Futures in Biotech, 35: The Brain Machine Interface

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Marc Pelletier
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[Music]

Marc Pelletier
Welcome to Futures in Biotech. I am Marc Pelletier. I wanted to start this week's episode by talking a little bit about some of the embarrassing moments that I have had while recording Futures in Biotech. There is two in particular that come to mind. The first one is when I asked Harrison Schmitt, who is the lunar module pilot for Apollo 17, whether or not living and working on the moon for three days was like camping. That one was pretty bad.

The second one is more relevant to today's show and that's when I asked Eric Kandal, he was the Nobel laureate for physiology or medicine in 2000 for his work on memory, I asked him whether or not there would come a time when we could interface directly with the human brain with a jack, sort of like a USB plug, whereby we can perhaps learn how to fly helicopter – or martial arts. And I, of course, took that from the Matrix.

Well, our guest today is doing something very similarly to this. So, I guess it is not that embarrassing to ask that sort of question. His name is Dr. Justin Sanchez and he is the Director of the Neuroprosthetics Research Group at the University of Florida. He is also an Assistant Professor in the Department of Pediatrics, Division of Neurology and in the Department of Neuroscience and also the Department of Biomedical Engineering. So, I direct the question to him.

Dr. Justin C. Sanchez
Yes. So, I think I can definitely answer that question. So, Kandal did not answer it or he did not understand it?

Marc Pelletier
Well, he didn't. Then he picked upon it because I guess nobody had ever asked him when are we going to be able to plug in an interface into our head, right, through a universal serial bus. So, you are one of the few guys who is sort of bringing this together. So…

Dr. Justin C. Sanchez
Yeah, we're doing that.

Marc Pelletier
Tell us your story. How did you get started on this and then what is it about?

Dr. Justin C. Sanchez
[3:20] Yes. So, we are developing these new devices that are really similar to the idea of the bionic man. In the old TV show that a lot of us used to watch, it was more for enhancing performance and an individual's ability. The premise behind what we are really doing, though, is trying to develop new therapies for patients that are disabled. So, you can imagine that if you have – if you sustained a spinal cord injury and you become paralyzed, let's say from the neck down and you have lost control of your

arms, we would like to develop this prosthetic device that we could implant into your brain and it would translate the signals that are coming out of your brain. So, just to put it in general terms, it would translate your thoughts and your intent to move and we could use this prosthetic device to control a robotic arm or computer directly from your brain.

So, and that – yeah, go ahead.

Marc Pelletier
A brain prosthetic, right?

Dr. Justin C. Sanchez
That is exactly right. So, what we are basically doing is we're bypassing the injury in your spinal cord and we are using engineering and technology and computers to translate your thoughts and use it to express your intent.

Marc Pelletier
This is most – probably one of the most difficult projects. Maybe that is why I am hesitant. You are interfacing, right? You are not going from a neuron that is in your arm that has gone through your central nervous system and spinal cord. You are tapping right into the brain?

Dr. Justin C .Sanchez
That is right. You are tapping into the primary or executive control command center of your brain and the first major challenge is what signals should you be looking at and how do you acquire those signals.

Marc Pelletier
How do you interface? What is that primary biological mechanosensory – whatever – connection? How do you do that?

Dr. Justin C. Sanchez
So we use electrophysiology. So, electrophysiology has been around for many years. I think one of the first instances of this was around the 1920s where it really became popular. So, what we do is we place these fine microwires – they are about the diameter of a hair, around 50 microns – and we build an array of these, a two or three-dimensional array. So, you have this kind of grid of electrodes and then we slowly insert them into the brain tissue and slide these miniscule electrodes right next to the cell bodies of neurons that are of interest to us. So, in the –

Marc Pelletier
Does that hurt?

Dr. Justin C. Sanchez
So, you can't feel pain in the brain, right? You have no pain receptors there. So, from all the studies that are out there, I do not think anybody has felt pain but it is a very interesting concept though, right?

Marc Pelletier
Dr. Penfield from Montreal back in the '50s was doing open skull surgery to resect the brain, removing parts of the brain to prevent epilepsy.

Dr. Justin C. Sanchez
That's right. For epileptic patients.

Marc Pelletier
So, I guess you do not really feel it.

Dr. Justin C. Sanchez

Yes, I do not think that you would feel it. So, we work with some epileptic patients in our laboratory. We have had some of them control prosthetic devices with the exact same type of electrodes that Penfield used so many years ago.

The only instances where they can feel some kind of sensation is if you stimulate through some sensory or motor cortices and you see some sort of physical response from that stimulation. I have some really interesting videos of some patients who have had some evoked responses from stimulation of that type.

Marc Pelletier
If these are available, I would love to link to them.

Dr. Justin C. Sanchez
Sure.

Marc Pelletier
How is that electrophysiological process? How does it go from synapse to electrophysiological probe? What is the chemical? Do you mind – I guess we can get pretty technical here?

Dr. Justin C. Sanchez
Yes, sure.

Marc Pelletier
The audience is pretty…

Dr. Justin C. Sanchez
[7:20] Right, but I can go in general terms here. So, we can think of these microelectrode arrays as an antenna array that is just sitting in the extracellular space in the brain and it is seeking to sense changes in ionic concentrations in that space. So, whenever you have any individual neuron depolarize, it will exchange some ions into that extracellular space. And basically what these microelectrodes are doing are sensing that change in concentration and referring it to some ground location.

So, whenever these neurons depolarize, we can see that change in ionic concentration. We can actually measure individual action potentials from all of the neurons in the vicinity of those electrode arrays.

Marc Pelletier
There must be quite a few – and before I go into how many are there, how do you ground an individual? Is this going to be grounded to a, does it have to be grounded to a structure? Can it be through your belt buckle?

Dr. Justin C. Sanchez
So, the type of grounding that you use usually depends upon what type of electrophysiology you are doing. So, for these types of microelectrodes, we will ground to the skull or to some surface electrode that is right on the very surface of the brain. If you use some modality like EEG for example, you could ground to somewhere like the ear or some other part of the body. So, you really just need a differential type of signal through which you can sense these change in ionic concentrations.

Marc Pelletier
How many probes do you require?

Dr. Justin C. Sanchez
So, since we're very interested in recording single neurons, we typically say how many single neurons are necessary for decoding a patient's intent. So there are many, many, many more neurons in the brain compared to the ones that we can sense. So let me just give you some reference for the numbers. Let's say we put 100 electrodes into the brain, approximately 60 or 70% of those electrodes will yield single neurons that we can discriminate. Okay, so – and for each one of the electrodes that we record from we can typically sample between two and three individual neurons. So that just gives you some scale for let's

say 100 electrodes if you were to implant them. It's not uncommon to implant hundreds of electrodes into the brain of either an animal or a human. So we are on the order of let's say between 40 or 50 neurons and several hundred neurons that we can tap into simultaneously.

Marc Pelletier
Is that enough to get intent?

Dr. Justin C. Sanchez
Right. So there have been a lot of studies that have been out there with the last, let's say, 10 years that have showed that you can decode a person's intent to move their arm with very precise resolution with only a handful of neurons. And it's quite interesting when we think about this because from a technical point of view a scientist may say, "Oh yeah I am extremely lucky, I have placed these electrodes in the brain so precisely that I have gotten exactly the information that I need." I tend to take the opposite perspective. I think that there is so much redundancy in the systems that we are trying probe that even by chance putting in these electrodes even remotely in the vicinity of the right areas, we can extract the information that we need. So again I don't think it's any luck that we are getting the relevant information from only a handful of neurons.

Marc Pelletier
Is it a process malleable in terms of the biology? Will a person be able to develop the correct synapses around the array to be able to learn how to manipulate?

Dr. Justin C. Sanchez
Yes, so over these last 10 years that I have been referring to, it has basically shown the proof of concept that an individual can control a device directly from the signals from their motor cortex, for example. We are only now just starting to get into an area of neuroprosthetic or brain machine interface research where we are trying to study how does the neurophysiology change as an individual is using this type of device. So throughout our lives we are encountering new experiences, we are changing our perspective of the world and that is really represented by the activity of these neurons in the brain. So we should expect that by interacting with an artificial interface that that process will also happen. And again it is very exciting right now, because we are just being able to study these large populations of neurons in conjunction with use of this artificial prosthetic.

Marc Pelletier
[12:26] Is it a permanent installation? So it's – if you are paralyzed and you decide to go ahead with this form of therapy, do you see it as being a permanent structure that gets inserted inside the skull and then – as we were kind of joking around before, with a serial bus? This is just so fantastic I mean this is the stuff of science fiction absolutely. So would you see that kind of installation permanent in the brain? I mean you can't keep going in, these things can't be adjusted too many times you don't – I guess you don't have access to the human brain as often as you want is – it's not like changing…

Dr. Justin C. Sanchez
Changing a light bulb?

Marc Pelletier
I hate to say it…

Dr. Justin C. Sanchez
So exactly. I think at least my vision for the future is to implant one of these devices into the brain – you would have a microchip, a fully self-contained rechargeable type of microchip that has a wireless telemetry on it, and you would implant it underneath the scalp and through the skull and directly into the brain tissue and you would leave it there and you would want it to work for 10s of years. We are actually working on one of these devices right now. Here at the University of Florida we have a large NIH grant to actually build one of these devices and to give it some scale it's roughly the size of the area of quarter, a U.S. quarter. And it will be a fully contained device, has electrodes and wireless telemetry and battery power. So, once you implant…

Marc Pelletier
Of course you want wireless. I'm so '90s

Dr. Justin C. Sanchez
Of course. So the studies that we actually do now with animals and even humans have wired types of communication systems and of course that's not really feasible for the activities of daily life. So again the vision for the future is to have these devices implanted into the brains of individuals who're disabled and you will not be able to tell that they actually have an implant, right. We are going to be streaming this data out of their brain and sending it to whatever thought translation device that we would have that would interpret their intent and use it to control a prosthetic device.

Now you also asked about this idea, can you move it around? How would this really work in? So right now all of the designs – you target a location in the brain and you will implant this entire device at that location. The only amount of movement that would be possible with the current technology is that you could possibly change the depth of the electrodes as they are inserted into the brain. So let's say you wanted to fine tune into a specific group or population of neurons that were really relevant for you. There are some motorized types of devices that can move the positions of these microelectrodes.

Marc Pelletier
Wow, so you could actually go fish a more precise signal.

Dr. Justin C. Sanchez
That's exactly right. Tune into the right neurons. That's right.

Marc Pelletier
Tune into the brain. Wow. I am thinking, so you basically right now working on animals and that transition – and some humans? Are you transitioning? And some wireless mouse? Competing with Microsoft.

Dr. Justin C. Sanchez
That's right, so. Yeah wireless… so there are some wireless rats out that are out there but we primarily do a lot of the technology development and prototyping in rat models. So we dream up these great dreams of how technology is going to be in the future and then we bring them to life on the electronics workbench and then we transition them into some animal studies that really show proof of concept and feasibility and then – so my position right now at the University of Florida is quite interesting, my Ph.D. is actually in Bio-medical engineering, but I work in a clinical department, I work in the department of pediatrics and the division of neurology. And the main reason for doing that was I wanted to create an environment where we have a direct path to translate these great new enabling technologies from the animal lab and the electronics workbench directly into the patient's room, the patient's bedroom there. And by working closely with clinicians we are doing that. So we have undergone a few clinical studies with some patients where they have had electrodes implanted into their brain and we've had them control computer cursors just with their thought.

Marc Pelletier
This is not teleportation, not teleportation, what do you call it? Telekinesis, by the fact especially you are going wireless, what couldn't you control?

Dr. Justin C. Sanchez
[17:28] Right, so there are a whole lot host of devices when you actually think about – if you engineer a new communication device, I think that we are only limited by the signals that we can capture from the brain. Right? I typically think of biology as a robust type of communication channel but it's typically very slow compared to the types of communication channels that we have in our current – say computers or cell phone type of communication devices.

So, it may be even possible to scale a person's abilities if you communicate through these types of engineered devices.

Marc Pelletier
So, you could have added or you have a fighter pilot just thinking about controlling his flying?

Dr. Justin C. Sanchez
That's right.

Marc Pelletier
Flight controls and then he can work on navigation or some other kind of task with his hands. He can be thinking, "Oh I feel like moving left and then airelons swing over and… This is – it just opens up so many possibilities of using our mind to control devices, not to mention I mean the huge biology and medical evolution. This is evolutionary, not revolution – sorry it's revolutionary, it's not evolutionary.

We should continue a little bit about the process of your work on rats so that we have a – it's concrete. I mean, as a listener here and I consider myself a listener. Is it tangible, right?

Dr. Justin C. Sanchez
That's right.

Marc Pelletier
In your lab you're sticking electrodes and doing surgeries probably multiple times a week and see animals behave and control devices and this is so far ahead in time for me, I guess I am an old timer. To think if a wireless mouse in whole new way – this is a wireless rat. Are you working with paraplegic rats, are you causing spinal cord injury in rats and seeing if they can start to move devices? Can you then re-send the signal back into the appendages, back past the spinal cord – can you – is this an input/output device back into neurons?

Dr. Justin C. Sanchez
To answer your first question, we all have able-bodied rats right now. But there is an interesting story around the able-bodied rats. So we perform the stereotaxic neurosurgery in my laboratory, we place these electrodes in the brains of these animals. And then we put them into a behavioral experiment where they have to control a robotic arm in order to get some water. Okay, so they have to navigate this robotic arm directly with their neural activity and when that robotic arm gets to one of a set of targets that we cue them on they will get a reward back.

Now, what's quite interesting is that when you first put the animal into this behavioral experiment they try to still move their own appendages to influence the robotic arm. Now, of course in this experimental paradigm no amount of movement on their part will control that robotic arm. And then rather quickly, even within one recording session over say a couple of hours, they will learn that they can stop moving and rely solely on their neural activity alone to control that robotic arm.

So, it appears that the switch from physical movements to brain control of a device is very seamless, even in lower animals such as rats. So, it's really, really interesting that an individual will really learn to rely just upon this direct neural activation instead of their own physical behaviors.

Marc Pelletier
That's pretty amazing that, for them it's not a – I guess there is a learning aspect to it, but they have no fear of – or no resistance to just simply using their minds.

Dr. Justin C. Sanchez
That's exactly right. I think rats are extremely clever opportunistic type of creatures and they will do – they will exert the minimal amount of effort to get what they want back from the world. And in this case it turns out that using their brain activity to control the device to get water rewards, is actually easier than them physically moving. So, I think that if a rat can learn that relationship, the possibilities for humans are quite tremendous.

Marc Pelletier
[22:30] So, how technical is this? How long does it take to do the surgery? So, do you have a little saw, you go into the skull, the animals are anaesthetized, asleep?

Dr. Justin C. Sanchez
Yes, so we do, as I said before, the stereotaxic neurosurgery. So, the process is quite technical and takes a lot of skill and precision. This type of stereotaxic neurosurgery is also used on humans who have surgery on their brain. And essentially what it does is that we create a co-ordinate system in the rat's head so that we can precisely target specific structures within their brain. And once this co-ordinate system has been made we move the electrodes to the appropriate location and then slowly drive them through a very small hole, what we call a burr hole or a craniotomy, and then insert these electrodes.

Just to give you some scale on what it takes to do this, if you, let's say, want to put in a hundred electrodes you can easily take a several hour procedure to place these electrodes.

Marc Pelletier
Where did you learn this? This is not an easy skill to acquire. I suppose neurosurgery residency? Your training as a Ph.D. in biomedical engineering.

Dr. Justin C. Sanchez
Biomedical engineering, yes, so I worked during my Ph.D. with one of the pioneers of brain machine interfaces. His name is Miguel Nicolelis at Duke University. So, he was one of the people who has shown tremendous advancements in this area, in the ability to control devices. The idea of stereotaxic neurosurgery in placing in microelectrodes or arrays of microelectrodes has been around for quite a long time and it's been perfected over the last 15 or 20 years. So, it's working with great people who have great technique and we really pass along the experience. It's kind of like learning a very skilled type of art form. So, it's tremendous.

Marc Pelletier
You must have a really good pair of hands too. I mean, you need calm hands.

Dr. Justin C. Sanchez
Yes. Keep those steady hands, and sort of keep a cool temper.

Marc Pelletier
With rats, what's your success rate? You know, you miss one and that becomes python food. You can just feed your pet snake.

Dr. Justin C. Sanchez
Right. So, in all of my experience I have never had a rat that did not have useful neural signals that we could use to control a prosthetic device. And again I think this comes back to amount of redundancy that's in these neural circuits in the brain. I don't think that this result is luck I think it's the physiology which helps us to be so successful.

Marc Pelletier
When, I guess, people first started to think about inserting a valve inside a heart that must have been tremendously scary, you know, a mechanical valve just to assist in pumping inside the heart. So you open the heart and they insert this device that could have failure. And that mental hurdle into the process of surgery, I guess, could be overcome pretty quickly too when people see how amazing it would be to have a device that allows them to be telekinetic. For someone who has a severe disability, it would be so great not only would they become mobile with some bionics without cumbersome cables and packs, they could do things that are superhuman.

Dr. Justin C. Sanchez
There is a nice analogy and I often tell this story also in some of the talks that I give. Back in the cardiac pacemaker days, this is in 1960s, it was a revolutionary idea that we could put these little electrical leads

in the heart and really bring back life to those who are suffering from some sort of heart disease, you stimulate the heart when you need it and it really opens up a whole new perspective and it was revolutionary and quite shocking. People will say why are you putting these machines into the heart and what are you doing? That's right, what are you doing to these individuals? Are you making them less human and I think the benefits of such technology are so great that today millions of pacemakers are inserted into the hearts of humans and it's a common idea now, right.

Marc Pelletier
Yeah.

Dr. Justin C. Sanchez
And so I think that we're at a crossroads like that with direct neural interfaces for the brain. Right now, it seems so futuristic but the potential benefits for helping humanity are so great that the technology is absolutely necessary to be developed and once we start realizing these benefits in many humans, I think it'll become a common scenario.

Marc Pelletier
[27:43] Isn't there two major issues that affect human health, I mean, there is, well there's three, I would say. Genetic disease which is predetermined, you can try and develop a therapy for it. Two, there is disease that happens without your control, infectious disease and you can try and tackle that. Then there's injury and that whole level of medicine where you're trying to recover and reinstate somebody's quality of life is a tremendous, tremendous field, right because it's the third wing, in my opinion, of medicine. Although I guess my view of medicine is one of an oversimplification but if – this could be the last, not the last frontier but an important frontier. Here is the big segue. You are saying that the pacemaker was able to add current at the right of times and regulate heart to restore heart function, that's an output device, right. Can your electrodes detect the changes of ions, enhance conductivity in the brain, translate that to a signal that a computer can respond to? Can you send a signal the other way? Can you trigger a synapse?

Dr. Justin C. Sanchez
Right, so we think of these systems as closed-loop types of devices and the types of communication that we've been discussing so far has just been in the realm of signal translation. So these neurons change their firing properties, you have a computer which translates this activity and then does something useful with it. There are studies that are ongoing right now that are trying to send information back into the brain via the concept of electrical stimulation. So if you send a little bit of current into different parts of the brain you may be able to excite neurons and change the firing properties of these ensembles or neural networks.

One of the most obvious implementations of these are for retinal type of prosthetics or cochlear implants where you're trying to restore sights or hearing in an individual. You're sensing something back from the environment of the world and exciting the brain in a particular way that it evokes a hearing response or a visual response.

There are also some other studies that are trying to work for the part of the brain called the hippocampus where you're trying to restore memories to those who have Alzheimer's for example and then even for epileptic patients you may have abnormally firing neurons that you'd like to send some information back to them to tell them to stop firing abnormally and you may be able to achieve that through stimulation also. So, yes, there is a huge area of neuroprosthetic research is trying to bring back the sensory type of information and trying to send information back into the brain about what's occurring in the external world.

Marc Pelletier
And you use the same electrode?

Dr. Justin C. Sanchez
So there're some technical challenges with using the same electrode but there are examples out there that you can use the same electrode. I guess from a physiological point of view you have to also ask: are

the neurons that are sending control commands the same ones that you also want to send information back to? At least for the motor system maybe you want to go to the sensory or somatosensory areas. It's not quite clear yet what are the exact locations through which we want to send this information back to the brain.

Marc Pelletier
I guess not, you really – you wouldn't want them to be the same. As you're saying the areas that acquire information and the areas you want to stimulate would be different. So…

Dr. Justin C. Sanchez
Yes, possibly.

Marc Pelletier
But you could have it on the same device, right? Or the same implant array, you could array them in each – one's series A and then series B or C.

Dr. Justin C. Sanchez
[32:00] There is another aspect at least along the lines of interacting with the same population of neurons is; let's say you could build some artificial firing neurons in silicon and you could communicate with the neurons in your brain that are linked to these artificial neurons that could possibly expand the computational aspects of the biological neurons. So that could be an instance where you'd want to both stimulate and record from the same group of neurons.

Marc Pelletier
How would you go about this? Would this be for patients that are disabled first and then move as into an elective surgery format, or do you see this – You see the success rate that you have with your – the animals. How do you translate this into the final stage of brain interfaces where everybody would have one, just about?

Dr. Justin C. Sanchez
The phase that we're at right now is we're really trying to prove the safety and efficacy of these types of devices, and from a regulatory point of view these things are absolutely critical, from a patient's point of view these aspects are absolutely critical. So once we go through the process of showing the benefits and the safety of all of this then I think that it will start to open more possibilities for patients that are out there. So, of course the first ones that are going to have these types of devices are the severely disabled, right. These are the ones that, this is their option for regaining a high quality of life, but as the technology improves as we see the benefits, then it's possible that it could expand outside of that realm but to what extent, I think it remains a little bit unknown at this point.

Marc Pelletier
I would like to take a minute and thank GoToMeeting for sponsoring Futures in Biotech. Now when taking on a new sponsor for a podcast, I think there is two criteria that I like to have in that and one, it would be a product that I can endorse and two let the sponsor give something back to the audience.

Now, why would I be able to endorse GoToMeeting? Well, I think it's a great tool for the scientific community. Traditionally, when you have a meeting over the phone in a conference call, it's really hard to share that data; you have to formulate it in the form of a PowerPoint or PDF document or you print it out and mail it to them and then you have to organize it in a way that's concise and simple and easy to communicate using these traditional means. If you could go online and share your desktop, you could really have a collaboration going on where you can analyze your raw data and work on it together and save a huge amount of time. You don't even have to leave your lab. So this, I think, is the number one reason why I think GoToMeeting is useful, and I can endorse it.

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Dr. Justin C. Sanchez
[35:38] So there's another aspect, I don't know if you want to talk about, that may be of interest to the tech side of the community…

Marc Pelletier
Absolutely.

Dr. Justin C. Sanchez
…listening. You want to maybe go over that real fast.

Marc Pelletier
There is no rush.

Dr. Justin C. Sanchez
Yeah, so let me tell you about this new aspect that is really – it just came out and this is one of the reasons that I sent you an e-mail because we had this huge press release behind the decoding aspect of neural interfaces. So, we briefly discussed about how you have these computers that are interpreting a user's thought, right? They're deciphering the neural code in the brain and again they have all been working from the signal translator perspective. You have thoughts that are coming out. I translate them and I do something useful for you.

The real change that we are trying to invoke here is that we are trying to build intelligence into the computers that are doing the decoding. So, effectively, not only are you able to interact with a computer or prosthetic device with your thoughts but that interface itself is assisting you, is acting as an intelligent assistant that can help you to achieve your goals. So, basically the computer knows the goal, you know your goal and it's going to do everything that it can to help you achieve that goal. So, it's a transformative idea in terms of how we interact with the world.

Marc Pelletier
It doesn't have to be a binary response. You can have a human-type response and then the computer says, "Well that's human." If the algorithm fits within a framework, you make a decision, I guess, logic gate structure.

Dr. Justin C. Sanchez
Yeah, so we actually – we use a concept called reinforcement learning in this paradigm. So, to put it in simple terms, if you create a neural activity that moves you closer to your goal, you are going to emphasize those types of behaviors and make them much stronger. And if you do the opposite, the same is true, you are going to weaken some of those connections. So, both the computer knows what your goals are, you know what the goals are and you are going to both choose strategies that enhance or reinforce these positive types of behaviors.

Marc Pelletier
How about time shifting? Have you ever thought about the possibility of somebody performing a whole series of functions that could then be time shifted? I mean, you could store all the brain signaling? This is great.

Dr. Justin C. Sanchez
Yes, yes you could.

Marc Pelletier

You could store everything and then say, all right go ahead, I'm walking and going home. I've done my homework and –

Dr. Justin C. Sanchez
That's exactly right. If you know that neural activation you can send that information to this intelligent type of device and it can carry it out for you. And if you link back in the sensory type of aspect, you could be updated on how that progress is occurring. The other aspect of time shifting is you could potentially do it much faster, again these communication channels and the speed of the processing of the hardware that we have today is so much greater then biological systems that you could potentially complete these tasks much faster.

Marc Pelletier
And you refer to biological systems as my hands on a steering wheel or –

Dr. Justin C. Sanchez
Yeah, it could be your muscles or the nerves that are stimulating your muscles or the pathway from your brain to – through your spinal cord to your muscles. These things typically are on the orders of, let's say, a couple hundred milliseconds.

Marc Pelletier
Damn biology!

Dr. Justin C. Sanchez
Right biology, right, but we know that with sending electrical signals even over a copper wire is much, much faster than that. So again, that's – you could – if you take the cumulative sum of all of these latencies, you could potentially do things much, much faster.

Marc Pelletier
What a way to tap into the power of the human brain.

Dr. Justin C. Sanchez
That's right.

Marc Pelletier
The untapped aspects of the human brain.

Dr. Justin C. Sanchez
Yeah, that's right.

Marc Pelletier
That's pretty wild

Dr. Justin C. Sanchez
[39:41] So, a lot of the enabling aspects that are making this happen are the great advances in computers, both in processor power and the ability to store huge amounts of data. I mean, we can easily store terabytes of data in a very short period of time if we record from hundreds of neurons. So, even five years ago…

Marc Pelletier
It's cheap now.

Dr. Justin C. Sanchez
That's exactly – that's what I was going to say here is that I can go down to your favorite hardware, computer hardware store and pick up a terabyte drive for $150 but even several years ago this wasn't possible so we had huge technology constraints on implementing some of these devices.

Marc Pelletier
Yeah you -- I suppose wireless would have been expensive 10 years ago when you were starting this kind of stuff and now you could make a Bluetooth brain, right?

Dr. Justin C. Sanchez
That's right, low-power wireless systems that have huge amounts of bandwidth. There are so many choices right now that, again, even 10 years ago, I would say, 99% of the experiments that were ongoing were all wired.

Marc Pelletier
Are you – have you contacted SEC to potentially reserve a bandwidth for this wireless? I mean, I would hate to see somebody walking down or somebody in a wheelchair who is trying to control his wheelchair…

Dr. Justin C. Sanchez
Have some interference there.

Marc Pelletier
And somebody with his mouse, his Bluetooth mouse is sort of sending him down the stairs.

Dr. Justin C. Sanchez
There is some bandwidth that is reserved. It's a medical bandwidth and this device that the team is working on here at UF we are working within that bandwidth there. So the guy who is doing the telemetry side of this is working there.

Marc Pelletier
All right.

Dr. Justin C. Sanchez
So I don't think that there will be any interference, at least in that band.

Marc Pelletier
Well, there's pacemakers, not pacemakers, EKGs, microwaves.

Dr. Justin C. Sanchez
Microwaves.

Marc Pelletier
I had heart surgery a while back and I had a wireless EKG that was sending signals and I suppose I was beaming to somebody who had an input device. I suppose we were pretty far away from the input devices and the bandwidths were wavelength, radio wavelength. It's getting incredible now if you look over how cell phones when they went first digital, how they sounded crappy and now with 3G we can send enormous amounts of data.

Dr. Justin C. Sanchez
That's right.

Marc Pelletier
On very, very narrow bandwidth. So, I think we are pretty cool and the devices are so small, have you seen the Eye-Fi card?

Dr. Justin C. Sanchez
No, I haven't seen this card.

Marc Pelletier
It's a little SD card I think that –

Dr. Justin C. Sanchez
Oh, okay.

Marc Pelletier
That you, pop it into your camera and it sends it to your computer with your photos.

Dr. Justin C. Sanchez
Oh yeah, yeah I have seen one of those. Way back in the early Palm days I always wanted an SD card that had Wi-Fi on it and I think that now it's -- they're finally coming out.

Marc Pelletier
Of course you did, right. Because the stuff that you are working with was about 30 years in advance of the stuff that's current in computer technology.

Dr. Justin C. Sanchez
That's right.

Marc Pelletier
I mean, if we can send a signal, a brain signal wirelessly across the room why can't you just send an image, a jpeg, right?

Dr. Justin C. Sanchez
Yeah, yeah. Right.

Marc Pelletier
Right. You guys are so way ahead of the game. I guess these two technologies, the two areas, information technology and that – you're really at the interface of this and you can borrow technology from one and they can borrow technology from you and the more there is an exchange, the more it's catalyzed, right and the transition to these medical devices. Have you had any interest from industry, is this privately funded at all, or is it mostly public right now? I mean, it has a huge industry potential, but industry is very, very conservative.

Dr. Justin C. Sanchez
[43:25] That's right, so right now the majority of the studies are federally funded from either the NIH, National Institute of Health or the National Science Foundation. But as these technologies become developed, we have patented a lot of the ideas and we are currently seeking venture capital to spawn and spin some of these ideas off into some startup companies and hopefully move the technology into an environment where it could be advanced even, even much faster than it is now.

Though I think that both of these approaches are necessary to take this technology from a dream into a reality, right. You have these great ideas and high-risk types of projects that occur in the university system, and when they are shown -- the proof of concept is shown then we can move some of that out into industry where we can build the technology on a much more powerful scale and do that with tremendous types of resources. So, I would really love to see both happen.

Marc Pelletier
I think industry could give you the unlimited resources, because the demand for a device like this would be so enormous that the money that could be generated from selling the device and developing it as a permanent chronic patient care that is associated with it. The economies are so large that the developments would, would just go through the roof, I mean you would have a staff of 500 rather than a staff of five or, I don't know 10. Which is – even in an academic lab, 10 is a huge lab, so, you have to – you develop collaboration and network. This is a tremendous story, absolutely, we have to have you back as you move this technology forward because this is just, it's really, really wild. This is the IT of the biological world here.

Dr. Justin C. Sanchez
One thing that I think is really nice about this technology is that it really started off as a dream and even as a science fiction type of dream that you interface devices directly with the brain and you build this prosthetic or bionic type of device. And it's tremendous that we are seeing it realized in our everyday life now. So I think that it makes the future very bright for this area of technology. And I am extremely excited to be a part of it.

Marc Pelletier
I think Leo's going to be – Leo and Scott Bourne are going to be the first adopters of the elective surgery. These guys –

Dr. Justin C. Sanchez
Sign me up, right. I always listen to these guys on the TWiT show also and they go off at – some new product or something will come out and you'll hear Leo say, "Sign me up, that's what I want."

Marc Pelletier
We will know that it's really a common household device when it gets on to the Daily Giz Wiz.

Dr. Justin C. Sanchez
I would be interested to hear what Dvorak would say about this. "Oh, these guys are crazy"; "Oh no, they are doing great things", who knows what he would say.

Marc Pelletier
The keyboard is the way to go.

Dr. Justin C. Sanchez
That's right.

Marc Pelletier
Well, he's a great guy. Actually as a commentator he's pretty insightful and he would be a good guy to have on your board of directors when you translate…

Dr. Justin C. Sanchez
That's right, that's right.

Marc Pelletier
Of course, a whole new form of GUI, right? Our keyboard is a hundred years old and our mouse is what… Are there competing technologies, just before we go, are there competing technologies other than inserting electrodes, can this be done with other forms of imaging, MRIs?

Dr. Justin C. Sanchez
[47:10] Yes, so MRI, fMRI there is some small evidence that you can use that modality, but it's typically very slow compared to electrophysiology. So, it may not be suitable for motor types of tasks. There is evidence that you could use the electroencephalogram; that you just place upon the scalp of the user, but there are some issues there with resolution also and both in time and in space. So, there is some more tech development that needs to happen in order to really make these things feasible for everyday life.

Marc Pelletier
I guess in terms of the fashion statement as well, I'd rather have your device then have a really weird looking cap.

Dr. Justin C. Sanchez
Right, that's right.

Marc Pelletier
All right, I'll definitely let you go. Thank you very much for coming on.

Dr. Justin C. Sanchez
Okay, thank you so much.

Marc Pelletier
Before I get to the traditional thank yous of the show, I would just like to send a quick shout out to Leo and Scott, both Justin and I are huge fans of your shows. This WEEK in TECH, MacBreak Weekly, This Week in Photography. What I think is really important here is that you guys have an incredible enthusiasm for technology and that enthusiasm that you have is infectious. This is really important in moving the frontier of science forward. So please keep up that enthusiasm.

So, I would really like to thank Dr. Justin Sanchez, Director of the Neuroprosthetics Research Group at the University of Florida, for sharing his scientific story today. I would like to thank Phil Pelletier and Will Hall for the great opening and closing theme.

Lastly, I'd like to thank the kind folks at Pods in Print for providing the transcripts to today's show. They are available at futuresinbiotech.com.

Now, I must mention that producing transcripts with this high level of accuracy that these guys do in a field as specialized as biotech is really tough. So, if you want to get some transcripts done, you can contact Tom Price at Pods in Print. That's tom.price@podsinprint.com and he will make sure that they get done by the right editor who's familiar with the topic of the transcript. He goes out and gets these editors from top 10 UK universities, so they are as accurate as you can possibly get and we really appreciate them.

So that's it, for Futures in Biotech, I'm Marc Pelletier.