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Dr. Pawluk: This is Dr. Pawluk. This session of the Pain Solution Summit is going to talk about the brain impact of chronic pain in people in general who have chronic pain. I apologize for my voice. I have a little laryngitis. You don't have to feel sorry for me. It's not hurting. It's just sounds horrible. So I'm going to have Dr. Mark Tommerdahl do most of the talking today and I'm sure you'd appreciate that anyway cause he's the one with all the information. So Dr. Tommerdahl is a co-founder of Cortical Metrics. So Cortical Metrics is a company that developed a product called the brain gauge. I've been working with Dr. Tommerdahl and his partner Dr. Robert Dennis for four or five years now. And I actually use the device, the brain gauge device and a study that I did on concussion. So I was very impressed with it and I, and he also related to me the fact that this tool is very useful for measuring brain impact of pain. It's useful for a broad range of things that Dr. Tommerdahl can talk about that. So without spending more time for you listening to me, I'm going to have him introduce himself and then we'll sort of launch into what the brain gauge is and go from there. Thank you.

Dr. Tommerdahl: Hey, thank you. Yeah, thanks for giving me the opportunity to chat a little bit. as Dr. Pawluk said I'm Mark Tommerdahl I've been at the university of North Carolina since 1980 that sort of gives away my age. That's when I went there as a graduate student and matriculated through a doctorate, postdoc and, and you know, basically kept, stayed at the university and studied a lot of things like some somatic sensation and pain and how the brain works. And you know, up until around 2004, 2005, we started doing some experiments, looking at translating what we knew about brain function and to what we knew into what we could, how could we study how the brain works in a very simple manner. And so why don't I, I'm gonna go ahead and share a screen and talk a little bit about, let's see.

Dr. Tommerdahl: So I've got a little, I've got a few slides here and I'm just going to talk about the brain gauge and basically everything you need to know about the brain gauges on the first slide. But I've got a bunch more slides that you'll have to listen to me yammer about afterwards. But basically, if you look at the, the brain gauges, this computer mouse sized device that you see on the screen and those two white pro tips that you see on the surface, those are not buttons that you respond with like you would on a computer mouse. They actually vibrate and they vibrate and deliver stimuli or activate specific region in the brain. And when they do that, we ask questions, we ask whoever asked questions about what you feel in terms of those vibrations. Now this is very different from traditional sensory testing and that's why we call it cortical metrics because this was all designed around things that we saw in the brain and in the cerebral cortex over many, many years.

Dr. Tommerdahl: And what you see on the computer monitor, on the picture of the computer monitor is a sample results. And basically you see in the left hand corner you see the most recent results and we have bar charts and I'll go into that a little bit more. But basically the whole concept of this was designed so that we could measure some aspect of brain function and track brain health history. And our idea back in 2004 was that we could actually do something that would be low cost, have a high impact, and give people a way to measure brain function. So let's go on to the next slide. And so how does the brain gauge work and basically what you see here, like I said, the brain age vibrates the fingertips and the blue arrows on the pictorial cartoon of the brain shows that we direct these questions.

Dr. Tommerdahl: We direct this brain activation in many different places and a lot of people are very familiar with say neurocognitive questionnaires and all those questions are directed at all those questionnaires are directed by you know, visual, not so much visual stimuli, but just asking questions to test your memory and your learning. And what we do is we test a number of different mechanisms and these mechanisms are things like lateral inhibition. information processing speed, feed-forward inhibition, timing, connectivity, timing perception and plasticity or adaptation that all of these things are very, there is some overlap between them, but what we do is we target each of these different measures and when we collect these different measures, what we get is we get the basis for cognitive function. In other words, for example, lateral inhibition and plasticity play a huge role in learning and memory and it's much easier to measure.

Dr. Tommerdahl: So let's go onto the next slide. I put this slide up even just to emphasize where we have developed, where we've come from in terms of technology. And what we done is we basically started out with a hundred pound beast to do back in 2004. That's where we did our pilot experiments. And it's very, very hard to deliver extremely precise stimuli to the skin. But if you can deliver very precise stimuli to the skin, then like you see on these, basically on the very top left hand corner the very first pro tip, you see those when we'd delivered to very precise, stimulated skin, we got very very good results. And we could send very precise stimuli to specific parts of the brain and have those places in the brain interact and target questions that we wanted to ask. One of the first subject groups we looked at where it's actually pain groups, but we'll get into that in a minute.

Dr. Tommerdahl: One reason I want to put this up there is t, the very first stimuli stimulators, were roughly $30,000, and that was $30,000 to deliver a single stimulus to one

place on the skin. And what we have done is we've spent a lot of time and energy and actually a lot of the money from the office of neighborhood search to support us for development of this so that we could miniaturize everything and cram about a hundred thousand dollars worth of electronics into a very small computer mouse sized device. So this isn't a computer mouse, it's got a couple of buzzers in it. So you know, if any of your people want to try to do that, knock yourself out. But that won't be very precise. And what we've done is we've, we've driven that price down to where it's no longer cost prohibitive for anyone to own one of these. I mean basically it's a, you can get one in a home for as low as for under $20 a month.

Dr. Tommerdahl: Anyway, this is an overview of everything. I'm not going to go on a lot of detail, but again, alongside with that technology development, we, as soon as we had our first stimulator built, we started doing studies in the clinics and we've done a lot of validation studies. We've got over 80 publications, the brain gauges, FDA listed as a cognitive assessment aid. And basically our goal was to show how brain health is modified. And so what you see here this is a exemplary recovery from concussion where you basically, this overall score keeps getting better. So in this case, low numbers are bad, big numbers are good, are basically like to deliver a user friendly interface so that whatever you're looking at is really easy to understand. Green is good, red is bad, yellows in between.

Dr. Tommerdahl: That's kind of a universal color scheme that we had nothing to do with, but it seems to work pretty well. So let's go on the next. Why bother measuring brain function? That's always the important question is why, why bother? But a lot of people don't really think about this. They check their heart rate and blood pressure. They check their weight on a routine basis and but they never really checked their brain health. And this is the whole reason that we developed this was that so people could track their brain. And I remember the conversation that I had with my, co-conspirator, Dennis was that, you know, basically we wanted to look at brain function and not be slaves to imaging methods that really didn't work, for example. What a lot of people don't realize, you know, when people, somebody you're reading the paper all the time about people getting concussed and what a lot of people don't realize, they say, Oh, you've got concussed.

Dr. Tommerdahl: So go get an MRI, go get a cat scan or whatever. Well, the definition of the difference between mild TBI, which is a concussion and moderate TBI, which is a little worse, is that nothing shows up on a scanner in mild TBI, yet that's a big problem in the sports concussion world. So how do you actually check and Allie actually have something that's sensitive enough and inexpensive enough to

actually track a brain health? And so you know, at the time that people were trying to do imaging methods is still really not cost effective to look at. There 's some research too that show some small changes but you know, if you have a headache, you're not going to get a brain scan. You know, what you want to do is you want to track your brain function. And along with this, one question we always get is how often should somebody tests their brain function when they're going through a treatment and that treatment?

Dr. Tommerdahl: You know, my answer is always, it's really similar to weight gain or weighing yourself if you're on a diet, how do you, you know, what do you do? You really need to measure yourself. And that's the whole point. If you don't measure yourself, how do you know whether you're improving or getting worse? But anyway, so in other words, patient or individual self-perception is really not accurate that goes for weight gain. I mean I stand on the scale every once in a while and realize, Oh yeah, I did gain 10 pounds over the holidays. Not a good thing, but you know, it's good to know. Anyway, let's go on to the next. I want to get through some of these slides without spending too much time. As I mentioned, we tried to come up with some fairly easy to understand scoring system and this is intuitively from left to right day 1, day 6, day 14 post-concussion.

Dr. Tommerdahl: Day one after concussion, you expect somebody to be a bit groggy and you know, they're basically not doing that great. And if you look at these scores without any real knowledge of what those scores mean, you say, Oh well they're probably not doing well. They get red scores and you know, a few that are a little bit better. And then on day six they've got some yellow scores and the little bars a little bit longer. Day 14 all their scores on this particular individual are all normal. So that's one way to look at tracking. The other way to look at tracking is we take all the scores, he likes speed and accuracy and you know, all the ones that you see listed here, you take all of those scores and average them into the overall cortical metric.

Dr. Tommerdahl: And the overall cortical metric is what we plot. Typically we look at that and that's what we use to track brain health history and see how well somebody's brain function is doing. We use two different plots, two different types of graphs. And this is really just a matter of what you have preference between the end user. Basically notice from the left to right, scores are getting better, but on the top hand line, that's called a radar plot. And you just notice that once somebody is healthy, that radar plot fills up. And again, it's fairly easy to read. So one clinicians we work with one of my favorite quotes came, came from this team physician at a and he's team physician at a college where he looks at a lot

of sports concussion. And after a couple of years he said, you know, I don't care about them other tests they take.

Dr. Tommerdahl: He's from the mountains in North Carolina. He said, but I want to see some green before those boys go back onto the field. So basically he just without really he says, I don't know, I don't understand what these measures mean, but when I see green, I know they're doing well. And that's after a couple of years of looking at the scores and being part of a research group. But he basically understood quite quickly that these are very intuitive scores that were, that Eddie could use.

Dr. Pawluk: No Mark these. Go back that slide. The last slide please. So this is day one through day 14. Correct. And this is without treatment of any kind?

Dr. Tommerdahl: Without treatment. So yeah, one thing is we'll talk about some treatment situations with TBI, but in sports concussion, 80 to 90% of the people recover quite, you know, in a two to three week period.

Dr. Tommerdahl: This is a mild and keep in mind, this is a mild concussion. So if you were to do on this person, insurance paid for a cat scan, cat scan did not show anything and generally they also took neurocog test and generally, they pass that neurocognitive test on day seven, on average but they're never ready to return to play for at least two weeks. So basically most people recover on their own from concussion in a couple of weeks about a good solid 10%, though have trouble and need help. And those are the people that I believe somebody or some of the people that you saw in our study they'd had a concussion symptoms for about eight years so quite long. So it was, so some of these concussion symptoms can really persist for quite a long period of time, especially if you don't, you know, actually give them some help.

Dr. Tommerdahl: Okay. Anyway, sorry. Okay. So here's, here's a situation we do work with the DOD and what we're doing is developing methods or basically we have developed a method which is now in the process of being used and tested on military basis. And what we want to do is track people over time. In other words, if you get somebody, they joined the military and you want to start tracking them from the time they are in active duty and track their brain health until you know, well into their formative years, somewhere between my age and Dr. Pawluks. So anyway, after they left the military and they're at the VA, but what we see here is this person's got pretty good scores or an active duty. They get deployed, they get a blast injury and also their scores get a lot worse.

Dr. Tommerdahl: They recover in deploy again, they get another entry. This time they do even worse. Typically getting a blasted or getting a second concussion, you do much, you know, you do much worse than it takes longer to recover. And then this person actually retired. And then this is from a PTSD study where they had PTSD and recover. But basically what you can see is, again, left to right, goes from bad to better and this is just an expansion of this area here. And you can see how they track over time they slowly get better all the time. We see this all the time with, college athletes we'll be tracking them, you know, for a few weeks and they'll be ready to return to play and they'll test them one more time and all of a sudden their scores are terrible.

Dr. Tommerdahl: And well, just a side, I'll tell you one story about that. I had an athletic trainer contact me and say, you know, I tested this guy he did perfectly, he did great and on Friday, and then on Monday I was going to use Ray to return to play. I tested him again and his scores are terrible. The brain gauge doesn't work. I said, well, are you sure the brain gauge doesn't work? She goes, yes, because he was fine on Friday. And then the brain gauge said he was, he was, you know, about 70% on Monday. And my response was, well, what did he, I believe it was actually my Alma mater, so I knew that it was what they had done and it was their spring frolics and I just happened to mention that that well, he may have been drinking all weekend.

Dr. Tommerdahl: And she said, well, no, he wasn't drinking all weekend because that's against protocol. I said, okay. And she was kind of angry and hung up the phone and called me back an hour later and apologize because she had confronted him and found out, well, he had been drinking all weekend and that's why I score it. And when you have a concussion, you shouldn't drink. So one point of this is that tracking, this actually helps the athletic trainers with compliance. And that's just something that really works. Works well they, they see somebody who's all of a sudden, they're not getting better. That's part of their treatment plan. If they have a concussion plan or protocol for them to follow, and if they're not following that and they start falling off or they're, they're goofing off, it really makes a difference to actually be able to track people. So I have a few examples but this is a TBI example where this was a patient of someone who is used to bring gauge and they'd been tracking him for or treating him for a few months.

Dr. Tommerdahl: And basically what they'd done was try to improve his overall brain function with diet. And that was about it. And then what happened here, this little eye. And basically they started using postal like magnetic field for the next couple of months and all of a sudden he started getting better. So, and we've seen this in

a number of clinics where people track and they don't really get any better. And then they start using the last, you know, then all of a sudden they tried it, they decided to use pulse electromagnetic field, and then they get better and they say, well, yeah, there was the last thing that, you know, it's like they always find their keys in the last place they look, but it's it's a common thing that seems to happen. It seems to be like it's always the last place. Last thing they try after they've tried everything else. Anyway, I thought it was interesting in what you can see is this data point corresponds to the top right radar plot and you see how these radar plots really didn't change over time. But then on the third radar, the third test, after he'd had some treatment, he actually got much better. So this was one of those cases where the person didn't recover on their own and they'd actually had a concussion symptoms for at least a year before they went and got help.

Dr. Tommerdahl: Okay. So I talked a little bit about concussion, TBI. What are our applications that we've used? And when I say applications, these are also some of those publications. So we've got papers in a concussion and TBI pain. A lot of, we've done a lot of studies and or neurodevelopmental disorders such as autism, ADHD, some neurodegenerative disorders and pharmacological insult basically anything that impacts central nervous system function, anything that impacts brain function will impact bring guage stores. That's basically the way it works. Different scores will be impacted differently. So you'll have a different profile for different groups and you know, in some research studies we actually were able to differentiate migraine patients from concussion patients, but in general as far as utility, the device, it's very good at just looking at differences between people with some kind of neurological disorder, neurological insult and tracking treatment efficacy.

Dr. Pawluk: Now, Mark, probably it's important to say that people are often mixed, right? There's not probably, there is no such thing as a normal.

Dr. Tommerdahl: There is, norms are extremely hard to define. That's, that's very good point and you know we have arguments with other academics about those, but you know, a lot of people, the interesting thing, I have the privilege of working across many, many different neurological disorders and that's given me a very nice oversight. You bring up a great point one of the first studies I worked on was a program project. A program project if you're not aware is it's an NIH sponsored study and we had five, we were studying five different types of pain and with those different types of pain they were things like fibromyalgia, VBS, migraine, IBS and carpal tunnel. But we were looking at, as what we were doing is we're collecting, trying to collect normative data for all five of those pain groups.

Dr. Tommerdahl: And so what we did well or what the organizers did, they said, okay, what we'll do is we'll take the way that most people are studying pain. So if you studied pain, if you all you'd really study headache or migraine. And they took their own form and their own criteria for what a normal is. And then we took somebody, the next group, the fibromyalgia group, and then the TMJD group. Well, each of those groups had their own criteria for what was normal and how they ask questions to define normal. So you know, as, and this is just for the pain group. So what we were trying to study was what's common and what's common in these pain groups. And then we wanted to study the controls. So you, so I just wonder Bell, if you know what percent of the population was normal based on their criteria?

Dr. Pawluk: Probably 5, 10%

Dr. Tommerdahl: It was 3% yeah. I was also working with an alcohol studies group at the same time and if you had added in their criteria, it was more like 1% because you know, in their criteria, anybody who drinks more than a, if they're female and they drink more than eight drinks per week were male and drink more than 14 drinks per week, you're definitely defined as an alcoholic. So if you put that into the pain group, you wiped out another chunk of people.

Dr. Pawluk: Well, yeah, you have to know that obviously if you come to a doctor for pain, you have had the pain for a while, right? And before you got your pain, you were what you were at that time, which is your normal. Whatever you brought to that game with you, that before that that was your then now you have the pain. So now you're different because of the pain, but you're different. You're not only different because of what it caused the pain. Now you're different with the pain added on top of what you were before.

Dr. Tommerdahl: Right. Well, another interesting thing about that, that group was when we started compiling the data, there was a statistician that tried to invoke his own opinion and he would say, okay, and you're going through patient by patient. He said, well, okay, what did this patient have? You say, well, they have fibromyalgia and migraine. He goes, pick one. And then the next patient, fibromyalgia migraine and TMJD, he said, no, they can only be one. So that's, that's kind of the problem was doing studies like this. Yeah. They like all the studies like the NIH is sponsoring. They're demanding now more and more that these studies be formulated so they can go into a database so that it can be studied on more of an automation type scheme. And that just doesn't work

because people are people and you've got to study them individually, which is why I like case studies.

Dr. Tommerdahl: So we agree. Anyway, let me move on anyway. Go over just briefly some of the foundational concepts of the the brain gauge and why testing through this Somatosensory system works so well. And most people, you know, somatotopic organization basically just says that, you know, if you stimulate, if you stimulate one finger, you're actually activating a place in the brain that's side by side with the other finger. So that allows us to deliver extremely well controlled stimuli and activate places in the brain that are side by side. Now I highlighted here the, that is highly integrated with the pain system and that's really important because what a lot of people don't think about, you know, when they're doing sensory testing is that they might do visual tests and say, but you know, visual system, you can look all you want, but there are, you might hear things that you don't like and you might see things that you don't like, but you don't have no susceptors or pain receptors in the visual or auditory system.

Dr. Tommerdahl: Whereas in somatosensory system you do, all your pain is channeled through somatosensory system.

Dr. Pawluk: So somatosensory is sensation from the body, from the physical body, right?

Dr. Tommerdahl: Correct. Correct. Now there is a central and peripheral component to that and I'll get into that in a second. But anyway, and also this system is less susceptible to ambient environmental noise. So you can test the tactile system and sense of touch. Somebody walks in the room, it doesn't bother you in general. It's a very good laboratory because you're delivering stimulated just those two places and nowhere else and in that sensory system. Whereas when you're doing visual testing, light ambient light changes or auditory testing, you have noise walking around. So it's really a very, very good system the other part is that we have a lot of experimental information and we have a lot of, there's a lot of animal models for studying this and looking at how, what exactly these tests mean.

Dr. Tommerdahl: Again, so what I wanted, if you notice here over on the left, the highlighted areas of central sulcus, central sulcus is down here. If you look in the middle that area 3C and it's sort of a new designation, but area 3B and area 1, those are the traditional areas of tactile input. That's where you like when you touch the skin, that's where you localize where something is that's a part of your brain that makes a lot of decisions and helps make a lot of decisions on the brain gauge studies and area 3A and 3C, those areas actually light up quite a bit with thermal or noxious stimulation. So if you have painful stimulation, those areas actually

get quite active. And so what happens when they become active is that you have area 3B one becomes active here.

Dr. Tommerdahl: It actually works to suppress area 3A. Area 3A works to inhibit area 3B1 in other words, if you have a lot of activation, if you have a lot of pain area 3A actually becomes quite active all by itself and actually suppresses area 3B1 if that area is suppressed. It has a lot of hard time with a couple of the brain gauge measures and I'll get into which one of those in a minute this one on the left. What we did this is, this is basically the test results of looking at interaction between pain and vibration. And this is showing that some types of vibration actually can have a positive effect on pain. And are you familiar with the experimental windup procedure protocol? No. What would that experimental, it's called windup. And this was, these are all, this is a human study here on the left.

Dr. Tommerdahl: And basically what you do is you deliver a hot tap. In this case to the thenar, you just deliver one hot tap every three to eight seconds. Soif you deliver a tap every three seconds and then you get the pain rating, this is just a verbal rating, a verbal analog rating, and basically in between zero and a hundred where a hundred is, you know, zero is, you don't feel anything. 100 is you would commit suicide if you had to live with that pain. Well, each time you get attack, it gets hotter and hotter and hotter or it feels worse. Even though if you put a thermistor on his skin, the temperature is not actually going up. So basically what you see here is that with each tap, the pain keeps going up and up and up. So all of the subjects are sitting here doing this.

Dr. Tommerdahl: And you know, and that's because, and when you just do a simple tap or when you do a low frequency vibration at 25 Hertz doesn't have any effect. If you vibrate at a high frequency, you actually reduce the amount of pain. So that still ring a painful stimulus and vibration at the same time. And what's over here on the right is what the cortical analog is. And notice that the white area here was looking at we got 25 Hertz and one column, 200 Hertz in one column and thermal, and I'm not going to go in think we got 45 minutes to go into all the details of this figure, but the main thing to notice is look at the difference between 25 Hertz, about the five second time, 200 Hertz of the five second time and thermal at five seconds you see that the vibration is turning white.

Dr. Tommerdahl: That's actually inhibition is turning off that area that is being activated by the noxious stimulus at the five second mark. So that's just a, that's an imaging study that basically confirmed that there was interactions between those two areas. Now there's been, there were a lot of other studies that showed that and they go back to the 1940s, people actually ablated area those areas, not on

purpose, but this was a dominant on world war I, world war II veterans where they looked at bullet ablations that had just randomly gone through these places and those people had no pain. And you fast forward today and people are doing TMS and ultrasound studies where they're actually trying to turn off somatosensory cortex. They don't really have the resolution to do 3A versus 3B, but there were actually a number of surgical ablations that were done in the 1950s and early 60's where people actually just cut out that, you know, the all somatosensory cortex to stop the pain and it was effective.

Dr. Tommerdahl: I'm not recommending anybody do this right now it's not a standard medical procedure anymore but there is an opiate crisis and try to, it could be a target for pulse electromagnetic field if with the right parameters, I think. Um, but it's a very deep, it's very deep in the brain. So that's, it's an area of research I thought you might be interested in. Okay. Let me go through one measure. Just one. I'm just going to go through the accuracy measure very briefly and our test battery is composed of multiple tests, generate several scores. We'll see how and, and we do this with tracking. In other words, we start out track, you know, an eye chart is a method of tracking and it starts out very easy. It gets very hard. Same thing with this. Where we do is we deliver two stimuli at two different strength and we just here just compared numbers, 400 versus 200 very easy.

Dr. Tommerdahl: And if you get that right, then you go to the next one, you look at three 60 versus 200. In other words, as long as you're getting the answer right, you go to the next stimulus intensity. Just like reading the IHR keeps getting harder as you keep doing well. Um, this is just another, um, way to conceptualize tracking differenc limen,, comparing our camel to a square or a triangle is very easy. This is actually done on some cognitive tests. Hopefully you'll get all these right. The 1 hump versus 2 hump camel's a little bit harder. So anyway, that's a kind of, but we think delivering sinusoidal stimuli a very, they're very precise, is a much better way to objective measure something than to use pictures.

Dr. Tommerdahl: Okay. The original idea about lateral inhibition came from a guy named Georg von Békésy back in the 1960s and he actually extrapolated this model of inhibition where inhibition is where things are turned off and you always hear, I mean, how many times have you heard people say, Oh, only 10% of your brain is used. Well, that's because it's turned off. Inhibition plays a really, really large role. And if everything's turned on, if there's no inhibition, well that's a seizure. That's what happens when you have a seizures. Everything's turned off or turned on. Inhibition is completely off and you can't stop things from propagating. But if you have excitation, it's surrounded by inhibition all the time. Anywhere there's excitation is surrounded by inhibition.

Dr. Pawluk: And this applies to hemispheres as well as local areas.

Dr. Tommerdahl: Yes. Now this happens at all areas, happens locally within many columns within very small areas.

Dr. Tommerdahl: It happens between, it's in a fractal organization. So the small areas, and this happens say between adjacent mini columns, which are tiny, components of columns. And you can think of like when you activate a single when you deliver a stimulus to a single finger, you're activating multiple columns. And so it also acts between multiple columns and then multiple groups of columns and then between areas. So basically this inhibition happens across all different levels, all different scales. The interesting thing about this is that he came up with this idea doing nothing but sensory testing. He didn't do any, he didn't stick any electrodes in brains. That wasn't confirmed until many years later. This figure here is an image of something that actually confirmed it is an image from brain activity that was done in the 19, late 1980s.

Dr. Tommerdahl: Okay. So how do we deliver this test or how do we get an accuracy metric where we deliver, we ask a question, we asked which of two stimuli are larger. And so on the left hand side, what you're seeing is we're saying which of these two stimuli are larger? And then we'll track down and figure out how good you are at that test. And that's called simultaneous amp discrim because well there those two stimuli are delivered the same time or we'll deliver them sequentially. We'll do it both ways once we'll do it at the same time. The other time we'll do it sequentially. Sequentially doesn't tax the brain quite as hard. It doesn't tax lateral inhibition nearly as much. So let me show you what I'm talking about. Well first if we deliver a single stimulus, you get a simple percept. So if you were to take a pencil and just poke your finger or poke your palm, you would feel, Oh, I can feel where that is. But if you deliver multiple stimuli.

Dr. Tommerdahl: It starts to sharpen up. This is just to introduce that concept of contrast enhancement. That's what your brain is always trying to do with this lateral ambition. Now we do that test and think about it this way. If we deliver two stimuli the same time, and this is what's going on inside the brain, you activate an entire column here and activate an entire column here, and this group of cells is trying to turn off what's in between. Now, if we try to emulate something like a low GABA, a situation like a lot of pain patients have, they have low GABA and which is sometimes limited with a GABA agonist and you see that all sudden, nobody can tell the difference between these two columns, these exact

same experimental conditions. But here there's just a tiny bit of a GABA antagonist. So a little bit of the GABA is turned off.

Dr. Tommerdahl: In terms of when we look at that GABA deficiency is also a sort of happens and that's known to happen in concussed individuals. And the accuracy metric, you can see that this is basically the higher numbers are worse in this graph. So Day 1 post-concussion is fairly high. You get the worst numbers a week later and it trails off and gets back to normal between around 3 weeks. These little arrows that you see on here, red arrow means they were cleared by balance testing. The balance testing is one of the standard of cares in the concussion world, for some reason, every paper says it only works about 20 to 30% of the time, which means it's worse than flipping a coin. This blue arrow indicates when there clear by impact, which is a standard neurocognitive online tests of standardly used in sports concussion world. And this green bar is when they were cleared by the physician for return to play. So anyway, I just wanted to give you an example of accuracy, but basically a lot of, there's a lot of populations that have low levels of GABA besides concussion. There is anxiety, chronic pain, a lot of neurodevelopmental disorders. Epilepsy's a big one obviously. Let's go on to the next one.

Dr. Tommerdahl: This, we move on and get onto the, get onto the some of the examples. These are case studies. In this case, what we're looking at is what I want you to know. Look at the motions that is the overall cortical metric. And this is not a 0 to 100 scale and this is after multiple PMF sessions. This person was treated twice a week and basically they slowly got better over this amount of time and I'll just give you just, that's the overall score. The accuracy metric is actually much more sensitive in general and this was a lumbosacral pain where the PMF was used and basically over multiple sessions of that, this person's accuracy score got much better. So you see their scores 100% here and they start off about 30%. So they actually improved quite a bit.

Dr. Tommerdahl: Another example of the accuracy metric getting better, and this was an improvement in cervical pain with pulse electromagnetic field. And this was again, multiple sessions over 3 months period. But what I wanted to jump to while we still had time is I wanted to look at this. He's talking about the study that we did together Bill. And this was your patient group and this is just a few of them. What we see here is this was a study well do you want to discuss your, how your patient recruitment or, or how they came to you? I know they were anywhere from eight months to eight years of symptoms.

Dr. Pawluk: All we did is send out an email asking people to join the study fully what the study was about and they'd get a free post magnetic field device to join the study. We recruited 10 people. I just took them sequentially first come first serve. We didn't have a control group. We use the patients as their own controls. So we got the pre-treatment tests and then we started treating them. They were treating themselves with this PMF device for two hours a day. Then we tested them weekly for four weeks, then monthly for another two months and then we have them stop and retest after that.

Dr. Tommerdahl: Yeah. And the thing that was really interesting are there are a lot of things interesting about it when you start looking at data. But what I find is that just how I'm always, you know, even though I basically invented this technology, I'm always amazed when it works, you know, it works just about every time. So pretreatment either terrible scores, look at this bottom left hand corner that basically that person fail at every test. But, and everybody responded on a different timescale, which is, you know, basically that's not, you know, that's not anything that should be a shocker that some people take longer to recover than others. But the fact is these people had been chronic forever. I mean, some of these people had, had been chronic for years and so two months, you know, in a second, you know, this person went from pre-treatment to five months, you know, where they did fairly poorly to five months, they were back to normal but this person on the bottom was really amazing. They couldn't barely function on the first test. Two weeks later they're doing much better and a month later they're performing very well. And the overall scores showed the same, showed overall improvement. And you know, I know this the thing that we don't have posted up here that we were talking about before we started was that after they quit treatment, their scores got worse. So maybe they had, they need to, I don't know. Do you want to say anything about that?

Dr. Pawluk: They didn't all go back to baseline.

Dr. Tommerdahl: Right.

Dr. Pawluk: It's a good thing they didn't go back to baseline. So they stopped treatment for one month and we retested them after a month of being off. So we didn't have intermediate testing. Then a month later everybody continued their treatment. One woman had several TBI's in car accidents. She had temporal lobe abs epilepsy as a result of her damage. She lasted two weeks off the device and she couldn't stay off it any longer. She had to go back on and we did, we did the test after the two weeks that she'd been back on again as amazing results.

Dr. Tommerdahl: Good. All right. Well anyway, I think this is a pretty, we're getting pretty close to a conclusion here. There's lots more information, but which brain gauge if, if you're interested in different brain gauges, we have several. We have the brain gauge home, which is what we recommend for individual and you know, that's that you can either buy that outright and not have any testing, not have any subscription fee or you can subscribe for as low as $19 a month. The brain gauge pro is a very low cost, clinical tool and the brain gauge MD is FDA listed and we have to do a lot of paperwork on that so it costs more. That's the main difference. I'm not supposed to say that am I. Anyway, you can just go to gaugeyourbrain.com for more info on purchasing. But as far as there isn't, there is an interplay between the brain gauage home and the two professional models.

Dr. Tommerdahl: And basically any of these brain gauge homes can share their data with the clinic. And so the clinic can look and we find that there are a couple of different groups that liked this option. One are clinicians who have patients that are very remote and they live, you know, 8 hours away and they want to just track their recovery. And you know, if they only see their patient every 3 months, then you know, that gives them a nice telemedicine approach to interacting with their patients. A second group are patients that live very close, but they're in the parking's a problem. So they'd rather stay home. And but the other thing is some people it does seem to help with compliance in terms of, you know, people are put on protocols that they need to stay on. If they quit using whatever treatment they're using.

Dr. Tommerdahl: You can notice right away it's a little bit like having people hop on the scale during their weight loss program and if you need more info corticalmetrics.com is the website. We have publications. Like I mentioned, we have a lot of publications and a lot of different areas and if you want to read the really stuffy versions of that, that's on our publications page. We have easy reading, which we wrote a blog we've written, I would call them blog. They're really not blogs or short layman's term articles, which convert the publications into something readable and I wrote majority of them. So I guess I can say that there it's a trashy reading. Now if you really want the ugly viewing, the ugly version of this is on grumpy science, it's on YouTube channel. And so, and you can actually find that on grumpyscience.com or you just email us questions. for your discounts, if you'd like to get, or if you'd like to get a discount on any of our products, you can go to gaugeyourbrain.com and the discount code is DrPawluk.

Dr. Pawluk: What is the discount?

Dr. Tommerdahl: Oh, the discount. Hang on, let me go back.

Dr. Tommerdahl: Ah, discount is 10%. So $50 on the brain gauge home to buy it outright? The subscription is not discounted but it's pretty low already so the brain gauge pro is discounted $200. Brain Gauge MD is discounted $500.

Dr. Pawluk: Let's talk about that for a second. How would somebody decide whether to buy it or whether to rent it or can you do a rent to buy?

Dr. Tommerdahl: That's really up to the individual. Some people, like for myself, I don't like subscriptions, so I buy things outright. Other people, they prefer, you know, it's really, there's different plans you can get. If you want to rent it for a month, that's roughly $29 a month. If you want to get it for three months, that's a $25 a month or $24 a month. And if you get six months of description is $19 a month, uh, if you, if you buy it outright then it's, you never, you know, it will last a lifetime and you'll never have to subscribe unless you, you know, feed it to the dog or run over with your car then we generally replace them for 99 bucks if there's any after two years. There's a two year warranty. So anyway, it's just up to individual.

Dr. Pawluk: If you do any subscription plan? You have to, if you decide to buy it, you still have to end up paying the full price for purchase.

Dr. Tommerdahl: You don't have to. If you start out subscribing, we generally, we don't advertise that now we just did. Most people that subscribed, a lot of people that subscribed end up buying and we just put whatever they paid goes towards cost. The cat's out of the bag now. We don't, we don't advertise that. Thanks. Thanks Bill.

Dr. Pawluk: This is being viewed by limited number of people.

Dr. Tommerdahl: Yeah, no, it is basically like a rent to buy. If you, if you rent it and then want to buy it, that's fine.

Dr. Pawluk: Oh wonderful. Hey, let's stop sharing.

Dr. Tommerdahl: We don't have a subscription version for the brain gauge pro yet. If there's interest, we'll, we'll start it, so, okay. I'll pull that down.

Dr. Pawluk: Perfect. Okay. So it's complicated science, but it doesn't have to be complicated for you. Right. Not for you, Mark, but for the viewers. Basically what we're doing with a very simple test that taps two fingers on a mouse, you get a lot of information about the function of the brain. If you want to drill down to individual scores, you can do that and there's information that tells you what that means. Most of the time you're going to be interested in the composite score, the cortical metric score. Right? So what we are recommending is obviously that you do your, if you're going to start any kind of treatment, whatever the treatment program is, it doesn't matter whether it's nutrition or counseling or physical therapy or medications, then we recommend doing a baseline. Right. All right. And then monitor your progress. You're in the concussion work, you discovered that it could take up to two weeks for you to see changes,

Dr. Tommerdahl: right? Yeah. Usually takes a couple of weeks to recover. Yeah.

Dr. Pawluk: So certain treatments are going to result in changes faster. Right? You want to, do you have any sense of that?

Dr. Tommerdahl: Um, do I have any sense of how long it takes to recover or?

Dr. Pawluk: Which treatments for chronic pain? Cause this is all about chronic pain, which treatment?

Dr. Tommerdahl: So if it's about chronic pain the ones that we, when the treatment works, it will give you a hint that it's working. So, you know, you don't see any improvement on treatments that don't work. And like I mentioned before, you know, it seems like we've worked with a couple of people who use PMF as the last treatment. Uh, like this one person had tennis elbow and they did eight months of physical therapy and then they put them on a PMF device and all of a sudden he got better and he's worked, you know, he wasn't going back to physical therapy or anything like that. And they said, Oh, well it must've been the physical therapy. No, he's pretty convinced what it was because he saw no improvement. We saw improvement in the scores. The scores never budged until he started doing the right thing.

Dr. Tommerdahl: So it does, you know, one thing is a lot of treatments, a lot of times you're getting better, but it's really hard to tell you're getting better. And if you're measuring it with a very sensitive tool, like I mentioned, self-perception is really not very good at determining it. Did you really not very good at making a good

assessment of how well your brain function as you're using your brain to determine wether the brain is working. Now you might have brain fog and then you know you're short. But chronic pain does have an impac on brain function and we've all experienced that but if you're trying different things, you can see some things would work better than others.

Dr. Pawluk: I think that's an important point that I want to make is that you can actually track any of the treatments that you're doing to see which one is having the most impact because if you're very anxious and have chronic pain, which is a very common problem, then both of those are impacting your pain, right? So for example, I don't know if you have any experience of research would using say, CBD or marijuana and how that impacts your assessment scores and therefore your chronic pain,

Dr. Tommerdahl: right? Right. Anxiety actually impact some scores more than others. But you know, we see that a lot in pain patients is some pain patients have a lot of anxiety. That's true.

Dr. Pawluk: What you can also do is to do subtraction therapy. You're on a whole lot of modalities. You're doing a whole lot of stuff that gets expensive and tedious. It's on. So you can start removing therapies you don't think are working as well for you and you can manage, measure and monitor the progress with that. So I think at timescales for the cortical metric, showing a change can actually be days. It doesn't have to be weeks or months. Right? So the symptom measures in particular can get very, very quickly. And during durable benefits or durable treatments, things that will actually heal the cause of the pain. Like PMF scan may take a bit longer. So symptom improvement happens earlier and then you get physiologic change and then you get healing responses.

Dr. Tommerdahl: Right? Right. So one of the clinicians that uses us is we'll looks at uses the brain gauge, try to differentiate where the pain, whether the pain is more central versus peripheral. And that gives her a lot of insight into what treatments she can drop. Like she gets a lot of patients who are on that big basket of treatments. They come to her after they've been somewhere else and they come with a whole boatload of pharmaceuticals and she slowly gets them off those and it gets them on other treatments and uses nerve block and a lot of other things and does a lot of physical therapy. But, but basically she uses the brain gauge very effectively to do exactly what you're just mentioning. Subtraction, therapy.

Dr. Pawluk: I coined that. I coined that word.

Dr. Tommerdahl: Yeah. Yeah. You did. I'm just using it to describe what somebody else was doing. I didn't realize, she hadn't called that.

Dr. Pawluk: So in the cortical metrics, what are the score readings that differentiates central versus peripheral?

Dr. Tommerdahl: Well, right. So for example, plasticity, if you see, if you've got a lot of pain that's peripherally mediated and it will say it's all on your knee and it's new. It's peripheral, you probably won't see that big a change in your plasticity score. So plasticity is sort of a learning type function of the brain and it's well do you adapt? And what we found in our studies is around two and two and a half years of having pain you see it or over that period of time you see a huge shift in the plasticity score. Whereas people that haven't had the pain very long, you know, don't have a shift in plasticity score. And what happens is over time there's an interaction between peripheral and central. It starts out, there's always a central component. There's always a peripheral component, but you know, it's sort of like the extreme case is phantom limb pain.

Dr. Tommerdahl: And we've actually looked at Phantom limb pain too, but Phantom limb pain, you don't even have the limb, but you're going to have the pain there. It's obviously central. So what we're trying to do is figure out where, where that, that happens. And somewhere along the line the balance between periphery and central, they start interacting and they start interacting in that inflammation that gets so bad in the periphery, starts impacting what's going on centrally and you get hyperactivity and area 3A, which starts this maladaptive adaptation. And after a while you're just going to have a very poor pain response anything is going to set it off. I think you get hyperactivity in that particular area after a while and becomes much more central. yeah, I remember when we first started looking into this back in the 1980s and 90's, we were talking to people who were, we thought were doing the wrong thing because they were, they're finding people with pain and then excising the nerve.

Dr. Tommerdahl: I mean basically cutting, you know, and saying, Oh, that's what way to get rid of the pain. And they started cutting off one place and they say pain would come back and get worse than they cut the nerve up a little higher, a little higher. And they were doing this and it was sort of a really bad system because it was usually a result of jaw surgery and then they would go in and cauterize a nerve and keep going further and further up the line and it just kept getting worse and worse. You have to have that mechanical offset you got to have to have normal mechanical input to drive pain down. And if you don't have that, then you know,

it's got to come from somewhere else. But anyway, that just gives you sort of a line of evidence for that peripheral versus central component. It's kind of a long story.

Dr. Pawluk: A take away that I will take away from that discussion is that peripheral pain that is there for a long time and it's bad enough over a long enough period of time is more likely to affect plasticity. Which is a measure of centralization of the pain.

Dr. Pawluk: That's probably your best measure of centralization in pain. Now if the pain is really bad, it can also affect centralization. Right? So you don't have to, it doesn't have to be chronic for a long time. It can be acute, severely acute and lasts a week or two weeks. And that will also affect centralization, right? So, but anyway, it's individualized.

Dr. Tommerdahl: It is very individualized. And you know, like one person may get high anxiety with pain and another person might not. And then you have to factor that into their scores. So, but the anxiety really does impact one score in particular. Sometimes it affects your focus and that impacts another score. So we actually have a focus score. So how well can somebody, what, how good is somebody's attention? So anyway, that that plays into it. And when that gets impacted, then obviously a lot of things in your life are impacted. But that's a good way to measure it.

Dr. Pawluk: All right. So, but related to this and each of the different measures, they mean something to a neuroscientist, but each measure will mean something different to a user who's not a neuroscientist.

Dr. Tommerdahl: Right? So we've got that all written up. I mean, it's in our support page and we have the support group and basically we provide support for people that don't understand. But we write it out and like one part of the blog, I've got articles on each measure and we've translated the literature into what ever each measure means. And we've tried to, like I mentioned, we tried to make it intuitive or I think we did a pretty good job making it very user friendly so that there's something wrong. You just click on it and clicks on it and it takes you to a link to describe what that measure is. So that's, you know, there's, there's a lot of information on the website and on the app.

Dr. Pawluk: Okay, good. And if they have any further information about an interpretation that you could always email.

Dr. Tommerdahl: right, they can always email me or the company, depending on the question. If there's a technical question usually there, we've got several PhDs and our company, we've got their PhDs in brain gauge. So I'm not the only one answering questions. So.

Dr. Pawluk: Let's shift a little bit. Let's talk about groups. One group in particular that has a lot of chronic pain and I'm sure are going to be viewing this, are people with fibromyalgia. So what have you found, you've done research on fibromyalgia with the brain. What have you found in general about what describes that?

Dr. Tommerdahl: Well, so I don't know how useful this is, but the most useful, the most interesting finding we found on fibromyalgia was that, well, first of all, their plasticity scores were terrible.

Dr. Tommerdahl: But the most interesting part about it was we actually built a stimulator where they rested their arm or a device, an armrest that which warmed up their entire arm. And when we heated their arm up to like 40 degrees C, their plasticity scores went back to normal. So that was, and everyone said the same thing when they came in and they said, this fuels great. I want to take it home with me. He said, Oh, I mean, all of a sudden their pain in their arm went away. When we heat it up their arm. It's like, well, I mean it was, it wasn't a production device. It was just something we built to test that theory. But it was a very remarkable to give acute relief and see the plasticity score come back. So that was really kind of a impressive instant change in a plasticity score.

Dr. Tommerdahl: In reverse by, you know, we can wipe out the plasticity score by taking, when somebody takes over the counter cough syrup you take dextromethorphan and you get a little loopy when you take cough syrup and what happens is your lab test results gets terrible. It goes way down that's because actually an MDA receptor antagonists. So, you know, basically it's like taking a very weak version of PCP.

Dr. Pawluk: So the score gets worse. So heating is a counter-irritant. is that the way it work? It's a counter irritant. The heating is a counter irritant.

Dr. Tommerdahl: Yes. Yes. The heat was a counter irritant but I'm not, I really don't understand fibromyalgia, it baffles me. I couldn't, I just,I mean, we've looked at it and, you know, their scores aren't great, but the fact that we reversed them with that heat was very bizarre. Just, I couldn't figure it out. I couldn't come up with there,

it could be some kind of a counter and the 3A, 3B circuitry that's doing that. But I.

Dr. Tommerdahl: I don't know how to test it.

Dr. Pawluk: We don't know whether cold would do the same thing?

Dr. Tommerdahl: No, we didn't test cold.

Dr. Pawluk: And how durable is that heating response?

Dr. Tommerdahl: Uh, it seemed to work on every patient, but I or every individual, but we didn't test them again like after.

Dr. Pawluk: To see how long it lasts or how often do you have to repeat it?

Dr. Tommerdahl: Yeah we didn't do that.

Dr. Pawluk: Okay. Another group that I think is incorrigibly relative to their pain are complex regional pain syndrome. Can you talk about that and what your studies have shown about them?

Dr. Tommerdahl: Well, basically it's something my daughter has but we've got it, looked at it there, but it's another pain. It's another pain, chronic pain syndrome that does show up. The data does seem below normal with treatment. And we've got a blog written on this or an article, actually a case study written on this is where somebody was CRP at with complex regional pain syndrome, before and after treatment, treatment does improve their scores and the treatment in this case was interacts, I don't know if you're familiar with that, but it's just electrical shocking was a treatment they're using.

Dr. Pawluk: And that improved the scores?

Dr. Tommerdahl: That improved. Yeah, that does.

Dr. Pawluk: So another counter irritants basically. Any other points that you want to leave with us?

Dr. Tommerdahl: Uh, like I said, we haven't, we haven't run into any neurological disorders or insults where this doesn't seem to be sensitive.

Dr. Tommerdahl: And again, every patient's different, but we've had a lot of success and it's been very interesting, very exciting to see applications. My goal was I spent 20 years in basic science and my goal for the last 10 to 15 years has been to translate all this stuff that people know in the neuroscience world into something that's usable. And the thing that, what the brain gauge does is not just giving you a way to track brain history, it actually gives you some clues as to where to go to the literature and where, you know, where people have been studying things and writing papers on for decades. But it's totally useless if you can't translate it. And so now we can actually talk about, you know, go and look in what other people were looking at in terms of, you know, different neuromechanisms different mechanisms of information processing and things like GABA and MDA receptors, things like that, and see what the predictions are. And we can see that for both aging and neurodegeneration, for pain, for concussion, but we're making quite a bit of headway translating the literature into something useful.

Dr. Pawluk: Let's talk one final thing. Who shouldn't use a brain gatge who can't use a brain gauge?

Dr. Tommerdahl: They have to be able to read. So the youngest group that we've had, we've got one study going on with age three to six. But if, but in that case or when they can't read, we have to have somebody read the instructions to them. Phantom limb pain, we actually have done studies with, if you don't have a hand, it's difficult, but we actually have a different device that we custom build for the military amputees so we'd be or any amputee really it's just that most of them were in the BA, that we've looked at.

Dr. Pawluk: Obviously who has numbness in their fingers or hands?

Dr. Tommerdahl: Well, okay. So one thing about this, as we get a question, every once in a while somebody says, Oh, you can't test people that traditional sensory testing cannot test people who have any kind of peripheral neuropathy. So if you have a little bit of peripheral neuropathy, that's okay. So basically traditional somatosensory testing looked at primarily thresholds looked at mostly in your thresholds are between 5 and 10 microns. And if you have a little bit of neuropathy, it's going to go up to 10 or 30 microns. In other words, that's a size stimulus that you can feel. And the smallest stimulus we deliver is 200 microns. So we jacked up the stimulus so that everyone can feel it no matter what. And what we're looking at is the interactions between stimuli, we're not looking at. So we just have to deliver something that's large enough so that you can feel it. And now obviously

if you have no feeling whatsoever in your hands, then then it's going to be difficult.

Dr. Pawluk: Do you have a list on your website who shouldn't or who can't do the brain gauge?

Dr. Tommerdahl: I don't think so. I've not, not really thought about that, so I guess we could put that on there.

Dr. Pawluk: All right. I think we've had an excellent session. Thank you very much Dr. Tommerdahl For spending time with us about this marvelous device. I also want to say that we are working together collaboratively, Dr. Tommerdahl , Dr. Dennis and myself, we're going to be on drpawluk.com over this next year, not today or tomorrow. Begin to do some work with chronic pain patients and brain gauge testing on a regular basis over periods of time. So we can get an even better library of information about the impact of pain, the impact of treatment, and the results as measured by an objective device.

Dr. Tommerdahl: Excellent. Yep.

Dr. Pawluk: I encourage you to get your own system and begin doing your own studies, your own experimentation.

Dr. Tommerdahl: I know, too. I think it's great. Everybody seems to enjoy it. All right, well thank you, bill.