroke that would affect the cortical structures that generate those signals will be a more difficult solution for us to address with a brain computer interface.

I see.

Leslie Schlachter: What about patients-- So you're talking a lot about the electricity of the brain and how you can kind of harness that for change. What about patients with epilepsy? How does a BCI or the future of BCI affect patients with intractable epilepsy? Great question. And that's for those listening, that seizure, that's-- epilepsy is seizure disorders.

Josh Bedersen: Yeah. That's a great question, Leslie. Um, put simply, epilepsy is an excess of uncoordinated electrical activity that occurs when certain parts of the brain are irritated. Um, those are really well suited for certain types of brain computer [00:29:00] interfaces because we have the capacity now with electrodes to detect the onset of the abnormal electrical activity- Feed that into a computer that has been created to be embedded inside the skull of the patient

Ben Rapoport: Mm-hmm

Josh Bedersen: And then through the same electrode that detected the abnormal activity stimulate that electrode to stop it from spreading.

That's called responsive neurostimulation

Leslie Schlachter: Kinda like the way ADD medication works

Josh Bedersen: How's that?

Leslie Schlachter: Stimulates an already stimulated brain to calm it down

Josh Bedersen: Yes. Okay. And in this case, it's electrical Mm-hmm And in this case, the stimulation occurs after the abnormal discharge has been detected

Leslie Schlachter: I see

Josh Bedersen: So it's truly a brain computer interface, but in this case, much to my fascination, the computer's implanted in the person, so it's a fully self-contained brain computer interface.

And at Mount Sinai we've [00:30:00] done more than 200 patients-

Leslie Schlachter: It's kind of like a pacemaker for the brain almost

Josh Bedersen: That's right

Leslie Schlachter: It, it senses like a pacemaker

Josh Bedersen: It, it's, it is a pacemaker for the brain in the sa- in the same way that a pacemaker might work like an AED, an anti, uh, defibrillation device. You first detect the abnormal signal and then you stimulate it.

Some pacemakers work just by to- chronically stimulating the heart. In this case, we don't chronically stimulate the brain. We wait for the brain's abnormal signals to occur, and then we stimulate it

Majidi: Yeah. Kind of back to your original question about the state of neurosurgery or brain surgery.

Neurosurgery Goes Electric

Majidi: Historically, we identify a pathology, whether it is a brain tumor or brain aneurysm, and you go open the brain through open or endovascular approach and target that pathology and fix it. Now, in two thousand twenty-six and moving forward, because of advances in really [00:31:00] technology,

multiple technologies like AI, uh, uh, electrophysiology, now we, we see that brain electrical activity is becoming major part of neurosurgery.

Yes, we had functional neurosurgery now for over five decades, but with these new advances now, we are not only just going to fix the pathology in the brain, we're gonna i- uh, we're gonna interact with the brain, uh, with a minimally invasive approaches, with microelectrodes, less invasive approaches that we can offer, then that will put us in a place that offers some treatment for diseases like addiction, obesity, depression, et cetera, beyond the current state of BCI.

Leslie Schlachter: When you were gra-- think back to when you were graduating medical school and knew you were gonna go into a neurosurgery residency. Could you have imagined this is what we'd be talking about? You probably did imagine.

Pain Circuits to BCI Therapies

Josh Bedersen: Well, you know, we were looking forward, uh, to the day when we could [00:32:00] translate some of the electrophysiological experiments we were doing in mice and rats to people.

Um, I spent a year during my residency studying the rostroventromedial medulla, a certain part of the brain that is activated when someone feels pain, and that act- that type of activation was completely disordered in either patients or in animals who had become addicted to opiates.

Leslie Schlachter: Hmm.

Josh Bedersen: So the op- the opiates actually change the response of that part of the brain to both pain stimuli and also pain medications.

And in unlocking the secrets of that interaction, I think we've-- we started, this is now 30 years ago, we started on the path towards understanding how the brain perceives pain and how we can stop that pain electrically with implants and so on. And this pertains directly to what you were saying before about new treatments for [00:33:00] addiction, obesity, satiety.

It relates to depression. Um, it relates to other psychia- neuropsychiatric disorders, uh, that are all not necessarily part of the same circuitry, but you could call this part of neurosurgery advanced circuit therapeutics, and this is where we're heading with brain computer interface.

Leslie Schlachter: So a lot of people think that there's a ton of crossover between neurosurgery and neurology, and there is crossover, but not as much as people think.

So now let's talk about a couple-- There's a lot of conditions out there that people want help with and hopefully could look to neurosurgery to help. Is there any way any of this could help things like dementia? Parkinson's, MS, or is that totally a separate subject?

BCI for Degeneration and Plasticity

Josh Bedersen: Well, these could be considered as neurodegenerative diseases- Mm-hmm

um, each in their own way. [00:34:00] Uh, some of them have a very focal or localized area of degeneration, such as Parkinson's, that has a very specific impact on the circuitry of the brain. And so something that is quite localized, like Parkinson's, is more-

Leslie Schlachter: Like a damaged area ...

Josh Bedersen: a damaged area that- Yeah ... that's right, a damaged area that happens to be in a critical zone where the circuitry controls movement.

Leslie Schlachter: Mm-hmm.

Josh Bedersen: And when that circuitry is damaged, you see tremors and oscillations that occur that are abnormal electrical oscillations, if you will. That happens to be amenable to a brain-computer interface with deep brain stimulation- Mm ... as you have seen. Um-

Leslie Schlachter: But not actually reversing the disorder.

Josh Bedersen: N- exactly.

Leslie Schlachter: Right? So, like, there's ... we're not looking at something that could, like, jimmy-rig the neurons and build them up and get rid of a, a problem in that area.

Josh Bedersen: Well, there is at cert- [00:35:00] so there are many ways to attack the problems that occur after certain parts of the brain have been injured or damaged by cumulative damage or neurodegenerative change and so on.

One of the questions that arises is, is there something we can do to improve neuroplasticity, the ability of new connections to form and the brain to learn and recover? Um, at the moment, it's still an open question as to whether certain types of electrical stimulation can improve plasticity, uh, but that is an area of, of active research.

It's also shown that by stimulating parts of the brain adjacent or nearby areas that have been damaged by degeneration or stroke or something, we see improvements in recovery after those injuries, such as stroke.

Leslie Schlachter: Right.

Josh Bedersen: So with certain brain-computer interfaces that activate parts of the brain next to the area of stroke, right now it's limited to [00:36:00] areas of stroke that have occurred in one part of the brain.

We activate the brain with stimulation of the autonomic nervous system, um, and we see im- significant improvements in recovery of those patients. There are other areas of interest around the treatment of the clearance of proteins which are known to build up in diseases like Alzheimer's. Right now, those are not the subject of brain computer interfaces, uh, although I'm sure that there will soon be, you know- Something

some sort of investigation- Yeah ... into whether those pathways can be improved that way.

Ben Rapoport: Can I go out on a limb here a little bit? Yeah, please.

Genomics Moment for Neural Code

Ben Rapoport: So, um, you know, I sometimes, I kind of think that we're at a phase of the development of the technology of brain computer interfaces, which is in some ways similar to where we were in genomics at around the year 2000, 2001, where the first, if you think back to that moment, the first human genome was [00:37:00] sequenced, right?

That was like a pivotal moment in, um, in genomics. And from the standpoint of how technology Uh, helped that field. There was, in that moment, a competition, a race between the private sector and the NIH-funded consortium of many laboratories across the country and across the world which were trying to stitch together the first comprehensive map of the human genome.

And famously or infamously, the, the private consortium won, right? Craig Venter's sort of crazy, uh, you know, shotgun approach to sequencing won. And to me, that mattered less, uh, than just the notion that moving, uh, ready or almost ready technology from the academic setting into the industry setting at the right moment has the potential to help tremendously accelerate progress.

And what happened after that, nobody, almost nobody would've predicted, right? Right. Nobody really, really knew what was gonna happen when we [00:38:00] could sequence many human genomes, sequence them quickly, sequence parts of human genomes, sequence a tumor genome, sequence the genome of a microbe. You know, nobody really knew how that would inform cancer therapeutics, or infectious disease, or where the different tentacles of the tech- technology would, could lead once you could really read and decode the human genome.

Well, the neural code is another biological code. It's a different code. It's dynamic. It's two-dimensional or three-dimensional as opposed to being one-dimensional and more or less fixed. But it's another biological code that we're now able to compute on because we can digitize it, we can comp- we can compute on it, and we're just getting to the scale of accessing that code across many individuals, many areas of the brain.

And the scale of the data that, um, we now have as a field, uh, is kind of, in certain ways, mirroring what we saw 25, 26 years ago in genomics. And I think that [00:39:00] we're thinking very narrowly right now in terms of treatment of paralyzing injuries or some of the other conditions that you were talking about before.

But I actually think that the toolkit that we have, um, started to develop in brain computer interfaces, which is a toolkit that gives us access to high-resolution, real-time brain electrophysiologic data, brain activity, is a, is a toolkit that's gonna have, uh, applications well beyond these- We don't even know

specific disease states. Yeah. And, and I, I... One of the ways that, that we've started to see that with our technology is, um- We can see, for example, the

effect in real time of, um, drug interactions with the brain. So all of our patients in all of our clinical studies are, are on a host of different medications.

And, and just as a, as a byproduct of us just being there when they're getting their various medications, we, we see the interactions of different antiepileptics, [00:40:00] sedatives, you know, uh, steroids, antipsychotic medications, I mean, all manner of medications with the brain, and we're seeing those interactions on timescales and spatial scales that have never been seen before.

And, uh, that's, I think, beginning to give us some insights into drug-brain interaction mechanisms that have never been available before. I think what that will allow us to do for designer molecules and, you know, enhanced therapeutics we have yet to see. But it's-- I offer that just as an example of that, um, the technology has developed to a point, and the total data that we've accumulated has grown to a point where we're starting to see kind of emergent phenomena, meaning applications of the technology that are way beyond what it was designed to do.

Josh Bedersen: Yeah.

Ben Rapoport: And I think we're gonna see a lot more of that in ways that are, you know, hard, hard to predict, uh, e-even beyond the speculative conversations that we're having here.

Education Careers and Closing Thoughts

Leslie Schlachter: This is a really dense [00:41:00] topic. I feel like I could talk about this for hours, and it's a disadvantage to me that I know a lot about this already 'cause I-- there's so many questions that I have.

We're gonna have listeners that, that are in medicine, um, MD, PhD, researchers, scientists. How do we educate more people on this? Like, do we offer any sort of educational opportunities on BCI? I know we've had a symposium. Can we-- Can you guys talk about that a little bit?

Josh Bedersen: Sure.

Leslie Schlachter: Thanks.

Josh Bedersen: For the past two years, we've had a, a symposium in November, a two-day symposium at the New York Academy of Medicine,

where we have who I think of as the world's luminaries in brain-computer interface all converge on New York, and for two days, uh, an intensive discussion around all the topics related to brain-computer interface.

Mm-hmm. Some we've s- touched on today, but many others- Right ... um, [00:42:00] including getting patients who have brain-computer interfaces already implanted and who relay their experiences.

Leslie Schlachter: Mm-hmm.

Josh Bedersen: Uh, but we d- we approach it from the scientific aspect, the regulatory aspect, the ethical issues, uh, the patient experience.

Uh, we're looking at future technologies. Um, so certainly anyone who is interested is welcome to, uh, register and- Right ... and attend that, that conference. It's r- it's incredibly interesting and very exciting.

Ben Rapoport: We've had a lot of students historically. Yes. So to Leslie's question of, you know, people interested in the field who are maybe not deeply in it already, the attendees have-

Leslie Schlachter: You might even think that you're interested-

Ben Rapoport: Right, exactly

and you can come. Yeah. So just, just to make that clear

Leslie Schlachter: to everyone. Is there a limitation to who could show up?

Ben Rapoport: Only the

Leslie Schlachter: size of the

Ben Rapoport: auditorium. You just register, right? Yep.

Josh Bedersen: No, I think we can hold, like, 500 people, so.

Leslie Schlachter: Yeah, okay. And then hopefully a lot of students are listening and people that are interested in this field.

[00:43:00] Obviously, the way that you guys are all absolutely incredible, and it would take me an hour to go through your CVs, but can you guys all just kind of briefly go about, like, what degrees you have, how you got here, and was this, like, a goal in, to head in the direction of working with BCI, or is this just this happened upon you, and here you are?

Josh Bedersen: I'm gonna start with

Leslie Schlachter: Shahram We'll go with Shahram first.

Majidi: Yeah. Well, I was always interested in neuroscience, and, um, I did my, uh, neurology training, uh, and then, uh, vascular neurology training at NIH. Then I, I had a, a massive opportunity to join Mount Sinai to do my endovascular neurosurgery training, uh, and, and, and work in arguably the best endovascular, uh, neurosurgery, uh, uh, service, uh, in the country.

And then with that, with this all opportunities, uh, available around from BCI, [00:44:00] neuromodulation, vascular pathology, that really had a massive impact on my, uh, career and what I think is, uh, uh, my mission, what I wanna, uh, uh, my impact be in the field. Uh, you know, uh, yes, BCI is, uh, great, but at this point, what drives me and what makes me really, uh, feel that urgency is like finally we have opportunity to help millions of people with paralysis, uh, to get a very, uh, feasible and practical and pragmatic version of BCI that brings independence and autonomy to them.

So I think about this every day, and I'm grateful for the opportunity to be in the field.

Leslie Schlachter: Yeah.

Ben Rapoport: Uh, well, my dad is a neurologist who started his career as an electrical engineer, so I grew up with, um, uh, a real interest in [00:45:00] electrophysiology and a passion for it that was, um, kind of born out of it being part of what was going on or in the world around me.

Um, and, uh, and when I was finishing up college, I was aware of the early work in brain computer interfaces that was happening in the neuroscience community, so I, I did my, um, I did my MD-PhD in a time when the field was, um, still pretty young and, uh, but I, I knew that that was-- that I wanted to work on brain computer interfaces.

I, I went to medical school and I did my PhD with a, um, absolute fascination in that area, and, uh, there was no, uh, there was no hint at that time in, in my mind that a, um, of what was gonna happen in the, in the commercial world. At that time, it was purely, um, a-academic science [00:46:00] and a dream that, uh, we would use what we were doing in some way to, um, to treat paralyzing injury.

That was, that was the North Star of the field, even when it was purely academic. And then, um, at some point along the line in the early twenty, early mid-twenty teens, um, it became clear to a certain critical mass of people that, um, to make further progress, uh, the technology needed the help of industry and not-- and then there were certain things that just couldn't be done in the academic laboratory setting.

Um, at that time was I was headhunted to be part of the founding team at Neuralink. That was 2016. Um, so that was an incredible experience to be part of that, um, for about two years. And then, uh, that was actually during my neurosurgery residency, so there was a lot going on. Uh, I met Dr. Bederson during those years, actually, for the first time.

So it's probably, um, you know, good karma that, uh, that Dr. Bederson attracted a lot [00:47:00] of, um, brain computer interface work to Mount Sinai, and a-as, as was alluded to earlier in the conversation, um, New York City and Mount Sinai more specifically has really become, um, a center of gravity for brain computer interfaces.

Um, now s- you know, six years ago, I started, uh, with some co-founders, Precision Neuroscience, which is the brain computer interface company, um, that, uh, we've been working with, uh, in collaboration with colleagues here at Mount Sinai, including Dr. Bederson. And, um, so, you know, to your question of how I got interested, uh, there was a kernel of interest that started very early, but, um, I never would have predicted, you know, thirty years ago the, the full path that things have taken to this point.

Leslie Schlachter: Sounds like you've had your eye on the prize the whole time.

Ben Rapoport: Some version of that, yes. Yeah, some version. Definitely, definitely been deeply interested in, in brain computer interfaces specifically for basically my entire adult life. Um, but you know, you, you- it's hard to predict, [00:48:00] you know, a decade or two into the future exactly what the path is going to be.

And I don't think we know exactly what the path will be from here on out, um, you know, uh, harkening back to some of the questions in the earlier part of the conversation. But I think the North Star remains, um, delivering a treatment to people with paralyzing injury, and I think, um, you know, understanding that that is an important goal of the next, you know, five to, you know, five to 10 years.

Yeah. Uh, I think that's very grounding to all of us who are, um, developing the technology and helping to, um, bring it through clinical trials. It requires so many people and, um, and, and so many resources that only kind of a network of many institutions, um, you know, can bring to bear. And, uh, I, I do think that what happens after we have standard of care brain computer interface, um, really the sky's the limit.

We're gonna just see, I think, something very similar to what we've seen in genomics, meaning that this is not a one device, one, [00:49:00] uh, one condition kind of technology. This is really a platform technology and a set of tools that is really changing the way, uh, we think about certain aspects of neuroscience, computer science, you know, um, and even, you know, what it really means for the brain to interact with, uh, with the world.

So, um, I think that this is a field that's gonna have long longevity, you know, well beyond, uh, even what we're contemplating today.

Leslie Schlachter: Well, as my workplace partner, I know how your brain works. So if you actually had a BCI in your brain and it did everything you thought of, we would have to hire like 500 new neurosurgeons.

Um, how, how did you get here to now all of this added on top of your goal with what you want to accomplish in your career?

Josh Bedersen: Hmm. You know, no one is born a neurosurgeon or a leader of a department or a brilliant neuroscientist like my two [00:50:00] colleagues here, uh, or the leader of a huge clinical enterprise like you.

Uh, I-- my mom was a psychoanalyst and my dad a physicist. Um, I was really interested in psychology. Uh, I was an athlete, but I was not much interested in academics. But in college, I started, uh, as a psych major studying learning and memory. Uh, the questions I asked brought me towards neurobiology, and I eventually switched over to neurobiology.

Um, at some point, I realized that I probably would be best off in medicine. And, uh, in medical school, I was s- attracted to the brain, um, but I didn't know whether it would be psychiatry, neurology, or neurosurgery. I actually didn't think it would be neurosurgery until I saw my first surgeries, uh, and was taken under the wing by some brilliant people who guided me towards neurosurgery.

[00:51:00] Um, and it was very fortunate that whatever natural abilities I had matched what was needed to become a neurosurgeon- Mm-hmm ... uh, which was just luck. But I worked, uh, as I mentioned earlier, in an electrophysiology lab studying the mechanisms of pain gate control, um, and ultimately, though, went into cerebrovascular surgery.

And when I came to Mount Sinai as the first cerebrovascular surgeon, we needed ways of detecting when the brain was not getting enough blood flow during surgery when they're asleep, and you can't tell if they have a deficit.

Leslie Schlachter: Right.

Josh Bedersen: And so- '

Leslie Schlachter: Cause you can't wake 'em up and say, "Can you move your hand?" Yeah.

Josh Bedersen: You can, but you really-- it's, it's a very strenuous thing for the, the patient, and it can be dangerous. Mm-hmm. Um, and so we created the first intraoperative electrophysiological monitoring team here thirty years ago. Um, and at the same time, I also became [00:52:00] interested in advanced digital technologies to help me locate, localize, and get safely to those deep vascular structures.

Um, and so by bringing those things together, the electrophysiology with the advanced digital technologies, my interest in advancing an ecosystem that would itself advance technology grew. Um, and that led to the creation of programs like Biodesign. Uh, but more importantly, it also led me to wanna interact with people a lot smarter than me, like Dr.

Rapoport and, uh- Yeah ... Dr. Majidi. And so in creating an environment that supported technology, really what I was trying to do was create an environment that would attract and support people like these two characters, and you. Um, and so that really is how it kind of multiplied upon itself, because once you have talent like this, [00:53:00] everyone else wants to be here- Right

with them.

Leslie Schlachter: When it comes to conspiracy theories for the brain, do you think it's true that either big pharma or big, these rep companies are actually withholding from us, from our treatment of patients?

Josh Bedersen: No. My experience has been quite the opposite. Um, the, um, the exposure we've had to our industry colleagues has let me feel that they're competitively trying to advance the field.

If there's any, um, suppression, it's only that they don't want us to get there first. Um-

Leslie Schlachter: They wanna be a part of it.

Josh Bedersen: They, yeah. I, I don't know if they wanna be a part of it, or they want, you know, they, they would like to advance things. But where we collaborate, I've found that they have been, you know, quite supportive in trying to help us advance the field.

Leslie Schlachter: Yeah. I mean, they want the business. They, they want patients to get better. They, they wanna make [00:54:00] money from it, so they, they want to get better. And there's also a misconception about academia working with big pharma or these big med device companies. Like, we need them. We work with them every day.

Josh Bedersen: Well, we need them, they need us.

Uh, Dr. Rapoport and I had a meeting today with a major, um, corporation, and their main question to us about an rapidly evolving technology that we were talking about was But how is this going to actually help patients?

Leslie Schlachter: Mm-hmm.

Josh Bedersen: We were in the odd position, I felt, of both being enthusiastic about a new technology and there being skepticism there because they weren't sure if it was just a new shiny toy, or is it actually going to help people, and they wanted our opinion on exactly precisely how it's going to help, how much it's going to help, and what is the impact going to be.

So my experience has been [00:55:00] the opposite of a suppressive conspiracy.

Leslie Schlachter: What about the concept of humans only use 10% of their brain? True? Not true? Do we even know?

Ben Rapoport: I think it's a, it's a really interesting question. I think that, um, in certain-- It depends on how you measure, uh, what percent of the brain is being used.

I think that in term, if you take it literally, it's false because we can actually measure, uh, for example, what parts, what portions of the brain by brain volume are active at any given time and in any particular task. So if you, uh, if you, for example, do the experiment of an fMRI, um, you know, putting, putting a person in an fMRI and seeing what portions of the brain are active, um, over a range of tasks, you'll see that by brain volume, uh, the total amount of brain volume that is active over a range of tasks is much greater than ten percent of the brain.[00:56:00]

Leslie Schlachter: So what would be your guess? If you had to do best guess, what percentage of brain

Ben Rapoport: do we use? If you measure in, if you measure in that way, then I think we probably use, you know, there's probably less than ten percent of the brain that is not used- Okay ... uh, across a range of, a range of tasks that we can identify.

However, if you ask the question differently, which is maybe how it's intended, um, meaning, you know, do we, what, what portion of total cognitive capacity, um, you know, do we achieve, um, of our potential, for example? Or, you know, what portion of our working memory or what portion of our total memory or what portion of, you know, some other cognitive performance metric do we typically achieve versus what our ceiling is?

I think it's difficult to, um, it's difficult to totally know what the ceiling is. But I, I also think that, um, we're well, well beyond the ten percent mark, um, on average there. But I think that maybe taking the [00:57:00] question from a, um, from a Like a yet another vantage point, which is sort of the technological standpoint, which is, you know, what, what is actually possible to achieve if you combine, um, you know, uh, augmentative artificial intelligence or assistive technologies, you know, with human capacity, which I think is kind of the more interesting question.

You know, what can we do with a life, or what can we do with a career, or what can we understand scientifically? Um, you know, there I think we're probably

well under, as a species- Right ... well under 10% of what we can achieve, um, as a species. So there's a lot more to learn, to do, and to understand, and I think we're much, much less than 10% of the way to, you know- Yeah

understanding of the universe. Uh-

Leslie Schlachter: I love how you just answered that question. I'm not surprised at all that's how you answered that question. Awesome. Thank you.

Josh Bedersen: What do you think about the pharma conspiracy?

Ben Rapoport: [00:58:00] Um, I agree with your answer. I mean, I think that, uh- By and large, um, even if you take a skeptical, uh, stance, um, I think that the overwhelming, uh, the e- the, the overwhelming, um, incentive is for pharmaceutical companies to, um, commercialize and monetize whatever technology they, uh, they may have.

So I think it would be, uh, is there potentially a situation in which maybe there was some molecule or therapy that was known and kept hidden for some reason or another? Who knows? Maybe. I don't have knowledge of that. Yeah. But, but o- on the whole, I would say that the, um, you know, the human, the ethical, and the commercial, um, and other motivations very much favor rapid development, you know, as rapid as humanly possible and ethically possible and technologically

Josh Bedersen: possible.

And fiscally responsible. Yeah, [00:59:00] exactly.

Ben Rapoport: Right.

Josh Bedersen: Yeah. I think that is probably where this theory comes from. You know, just like in Hollywood, there are scripts that have been purchased but are never made into movies. Um, you could say that they're suppressing those scripts. Mm-hmm. But the usual reason is that someone has decided it just doesn't make financial sense-

Leslie Schlachter: Right

Josh Bedersen: to do it. And so there may be, there may be situations like that where things have not been developed.

Ben Rapoport: Right. I can... You can cite a recent, um, I mean, a recent, just for discussion purposes, you know, I mean, the recent, uh, Moderna advance that was a- that was announced, uh, you know, a week and a half ago. Um, you know, the, uh, the Moderna therapy combined with Keytruda for melanoma.

Right. I mean, and, and that has massive implications for the treatment of at least some cancers, right? I mean, probably mRNA vaccination is gonna transfo- I mean, if we're lucky and if the results hold up, um, that portends a tremendous advance in cancer therapy, you know, through mRNA and other vaccinations, something that we as a field [01:00:00] have been waiting for for a long, long time.

Right. Um, there was a quote in, like, the Wall Street Journal article, uh, I think one of, one of the r- one of the pieces of press that came out That, um, in, in which, uh, you know, the Modern- Mode- Moderna CEO and chief science officer had a discussion at some point about this is a completely different manufacturing process for these medications because it's a personalized vaccine.

You have to, you have to sequence the genome of a particular tumor. You have to computationally examine the mutations. You have to then generate, you know, epitopes that, uh, a vaccine could then target, make those into a vaccine for a particular patient, and then deliver that vaccine in a timely fashion to the patient.

Leslie Schlachter: Oh, so it's an-

Ben Rapoport: Right ...

Leslie Schlachter: specialized immunotherapy.

Ben Rapoport: S- no, it's a specialized vaccine. Okay. mRNA vacs- vacci-based vaccine. Uh-huh. Um, so that is a completely different manufacturing process from the- Totally ... one size fits all immunotherapies or drugs that we're used to giving, is a little more similar to CAR T therapy, [01:01:00] but even more, and that manufacturing process is, is actually quite expensive.

So, um, you know, as is the case for designer drugs and other things that have been around in each generation of pharma, the question of, like, can we do it versus does it pay to do it, um- Right ... you know, those things can be out of sync to what Dr. Bradison was saying before. And so, you know, if that, if, if that manufacturing process costs \$50 million per patient, you know, you could see, you could see Moderna shutting it down.

Mm. So one of, one of the, uh, technological hurdles that they have so far been able to achieve, and we'll see if they can do it at a s- you know, at scale, is bringing the cost per patient down, and, and that, that is an area where I could see a conspiracy s- theory developing over the years in with respect to particular molecules, but that's been a major advance.

Moderna fought very hard to make those, uh, personalized vaccinations, um- Mm-hmm ... affordable so that it could be, uh, really, you know, uh, [01:02:00] delivered as, as real therapy.

Leslie Schlachter: I've been with you now almost 11 years, and it's been a beautiful thing to see how this all grows and how this happens. So that's all for this episode of The Vitals.

I'm your host, Leslie Schlachter. Subscribe to The Vitals and the Mount Sinai Health System's other video podcast programming on YouTube, Apple, Spotify, or wherever you get your podcasts. To learn more about Mount Sinai's work in neurosurgery or about the Brain Computer Interface Symposium, or to book an appointment with a Mount Sinai expert, scan the QR code on your screen or click the link in the description below.

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