Speaker 1:

Welcome to Optimal Neuro Spine Podcast, a podcast about optimizing our brain and spine in health and disease. Each episode, leading neuroscientists, neurosurgeons, educators, patients, spine care, and quality improvement experts discuss their research, experience, emerging science, surgical advances, and insights about how to optimize neurological and spine care. Now here's your host, Dr. Max Boakye.

Dr. Max Boakye:

Welcome to the Optimal Neuro Spine Podcast. Today, this is episode four. We will be speaking with Dr. Eric Leuthardt, who is an expert on brain-computer interface. Dr. Leuthardt is a neurosurgeon, he's currently professor with the department of neurological surgery and the department of biomedical engineering at Washington University in St. Louis. He Is also chief of the division of neuro technology and director of the Center for Innovation and Neuroscience and Technology and the Brain Laser Center. We will be speaking to him today about his work, which is focused on brain-computer interfaces and brain mapping using engineering approaches to decode the brain to create novel diagnostics and treatments. Doctor Leuthardt, welcome.

Dr. Leuthardt:

Well, thanks very much for having me.

Dr. Max Boakye:

I always start by talking about your current practice. You are a clinician-scientist. What is your clinical practice like?

Dr. Leuthardt:

That's a great question. So I'd say that my practice is split between neuro-oncology, taking care of brain tumors, and epilepsy. So I'd say probably my practice is a little bit heavier on brain tumors and a little bit lighter on epilepsy, ranging from, for the brain tumor practice, the things within that I focus on, tumors around eloquent cortex and minimally invasive approaches such as laser ablation, which is a deep interest of mine. And then with epilepsy, it involves stereo EEG and laser ablation as well.

Dr. Max Boakye:

And you're also a scientist. So what percentage of your time is spent doing surgery, and what percentage is spent being a scientist research?

Dr. Leuthardt:

Well, I always say it's 70, 70, in the sense of a big clinical practice, but also a big laboratory practice, but they're about equal in the time that I spend between the two.

Dr. Max Boakye:

Excellent. So what is your clinical practice? Tumors and epilepsy. What about your research? What are you working on in the lab?

Dr. Leuthardt:

Yeah, so I think we cover a number of things in the laboratory, but I think the central ethos of my lab is to understand how the brain encodes information and translate those insights into practical clinical applications. And so I'd say probably the two cornerstones in my laboratory are brain computer interfaces, very specifically brain computer interfaces to modulate neural circuitry. And one of the big ones has been creating noninvasive brain computer interfaces for stroke rehabilitation, but we're now expanding that to other applications of sensory motor disorders.

Dr. Leuthardt:

And then on the other side of that, taking the same analytic approaches to decode how the brain does stuff to allow people to control stuff with their thoughts, we're doing the inverse. We're taking analytic approaches and to do advanced brain mapping. So we do a lot with resting state FMRI to basically create AI techniques to automate brain mapping to enhance surgical decision-making, whether it be brain mapping for planning of the surgery, or using those techniques in the setting of brain tumors to create radiographic biomarkers or survival. So we can actually predict how long you survive with a given tumor.

Dr. Max Boakye:

I will ask you a little bit about that later. So how did you get involved in this type of scientific research?

Dr. Leuthardt:

Well, I think fundamentally I love the interaction between engineering and neurosurgery. I think neurosurgeons are fundamentally tool makers and tool users. And so I think there's a real synergy between the surgical mindset and the engineering mindset. And I think really what got me started on this path was really thinking about brain computer interfaces or thought controlled machines. Because I think that that really sets the stage for, I think, really without speaking in hyperbole that creating advanced neural interfaces, and brain computer interface, and decoding the brain and our thoughts really has an exponential implication for how we can treat neurologic diseases, but also enhance or modify humans. And so I think that this is really just the earliest stages of how we rethink how humans interact with machines. So and that really captured my imagination. And so it was really one of my fundamental passions when I started out as a faculty to create a brain computer interface that was clinically relevant. And so that's what I've been working on, really, for the past, since 2003 and 2004.

Dr. Max Boakye:

What kind of background allows you to do this work? Are you an engineer by yourself or you work with engineers?

Dr. Leuthardt:

Well, that's a funny question. So I guess my formal degrees are in biology and theology. And I remember when I first met with the engineering chairman back in the early 2000s, saying that I wanted to do engineering research, and he raised his eyebrow and he said, "Why don't I get you connected to this new guy named Dan Moran," and he was a neuro engineer who just started at Wash U, and he and I became fast friends. And I think the one thing that neurosurgeons, and especially neurosurgery residents, know how to do really well is work really, really hard. And that's what I did.

Dr. Leuthardt:

So I learned from scratch, engineering software, coding and programming. I built my first amplifier that we used for our first human experiments, and really was self-taught with a lot of engineering principles. And actually, that dubious chairman actually was the lead in recruiting me back to Wash U many years later. And so actually now I'm a professor of biomedical engineering and a professor of mechanical engineering, and I've trained, I don't know, dozens, many dozens, of engineering students through my lab and my center. So, but I'd say self-taught engineering backgrounds, but no formal degrees in engineering.

Dr. Max Boakye:

So we actually also interviewed, my previous episode was actually also interviewing Dr. Jamie Henderson, who is also doing brain computer interface. And he talked about two types, one being invasive and one being non-invasive. So let me ask you about what type of brain computer interface, what is the approach that you're using? Is it similar to Dr. Henderson's, or is it totally different?

Dr. Leuthardt:

Yeah, it's different. So, and I would say that the range of, and I actually just recently published a paper on this in Frontiers of Neural Engineering, is there is a whole explosion of form factors of neural interfaces. And I think that they range from non-invasive, meaning things that you put on your scalp, or even light based techniques, such as near infrared, to invasive, which are technologies that are intercranial. And those are the things like electrocorticography, stuff that I worked on very early in my career, and such as electrodes on the surface of the brain to implant it in the brain, such as inter parenchymal, whether they're single electrodes, which is what Jamie Henderson works on, to local field potentials that are recorded from populations of cells, to intravascular technologies, and emerging technologies, or what we call him embedded, meaning stuff that's under the scalp or in the skull, but not intercranial.

Dr. Leuthardt:

And each of them, quite honestly, has different amounts of information they provide and different risk profiles. Honestly, I'd say with the exception of single neuron recording, I work with many of those techniques, from noninvasive, to embedded, to ECOG, to intracranial. And I think which form factor and which indication, it really varies a lot. So for our stroke patients, we have a non-invasive wearable electorate headset that connects to a robotic exoskeleton that's wearable, it's completely non-invasive. And we actually get these patients fitted, and we send them home, and they do their BCI at home. We're working on other technologies that are surgically implanted, and we're getting ready to do some clinical trials in humans for that after getting FDA IDE approval. So again, it really, I'd say, I work with all the vast majority of the form factors and we're working on them to optimize the form factor for the clinical indication.

Dr. Max Boakye:

Now there are concerns with these interfaces, so they can be used to help deficits, right? But it seems like there's a category of brain computer interface that actually enhances human function, like memory and things like that. Can you discuss that?

Dr. Leuthardt:

Yeah. And honestly, I think that there absolutely are at least the potential to have technologies that can serve a dual purpose, where they can potentially restore a deficit or can restore what I would call a

networkopathy, an imbalance in the brain networks to improve people's function. A nice example of that is in the setting of depression, an area that you would stimulate, such as dorsolateral prefrontal cortex, could, and actually with transcranial magnetic stimulation, has been shown to improve mood with therapy. And that's one of the classic uses of TMS for depression. Now, but that same target in a normal subject could potentially be used to enhance attention and memory. And I certainly appreciate the ethical implications of those devices, in that you could potentially make people better than their baselines. And I think there's several ways to think about this.

Dr. Leuthardt:

I think, one, we are going to see a natural progression between restoration and augmentation. And I think in many ways, we've seen that historically already. If you look at the history of plastic surgery, plastic surgery originally was a largely restorative approach, whether it be reconstructing a nose or a face after a traumatic injury or breast prostheses for after a mastectomy for cancer. And those technologies and those approaches and techniques evolved to become cosmetic in nature, because people wanted to change themselves because they had a self perceived notion of benefit, meaning that they felt they could be better or their better selves by changing themselves. And I think that we see this changing of values, and morals, and what is appropriate and not appropriate in the sense of body modification is really evolving.

Dr. Leuthardt:

And just as I think that cosmetic surgery is essentially evolved with these change in social perceptions, I think we're going to see the same thing happen with neural interfaces, in that people can be perhaps what we would consider their optimal selves with neural interface, whether it's an implant or a noninvasive version. And I think that raises some, again, further ethical dimensions of who can have it and who can't. That could lead to further social separation. And that's an important consideration. Now that said, I think fundamentally enhancing human intelligence is a good thing. And, again, looking at history, what is the technology that's really augmented cognitive capabilities, and what's the impact been on society? Well, that's essentially the personal computer, and now mobile phones, that these technologies have fundamentally enhanced our cognitive abilities, our access to information, our calculations, everything.

Dr. Leuthardt:

And I think that the global impact of that has been a net positive. Have there been adverse events, have there been negative things as a result of personal computing? Absolutely. But the net result in society has improved. I think we can process information faster. We can get to solutions faster. I don't think we would've gotten a COVID vaccine if we didn't have advanced computing and genetic sequencing to solve the pandemic. So I think it's a net positive. And similarly, if we can improve human intelligence in a meaningful way and have it equitably accessible, that improving human intelligence is a fundamentally socially positive thing.

Dr. Max Boakye:

Yeah. Obviously, it's a lot of ethical issues of who should get it, is there a psychological frame of inner criteria for getting it. But how far away from this? Are we talking in the next decade or another 50 years? How far do you think before this becomes available?

Dr. Leuthardt:

I think realistic things that we can see in the near future, or within a five to 10 year timeframe, I think it is very realistic that we will have implants for mood disorders. And again, full disclosure, actually one of the companies that I founded is working on that.

Dr. Max Boakye:

Depression, and anxiety, and things like that?

Dr. Leuthardt:

Yeah. I think that that's very realistic. I think things that can, perhaps, be cognitive augments, or I'd say, somewhere in between an augment and a restorative, is, for instance, age related degeneration, not dementia, or not some pathological process, but we all know, like with our eyes, that as we get older, we get cataracts and our eyes don't work as well. People get minimally invasive surgeries to get their eyes back to where they should be. I think that it's not unreasonable to imagine in a 10 to 20 year time frame that people get implants where, there again, just maintaining their cognitive abilities as they get older, because we're going to have an aging population, that demand is going to increase.

Dr. Leuthardt:

Now, the more science fictiony wild stuff, like can we share thoughts between people? Can we download memories? Can we, what Elon Musk likes to think about as having some type of union with artificial intelligence and our minds, or true, complete, neural decoding. I don't know exactly when that's going to happen, but I do think, whether it's 50 years, 100 years, 200 years, that that's a brief time in the evolution of human history. And when that does happen, which I do believe it will happen, that it's going to dramatically alter the fabric of our human experience. And whether we can download the information of our cognition. I think that that will fundamentally alter what it is to be human and how we interact with everything. Now, again, pinning that one down is a harder one, just because, again, technology moves so quickly. I could say it's going to be 200 years, and maybe it's 50 years. I could say it's 50 years, and maybe it's a thousand years. But again, the direction is inevitable. Again, and when it does happen, then I think we're going to hit another exponential spike and our human experience, just as we've experienced an exponential spike in the human experience over the last 100 years.

Dr. Max Boakye:

So you mentioned that you were a biology and a theology major, and you seem to, the area that you are doing research is the area that really gets at very core theological questions. How has that background shaped how you view the implications of all the research that you're doing?

Dr. Leuthardt:

It's a great question. I would say that, ironically, that my theology major was the most important area of study that shaped my career, because it really forced me to think about the meaning of things. And I think when you do that, you also think about the implications in the future. And the more you think about the future, the more you work your way backwards to the technical details and the here and now. So it really does. And I think that that habit of thinking about the meaning of things and the implications in the future really permeates my research, because I'm always thinking of, well, as we come up with these discoveries and as we develop these technologies, what does this mean? What's the implications? And sometimes it gets me excited and sometimes it makes me a little nervous. And also, I think that in addition to doing the science, I just think it is critically important to message and about the good, the bad, and the ugly of these technologies. And to be honest about them. That's why, for instance, I wrote

two fiction novels that are thrillers about what can happen when things go wrong. And so I think that I take a much more expansive view on the work that I'm doing and how I communicate it.

Dr. Max Boakye:

What is the fiction books that you've written about? What are the titles and what are they about?

Dr. Leuthardt:

So my first novel is a Red Devil Four. And basically, it's set 40 years in the future, when neural interfaces are ubiquitous, right? Everybody's got one, and it can draw information from your mind. You can share thoughts, you can download experiences, you can have virtual experiences that are truly real in the sensory perception way of thinking about it. And concurrent with developing brain computer interfaces is that AI will also, just as we understand the brain function, we will see also an emergence of more meaningful artificial intelligence. And basically the crux of the book is about this interface of AI and neural interfaces, when your brain and AIs potentially become hackable. And what are the negative implications of that? So for instance, could somebody have undue influence on your behavior, and what does that mean? And so it's written in a Creighton style, or DaVinci Code style way.

Dr. Leuthardt:

And so that is meant to be a little bit scary, a little bit interesting, certainly for the lay audience. And then my second novel called Limbo, again, just a little bit further in the future. And again, neural interfaces are ubiquitous. Everybody's got them, but now corporations are getting involved, and large corporations. And your data is important. And again, if people have had these implants for a long time, let's say they've had them for one or two decades, and not only does it decode your thoughts, but it stores them, it records them so that you have this running ledger of every memory and thought you've had for years, you can create a virtual version of yourself. And does that mean you can essentially, so in the book, companies are now offering basically to restore a virtual version of yourself after you've died. What happens when companies have that type of power over virtual renderings of a sentient being, and again, what are the adverse implications? So it gets into a deeper dive in terms of what does it mean to be alive and dead when every element of your mind can be stored?

Dr. Max Boakye:

Wow. That's fascinating stuff. Did you always want to be a writer? When did you decide to write these books?

Dr. Leuthardt:

Well, I do enjoy writing. I think that, again, having done my theology major, you had to do a lot of writing. And I like writing, and I like communicating, and I like fundamentally the creative and artistic process. Before I did a lot of writing, I did a lot of oil painting. But again, once I became faculty, I just found myself in a lot of airplanes. And certainly before I had a family and kids, I was traveling all the time giving talks, and I wanted to do something creative because, I think that, again, just I like the creative process, but I think also that really facilitates my science, my ability to invent things. And so doing stuff outside the pure scientific domain, I think really actually helps the science. And so I started writing. And again, that led to those two books, but also I ended up writing and acting in a play called BrainWorks. There's two versions of those plays. Actually, one of them won an Emmy. And actually, the most recent series was turned into a series on PBS.

Dr. Max Boakye:

Oh, wow. This is a screenplay you wrote?

Dr. Leuthardt:

I wrote the play with one of my colleagues, Albert Kim, and we acted in it. It was turned into a play, which we acted in. And then it was filmed, and it was turned into a documentary series on PBS. So if you look up BrainWorks and Eric Leuthardt, you'll find the series.

Dr. Max Boakye:

You said you won an Emmy award?

Dr. Leuthardt:

Yeah. The first series of BrainWorks won a regional Emmy.

Dr. Max Boakye:

Wow. Congratulations. That's very nice. Is it true that you also hold over 1000 patents?

Dr. Leuthardt:

Well, yes. I guess I've got around 600 issued, and another 1000 pending.

Dr. Max Boakye:

Wow. That is amazing. What is your secret? What advice do you give to potential innovators? That's amazing productivity and invention. What is a guide for young people that want to invent like that?

Dr. Leuthardt:

So I think, number one, I got involved with a number of inventor groups early on. One of the groups was called Intellectual Ventures. And since then, I started my center, which is the Center for Innovation in Neuroscience and Technology. And fundamentally, I think the inventive process, number one, to be an inventor, just like surgery, just like physical fitness, it's a skill and a mindset that you can build and become strong with. I think one of the things about being an inventor is that people have this, I think, misconception that a lot of inventors, like it's this singular thing where just magic pops out at one person's brain. And there are at times you have aha moments, but to get to those aha moments, it's really about, as a neurosurgeon, this is important, having a real humility to interact with people from very different domains, engineers, scientists, computer scientists, mathematicians, and sharing what you know, and really being receptive to what they know, and finding these interesting common grounds from different disciplines, that is the fertile ground for coming up with new things.

Dr. Leuthardt:

And I think being a good inventor is about having good relationships with a lot of different people, and having a network of really smart people, and having humility and respect to really listen to them and hear them. And then you take those interesting and novel insights and bring them into your world and see how you can recreate that for what's important for stuff that you work with, or taking what you know, and giving it to them so that those insights can be transposed and those solutions can be transposed into a new novel environment. Being a good inventor is really being able to really create,

again, the bottom line is good relationships with a lot of different people. So yes, I've been on a lot of patents. And fortunately, all those patents, I'd say 99.9% of them are where I'm co-inventors with some other people doing interesting things.

Dr. Max Boakye:

That is quite impressive. So for young neurosurgeons or young people that want to invent, is there some organizations that it would help if you belonged to organizations? For example, you mentioned the Intellectual Ventures. Is that an organization that helps you learn more about inventing?

Dr. Leuthardt:

It is an organization. It's a company that was really into creating novel ideas at the time. So they've changed course, and they do some different things now. I'm not as involved with them anymore, but I think the key is, number one, as neurosurgeons, we very much have the mindset we can only do what we're trained to do. And there's a good reason for that, right? You just can't go off and do cerebrovascular surgery if you haven't been trained to do it. But I think as an neurosurgeon, you have to force yourself to get outside your comfort zone and be willing to learn about domains such as engineering, or math, or programming. You don't necessarily need a degree to do it, you just need to be willing to put the man hours and to really start from scratch and learn about that stuff.

Dr. Leuthardt:

And I think that put yourself out there. Start saying, "Hey." Like again, I was a theology major going into engineering, like what the heck. But it really comes down to willfulness, and work ethic, and put yourself out there, and ask for mentorship from an engineer, or ask from whatever field of interest, and go outside your comfort zone and start to network and make friends with people who are absolutely nothing to do with what you do. And the more you do that, the more you're going to find really interesting places that are new.

Dr. Max Boakye:

That's fascinating. That's really incredibly helpful. So tell me about the most gratifying aspects of your work. What has been the most gratifying for you?

Dr. Leuthardt:

There's moments, most of them are human moments. I'll give you a very concrete example. So again, to me, something I'm very proud of is just recently we had one of our technologies called IpsiHand, get FDA approved, and that's a brain computer interface. It's a noninvasive headset using the uninjured side of the brain to control a chronic stroke patient's paralyzed hand. And if they use it for over three months, they really recover a significant amount of function. And it was given a breakthrough designation by the FDA. It was FDA approved about a month and a half ago, and it's gotten a lot of press. And for me, getting that device across the finish line, it's the first FDA approved brain-computer interface, was a big moment. But I'll tell you, but even more gratifying is when we were doing the clinical trials, a patient flagged me down, and he said to me, "Dr. Leuthardt, Dr. Leuthardt, I just want to tell you, I can put my pants on again." And I think what was so awesome about that moment was that I saw for the first time an idea that I had that was, at that time, a little crazy, using the uninjured side of the brain to control in a stroke patient to control their paralyzed limb, and to see it made real in somebody's life was really gratifying, because nobody had done that before.

Dr. Leuthardt:

And that feeling that your idea is now taking off or impacting people's lives. But so often, as neurosurgeons, we do impact people's lives. We make, again, we take out a brain tumor, we clip an aneurysm, we fix somebody's spine, put a deep brain stimulator, but these are things we're quite literally standing on the shoulders of giants who have made those things or developed those techniques. But when you do something that is your or your idea with some other people that is new, and you see it for the first time impacting a person, is deeply satisfying, because you know you've contributed something that is going to grow beyond your efforts.

Dr. Max Boakye:

Wow. That is amazing. Our show is called Optimal Neuro Spine about optimizing neurological function. And this is a typical example of that. But this is incredible, the first FDA approved BCI. Can you just describe briefly what exactly, is it a noninvasive stimulator or an invasive?

Dr. Leuthardt:

It's not a stimulator, just to be clear. The IpsiHand is three parts. It's a headset. It was specifically designed so a stroke patient could put it on one handed. A robotic exoskeleton. Again, that's a wearable. It opens and closes their hand, their paralyzed hand. And a tablet that basically walks them through how to use the system. So basically, the headset picks up signals from the uninjured side of the brain that's associated with the intention to move their paralyzed hand. And when it picks up those signals, it opens and closes their hand according to their movement intention. And after they use that for about three months, although we start to see results in the first four weeks, that they get a significant improvement in their motor function in the chronic phase of stroke. And I think that's what's so important, because basically we know that after six months, whatever motor function that they've lost isn't coming back in a meaningful way.

Dr. Leuthardt:

And I think the secret sauce of the brain computer interface approach is that it comes down to all about timing. That basically when you tightly couple movement, they're getting proprioceptive feedback in their hand with this robotic exoskeleton, that's tied to brain signals in the uninjured side of their brain. That's creating what we call a heavy and model, things that fire together, wire together. And that leads to, I think that really creates the right physiologic environment to promote plasticity, and these people gain significant hand function back.

Dr. Max Boakye:

Wow, this is so fascinating. I could talk to you for an hour, but let me give you one last question here. If you had a magic wand, what question or research would you do, unlimited resources, basically.

Dr. Leuthardt:

The key would be the unlimited resources, right? Because the honest truth is I think there's so much good stuff out there, quite honestly, whether it's in the labs, or some of these early startup companies. And resources is a real barrier to moving these technologies from the lab to getting it, all the regulatory hurdles which are there, which are necessary. I don't want to say that they're not necessary. They are necessary, but they're expensive. And so I think that the first thing I would wish for with my magic wand is unlimited resources, because I think there's many, many wonderful things out there. Now, if you ask

me, okay, well, which things am I going to pick? Well, I think that certainly, I think I would expand our current repertoire of non-invasive brain computer interfaces for functional restoration of multiple broken neural circuits, whether it be broken motor neural circuits, or broken attentional circuits to really improve people with stroke.

Dr. Leuthardt:

I think the other thing that I'm deeply interested in, because I think that there's an absolute, enormous need, is that I think with psychiatric, and mental health problems, and chronic pain, that these are what I would call networkopathys, where we've got an inbounds brain network. And I think that there's a number of technologies that are emerging right now that are minimally invasive or barely invasive that create these rebalancing of the network. And so I think that depression related inplantables, I think that that's a huge future opportunity, and especially after COVID, and the market crises, and everything, that mental health is a real issue. And creating technologies for that, I think, is another really important need that I think we could, as neurosurgeons, really address with some of these important neural interface technologies.

Dr. Max Boakye:

That's amazing. Well, this brings us to the end of this fascinating conversation. I want to say congratulations for your FDA approval for the IpsiHand. And really want to take the time to thank you for taking the time to speak with us about BCI and all the great work that you're doing. I wish you continued success. Keep up the good work. This is really incredible and very powerful for patients.

Dr. Leuthardt:

Thanks very much for having me. It's always fun to talk about this stuff.

Speaker 1:

Thanks for listening to Optimal Neuro Spine podcast with Dr. Max Boakye. If you enjoyed this episode, we hope you share it with others. Leave us positive reviews on social media or leave a rating and review on iTunes. Check out our website MaxwellBoakye.com/podcasts for show transcripts and other information. Join us next time for another edition of Optimal Neuro Spine Show.