



Futures in Biotech, 44: Cogito Ergo Sum by fMRI

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Marc Pelletier

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[Music]

Welcome to Futures in Biotech. I am Marc Pelletier.

Dave Brodbeck

And I am Dave Brodbeck.

Marc Pelletier

Glad to have you on the show, Dave.

Dave Brodbeck

It's a pleasure to be here, Marc. It's always good to talk to you and frankly especially considering who the guest is. It seems – maybe perhaps even sensible for me to be here.

Marc Pelletier

Well you have been on the show a couple of times. You have helped us with the introductions to some of our prominent guests and you have been a panelist.

Dave Brodbeck

Yup.

Marc Pelletier

And I thought that it would be great to have you on to help considering your background, right.

Dave Brodbeck

Yup.

Marc Pelletier

You are the Associate Professor and Chairman of Department of Psychology at Algoma University in Sault Ste. Marie, Ontario

Dave Brodbeck

Yes.

Marc Pelletier

And perfectly qualified to help figure out how to put the show together. So...

Dave Brodbeck

Yeah. Well, I mean considering like John Gabrieli, who is from MIT and he is – there are people that – there are certain neuroscience people that are doing really kind of neuroscience in a Petri dish. Then there's people like Dr. Gabrieli who are doing imaging work, which is I guess a little

more in a funny way we talk about – we might talk about this but it's sort of almost a holistic way. It's holistically molecular if that makes any sense.

And then there are people in psychology that do stuff like that's completely behavioral, cognitive stuff. So they are doing stuff like memory systems kind of experiments or they're doing that kind of stuff. The thing what – the thing that John does is he takes – he does that stuff and the imaging stuff together. And he knows how to do both of them and do them really well.

So it's almost like and he'd probably blush if he heard me say this but it's almost like he can be his own collaborator because he doesn't unnecessarily have to have the guy in the next lab to come over and read the MRI. He also doesn't have to have the guy in the next lab come over and help him design a clever behavioral experiment.

Marc Pelletier

I guess in kind of a layman's terms, right, he is using the most incredible technologies, the most – the technologies that allow you to image the brain with the highest resolution --

Dave Brodbeck

Yeah.

Marc Pelletier

But using it to image the human soul.

Dave Brodbeck

If you want to get into that, that's fun to show.

Marc Pelletier

Yeah, well, we kind of get into it in this episode. So it's kind of fun.

Dave Brodbeck

Yes, we do.

Marc Pelletier

Let me introduce...

Dave Brodbeck

And I...

Marc Pelletier

Go ahead.

Dave Brodbeck

Yes, I was just going to say that I mean in a way when you think about soul in the terms that when you read Descartes, right, where he says that humans goes into the first – to talk about dualism and he says that humans are animals with souls and if you read Descartes in the original French, I think half the time he means thinking, and the other half the time I think he does mean your immortal soul. So perhaps soul is not such a bad word here.

Marc Pelletier

Yeah, I meant it in purely the scientific fashion. So our guest is Dr. John Gabrieli. And he is the Grover Hermann Professor of Health Sciences and Technology and Professor of Brain and Cognitive Sciences at MIT. So we're going to actually get into the lab at MIT. This is going to be a little bit of an adventure.

Dave Brodbeck

Yes, and I mean it's interesting. I was just checking some stuff out about John Gabrieli and it's one of these things that you always have history of psychology classes to do, you find out who – what's the academic genealogy. So who did they do their Ph.D. with? Who did they do their Ph.D. with?

And his academic grandmother, I think he mentions this at the beginning, is Brenda Milner who we had on the show. When you go back far enough he goes back to Wilhelm Wundt, the first experimental psychologist ever at University of Leipzig in 1879. And so do I. I go back, I think I have got two more steps than him because I am a little younger than him. So I think that makes me his academic sixth cousin twice removed.

Marc Pelletier

This is kind of like a family reunion for you.

Dave Brodbeck

It is in a way except not really nearly as much drinking or disappointment.

Marc Pelletier

Well, so how about we get onto the interview.

Dave Brodbeck

Sure, let's do it.

Marc Pelletier

[5:27] Dr. Gabrieli is doing some pretty amazing work. And it fits very well with the context of the various shows we have done in neuroscience where we have had Dr. Carla Shatz who does work on neural regeneration. We have done interviews with Eric Kandel who studied the molecular events with proteins and genes that are involved in memory and Dr. Brenda Milner that was one of the pioneers of cognitive neuroscience.

Dave Brodbeck

Yeah.

Marc Pelletier

And the next step is really getting a more global understanding of the human brain. And I don't think there is a better way to look at it than the way Dr. Gabrieli has been studying human brains. So welcome, Dr. Gabrieli, to the show.

Dr. John Gabrieli

Thank you very much. Pleasure to be here.

Marc Pelletier

Thank you for coming. So I'd like to start by getting a little bit of a background of what were your first rounds of experiments? How did you get into the field that you are in and how did you bridge into that field because it's not easy to talk about the human brain and well you are doing it from such a global perspective, such an overwhelmingly top heavy. How did you build up to that?

Dr. John Gabrieli

Thank you for saying. So you mentioned Dr. Brenda Milner a few moments ago. And in some ways I am her intellectual grandson. So she is famous for many things. But one of them is discovering the case of HM, Henry Molaison, the man who had parts of his brain resected to treat epilepsy and who can no longer form new memories ever again despite retaining his intelligence. And this made a revolution in our understanding of how the human brain does memory.

And so when I began graduate school at MIT that was the only way really you could study human brain function was to look at people who had big brain injuries and see how they changed the

way they could remember or think or feel. And it was such spectacular cases in many – such cases, historically the case of Phineas Gage, the man who changed his moral reasoning or Broca's patients.

Marc Pelletier

Changed his moral reasoning, from an injury to the brain? Is that because it removed the moral segment of the brain?

Dr. John Gabrieli

It removed a part of the brain, the sort of bottom part of the frontal cortex that seems to be terribly important in moral decision-making, in weighing our appetites and our principles of good behavior. So when he had – he had a huge spike go through his head and his case was famous 100 years ago or more because he lived.

Dave Brodbeck

Yeah.

Dr. John Gabrieli

The spike was very large. It blasted through his head. And he got a lot of newspaper coverage because they were amazed that he basically went back to his hotel room and a few days later was back on the streets. We now know him as a famous case because that showed us how the material stuff of the brain is the stuff that guides a thing that seems as high and abstract as moral reasoning or the way in which we decide what's the right way to behave.

And so when I began graduate school the only way was to study these kinds of cases but they were rare. And you couldn't be systematic because you couldn't get a menu and say I want a patient with lesions here and here and here because they occurred naturally by stroke or bad luck. And so the advent of brain imaging has just incredibly opened up our chances to unlock the secrets of the brain in terms of how it lets us have our mental abilities and human nature because all of a sudden we could study everything.

So we could pick what we want to study. How culture affects our brain, moral reasoning, memory, desires, decisions; we could pick whatever we wanted to do. And as long as we knew a way to sort of interrogate the mind, we could then figure out which part of the brain is supporting that piece of human nature. And so for the last 20 years or so that's been my main kind of work, is to use brain imaging to try to understand bits of human nature, how is it physically supported in the brain in health and how does it go different in various forms of psychiatric or neurological disorders.

Dave Brodbeck

And of course the gear is a lot easier to use now too, right. And it's a lot more – like MRIs are a lot more, I wouldn't say available, well, I guess, I would say that. They are more available and they are also more, I think from what I understand, I don't do a lot of imaging stuff, well okay none, but I've a friend who does this kind of stuff and he has told me that it's quite a bit easier nowadays just because the sort of interface level of it is a lot easier to use.

Dr. John Gabrieli

[9:50] That's absolutely right. It's – just in the last decade or so it's gone from a kind of a brain measurement that only a few very sophisticated research centers could pull together. And all of a sudden it's all over the place, which is fantastic, because many people are studying many problems. So it has become a much more democratic form of science in a certain way. And things move faster. There's so many people are studying anything you think about human nature, there is groups of scientists around the world plunging forward on it. It's very exciting.

Marc Pelletier

I see this big disconnect in my mind here, well – you could probably see it through these earphones, the language of basically these fundamental human traits translated to the physiology of the brain through imaging. I don't – could you explain how you make those connections from somebody who is injured in that section of the brain? Do you use Brenda Milner style tests, psychological tests and sort of analyze the extent of that person's capabilities and then --

Dr. John Gabrieli

So yes, so most commonly with functional MRI or fMRI which is the tool that we – there is many different tools but that's the one that's sort of most famous that you most often see in newspapers or magazines. Yeah, we have to get you through some tests basically, some tasks to use a specific part of your mind. So sometimes people worry, you know, neuroscience is going to wipe out psychology. You hear this idea that...

Dave Brodbeck

Some psychologists worry about that, I don't.

Dr. John Gabrieli

Yeah, I don't either, but, well, because for a long time psychology was the only field that got to study lots of stuff and all of a sudden neuroscientists get to poke around in everything too.

Marc Pelletier

That's right.

Dr. John Gabrieli

And so some people say well, are we going to lose the sense of human spirit, human nature that psychology studies. And this is all going to be material. It's all going to be reduced to some very biological physical thing. And the only way we can study the mind is to use all the psychology, all the hunches we have about human nature, all the science we have about human nature to get you to use a specific mental operation, a specific part of your mind. And that's when the race begins because then we can say, okay, which part of the brain is allowing you to have memory or feelings or moral revulsion for something that's very unfair or terrible.

And we have to get that mental thing identified so that we can relate it to which part of the brain is related to that and that allows you to have that mental ability. So psychology is a huge part, yes, so we have to have people doing tests, the more we understand the better and then we try to identify which brain region is allowing you to have the capacity to make moral judgments, the capacity to laugh at a good joke or whatever topic that one would understand in terms of its neural architecture.

Marc Pelletier

Eric Kandel who studies memory was trained as a psychoanalyst. Is your training – was it a crossover training as well before you got into imaging?

Dr. John Gabrieli

It wasn't anywhere near the distance that Eric Kandel's gone so brilliantly and so amazingly. And in many ways you may know he is in some ways circling back to ask whether the hardcore neuroscience methods that he approaches can be used to understand things like psychoanalysis.

But yeah, my training was closer. It was in behavioral neuroscience. I have always worked with humans, always studied the brain, just it was incredibly more limited in what topics I could study and how I could study them when we were restricted to looking at brain injuries. So this brain imaging thing has just been fantastic in terms of all the range of human phenomena and the range of the human nature that we can explore.

Marc Pelletier

When did imaging start? When was – what were the first experiments and how were they taken on?

Dr. John Gabrieli

Yeah, there are many ways – our first kinds of studies were done with positron emission tomography of PET scanning, which involves injections of radioactive substances. There was only a few places at the beginning that did it well. Washington, St. Louis, NIH and their studies, we were all jealous. It was like they had the Hubble Telescope. I remember as a postdoctoral fellow you'd read their discoveries in Science or Nature and you go, man, if only I could do something like that because there is just a few places that could pull it off at all.

But they would show you these amazing pictures of the brain doing language, the brain doing memory, the brain doing vision. And so I was just very lucky that over time it moved from PET to fMRI and that all of a sudden everybody basically who wants to do it has an opportunity to do it now. And it's not done everywhere but in so many universities that's pretty wide open and available.

Marc Pelletier

Dave?

Dave Brodbeck

[14:25] Yeah, one of the things that always struck me about – when I talk with my students, my classes is that PET allows you to see function. CAT scan allows you see form. But I mean, I am always saying this, fMRI allows you to watch people think. It's form and function. And I don't think that a lot of people really, and I mean of course the resolution is getting better and everything, but when that came out, when that was the, I remember when I first started reading papers I was probably early graduate school, like late '80s, when you started seeing stuff and I remember looking at it thinking, because I did my stuff in animal learning and cognition. And we kept looking at it thinking we are sort of being attacked on two fronts, we had the sort of socio-biology on one end and on the other end we got neuroscience coming at us.

But it ended up, now it's something that is to me mind boggling. We talked last time on FIB about watching, taking a look at people's occipital lobe and actually getting the – being able to read the, this paper was in the journal Neuron where they actually had people reading the word neuron and I was reading some of your stuff and you were looking at one of those experiments that really intrigued me was rewarding people to remember and taking a look at the operation of the mesolimbic dopamine system. And in fact I talked about that in my neural pharmacology class last night because I said to them the same thing that you light up when you take a shot of heroin also works when you give someone 20 bucks to remember a stimulus.

Do you think that the use of imaging to understand things like reward and to understand memory, to push a little further, do you think actually that might end up sort of pushing sort of traditional hardcore cognitive psychology along the lines of what Endel Tulving did in his early part of his career? Do you think it will sort of maybe perhaps push that to the side a little bit?

Dr. John Gabrieli

Yeah, I don't think it will push that to the side at all. I think brain imagers are the greatest consumers of psychology. So to take Tulving, who you mentioned, a giant in the field of memory, and an enthusiast about brain imaging in his current career.

Dave Brodbeck

Yes, very much so yes.

Dr. John Gabrieli

He was one – among many ideas, he gave us the idea of a distinction between episodic and semantic memory. The difference between memory for a specific experience you have, the

sandwich you ate yesterday versus semantic memory knowing Paris is the capital of France. And we use that idea all the time in brain imaging research. And the animal behavior research you talked about, I mean imagers of various kinds scour the literature to look at clever, interesting, thoughtful approaches to behavior and map the mind, so I see it as a – mostly sort of a renaissance all around.

I do know that sometimes in the world we live in there's competition for resources. And I think that's – I think that's where the rubber can sometimes hit the road, which is the limited research budgets and then people are picking things and some people think that imaging is kind of a neat thing to do and imaging is relatively expensive. So there is that practical thing but in terms of intellect, in terms of sort of the world is a whole, I just think lots of ideas about the mind that have come from psychologists are just invigorating us and inspiring us all the time and we use those everyday.

Dave Brodbeck

You mentioned the episodic-semantic distinction, one of the things, because I mean I did my Ph.D. at UFT. So it was something that, you either had Endel Tulving telling you that there were these two memory systems. And then on the other hand you had Gus Craig in the same seminar telling you, no it's all about processes.

So – and they were sort of friendly about it. But you always kind of got a kick out of it as a graduate student. Do you find that this sort of cognitive modularity is something that you are seeing in your work or do you think it's more of a general thing or is it somewhere in the middle?

Dr. John Gabrieli

Yeah, like everything, it's somewhere in the middle and super complicated. So you are referring to this giant sort of pendulum in the field of understanding the brain, which is modular approaches, thinking that different specific pieces of the brain do specific things and then sort of generalist kinds of approaches, holographic approaches that see important mental functions as distributed over a big neural terrain. And I think everybody is somewhere in between; if we can't talk about what a brain region does, a specific one for vision or memory or if we always have to talk about most of the brain, then it's very hard to make progress, because things don't get simplified enough for us.

At the same time we know almost anything interesting in human abilities, in the real world outside of the experiments, involves whole networks in the brain, involve many different brain regions interacting. So as scientists we sort of strip things down to simple things that we have a chance of making experimental progress on, but in thinking about human nature and how people really behave we know big networks are interacting. So it's just – and it's debated to this moment, people in almost every field I'm in are arguing back and forth about how to find the smallest unit; do they make any sense; do they map onto anything that we could understand psychologically, so it's a very exciting debate.

Dave Brodbeck

Sure.

Dr. John Gabrieli

With brain imaging if you don't localize somewhat, if you don't say we think this part of the brain does X, it gets really hard I think to have a dialogue, and one of the gigantically interesting aspects of human brain imaging is that we've been able by localization to make contact with the animal work. So we've talked up the excitement of fMRI which I love, it's my career. But you have been polite enough not to tell the people watching or listening that we don't measure neurons that compute the mind. We have this very sort of modest measurement of blood-related changes. So we were very interested in relating our work to animal work where people can do amazingly specific neuroscience far beyond the specificity and detail that we can ever do.

Dave Brodbeck

It's funny, one of my students asked me questions like you hear the sort of old myth about you only use 10% of your brain, I often say which 90% would you like to lose?

Dr. John Gabrieli

Yes, we have not found yet that part of the brain that doesn't seem to do something we like to have.

Dave Brodbeck

Yes, that's what I usually tell them.

Dr. John Gabrieli

Yes, we all know people who are pretty convinced they are only using 10%, so I think that's what reinforces this feeling but...

Dave Brodbeck

I have colleagues like that, but I am not going to name them.

Dr. John Gabrieli

But it's spectacular. In fact sometimes when you think about say what does it take in the brain to read aloud a single word? I mean that's a pretty simple thing once you've passed first grade. But you have to have your visual system do amazing tricks to identify the characters in the word; you know that no animal can do as far as we know on the planet. You have to have your entire language system, the sounds of language, the meaning of language, your entire system that moves your mouth into action. I mean just to read aloud a single word, vision, language, motor control systems that move your body and your mouth, I mean that's a huge system to simply read aloud a single word. So you need a lot of your brain to do interesting things.

Dave Brodbeck

Sure.

Marc Pelletier

[21:42] Let me break this down a little bit because this is a tech network, and this to me is one of the most powerful technologies of this era in science, right. I think this is as powerful as the Hubble and is important as the Hubble because we are looking into the human soul, right. You know thought, emotion, memory all those together, one could argue is what makes us really human. And so what exactly is functional MRI, what are you measuring?

So, I would like to cover in a couple of sort of ways the mechanics of detection, the analysis, how does one interpret the image analysis that you collect and then what are the structures and functional relationships that you found with segments of the brain that have related to those different branches, thought, emotion, and memory, are all those the same? I mean my emotions are often just rapid thoughts where I am angry or thinking about something, how do you separate all that? So let's take it back a little bit and talk a little bit about the cool elements of MRI. So what does MRI stand for? Let's go...

Dr. John Gabrieli

Magnetic Resonance Imaging. And so here's what we would love to do. We'd love to measure single neurons. The neurons are the cells in the brain that computes everything we do, the stuff of thought and feeling and so on. With fMRI or functional Magnetic Resonance Imaging, we don't do that. What we measure is changes in the magnetic property of brain tissue that go with neural activity, so that when you use a certain part of your brain you use a lot of oxygen to support the neurons that have been doing all the heavy lifting and that part of the brain then gets a lot of extra blood and oxygenation to sort of replenish that part of the brain. And so we don't even measure the first moment of change which is oxygen pulled out of the blood. That would be great, that's a

tiny signal. We measure the emergency supply which is this oversupply of oxygen and blood to that part of the brain. So it's amazing that works at all. There is so much evidence now...

Marc Pelletier

Yes, does oxygen have magnetic properties? Is it – O₂ is not, it's polar...?

Dr. John Gabrieli

Right, so the hemoglobin's magnetic properties change after the oxygen has been extracted or to put it slightly differently, as the pool of oxygenated hemoglobin changes, that changes the magnetic property of that local tissue. So it's almost a house of cards, right, because you have the neuron doing something, you have the blood coming in, you have changes in the oxygen extraction to support the neurons; that changes the magnetic property of the brain that can be picked up by an fMRI. And early on people worried about whether it was too delicate a house of cards in terms of precisely measuring brain function, where it is, when it is. It's pretty weak because the blood supply slowly changes over course of something like four, five, six seconds that we are seeing. So when we see the big change in the brain, that's six seconds after your mind is done. So it's slowly happening.

Marc Pelletier

Mind is done, but how about housekeeping, the blood flow required for housekeeping?

Dr. John Gabrieli

Yes, so...

Marc Pelletier

You have to have a signal above that.

Dr. John Gabrieli

Yes, so you are absolutely right. So that's why we have what people call roughly speaking a subtraction technique. So we always have to compare two things, because there's so much blood flow in housekeeping as you are saying to keep the brain and mind going that we have to provoke you and so give you...

Marc Pelletier

That's wild!

Dr. John Gabrieli

Show you a face that's provocative, have you think about a problem, have you read a story about some miserable behavior on the part of somebody, we have to provoke you. And there's a difference between that provocation and the housekeeping, the constant stuff that's going on. So I think there is a huge signal problem because the housekeeping accounts for something like 99% of our signal. All our provocation of thoughts, feelings, actions, thinking, everything, it only moves things around 1% or less. So it's a very small signal even if it's a very big mental operation. So that's...

Marc Pelletier

If you are thinking with or trying to memorize something, it's not like a whole large percentage of blood is flowing to that side of the brain.

Dr. John Gabrieli

No, the difference between the constant blood flow and activity, the housekeeping as you said, that's a good term for it, and the additional stuff that happens in blood is very tiny. So that's why we have to have, now in a technology sense, that's why people want stronger and stronger magnets to try to amplify that signal and that's why we have to have people do stuff. We can't see, we would love to see like right now you are thinking, is he giving a good answer or just bloviating to one?

We would love to be able to tell that in one second from an fMRI, we can't. We have to have you think something kind of similar repeatedly maybe 50 times – average those and then we have enough of a signal to statistically measure it. So we had – so the signals – so that's the sort of the physiological thing and then we have you do it in bunch so we can measure the difference between housekeeping and a specific kind of perception or thought and then we do a lot of statistics afterwards across a group of people to come up with a statistically sound conclusion about which part of the brain is engaged to support a particular part of the mind. So that's offline after all the data has been collected, and it takes weeks of data analysis after the data has been collected.

Marc Pelletier

So you collect 20 minutes or an hour's worth of data and then you got three weeks of analysis?

Dr. John Gabrieli

Something like that. In many ways the field is getting more and more conservative statistically in the sense of finding things to be more certain, which is a reasonable thing for a field. So typically our experiment will have in it something like an average 15, 16 individuals and each doing something for about 20 minutes, it varies a lot but that would be average and then a ton of analysis.

Marc Pelletier

[27:20] So that analysis, is it structural based? Is it map based? Do you have maps of the brains and you are looking at vectors of oxygen change of the brain?

Dr. John Gabrieli

Yes, we are looking at changes in this oxygen – in this magnetic property that goes with oxygenation. The changes that occur relative to some either the background or often we have a control condition. Let's pretend we want to know which part of your brain responds to a face that's showing disgust. So it turns out there is a specific part of the brain that responds to disgust. But in order for us to be confident that you are responding to disgust, we need to show you some faces that are just, say, neutral, so that we are not looking just at seeing a round thing, not just seeing hair, not just seeing a face but specifically the part of your brain that responds to seeing something, an expression of disgust. So we always have to have – we often like to have this kind of controls so that in the end the difference we're seeing is of that particular thing we are interested in.

Marc Pelletier

I would like to take a minute and thank Audible.com for sponsoring Futures in Biotech. They have over 60,000 titles now I think.

Dave Brodbeck

Yes, something like that.

Marc Pelletier

If they are not there, they are going to get there very soon, and Dave and I have picked a book by René Descartes.

Dave Brodbeck

That's right and the title is – those of you who took like intro philosophy probably read this long time ago and if you haven't this is something an educated person should know about, Meditations on First Philosophy: With Selections from the Objections and Replies. And it's a – it's intense. Descartes was the guy who made it possible for us to study the mind. He is the first person that said that the mind and the body are separate things which most of us today would say is junk. But, he really got the idea of studying the mind scientifically going because he said we can separate the mind and the body and look at the mind, as I say in the show of course get over this

mind-body problem, but nonetheless this is great stuff and it's – I don't know maybe there is something wrong with me, but I enjoy listening to stuff like this.

Marc Pelletier

It's pretty heavy.

Dave Brodbeck

It's intense stuff, yes.

Marc Pelletier

Yes, so you might want a pause it every so often and breathe.

Dave Brodbeck

Yes, exactly.

Marc Pelletier

So let's play a little clip. It's narrated by Paul Hecht.

Dave Brodbeck

Yes, that's spelt HECHT.

Marc Pelletier

Here is the clip.

Paul Hecht

From this passage of Wisdom 13: They have no excuse for if they are capable of acquiring enough knowledge to be able to investigate the world, how have they been so slow to find its Master? And in Roman's, Chapter 1, Verse 20, they are said to have no excuse. In the same Chapter 1, Verse 19, the words, "what can be known about God is perfectly plain in them seem to be pointing out that all that can be known of God can be shown by reasons derived from no other source than our own mind." How this comes to be true and by what means God may be known more easily and with more certainty than the things of this world, I thought it would be appropriate to investigate.

Marc Pelletier

That's pretty amazing stuff considering that was written in 1685, right?

Dave Brodbeck

Yes, I mean it's well – Descartes is one of those minds that changed the world and it's, he had – you might even say he had a beautiful mind.

Marc Pelletier

Was he nuts? Maybe, after listening to that, I think so. A little bit. A little bit.

Dave Brodbeck

He's pretty intense.

Marc Pelletier

Well he was well ahead of his time,

Dave Brodbeck

Yes, I think so.

Marc Pelletier

And if you want to download Meditations on First Philosophy: With Selections from the Objections and Replies, you can head over to Audible.com/biotech and you'll get it as a free download. Now

you sign up for their plan and you get the free book. Now if you don't like the plan, you can just simply cancel and you get to still keep the free book. So it's a win-win situation.

Dave Brodbeck

Exactly.

Marc Pelletier

I think with the content that they have such as this, I mean this it's unlimited. If you Google the titles...

Dave Brodbeck

I was surprised they had this.

Marc Pelletier

Yes, you Google the title it takes it takes it to Audible, not to like some library or Wikipedia.

Dave Brodbeck

Exactly.

Marc Pelletier

Audible is on top. So back to the interview.

Dave Brodbeck

[31:44] There are really sort of two holy grails out there, right, in cognitive neuroscience, at least to me. I mean there is consciousness and the binding problem. Do you think that imaging work will help us understand, and fully understand what the binding problem is? It's how do we put everything, all of our memories, all of our thoughts, and all the experiences we are having right now, all the sensory and perceptual experiences, how you put that together to make the experience you're having right now, and we all have a rough idea of what consciousness is though I still want somebody to define it for me. Do you think that imaging is going to help us understand any of those things or are those may be red herrings?

Dr. John Gabrieli

Well, I think we, they are so deep problems as you just said just defining consciousness is so deep a problem.

Dave Brodbeck

Yes.

Dr. John Gabrieli

Knowing what the solution to a binding problem that is, how your brain all interacts together at a given moment of time, they are so complicated that I think that most of us even if we're very optimistic I think that's a tough one to get to.

Dave Brodbeck

Yes.

Dr. John Gabrieli

So we break it down to little problems. So imaging just show some more things that are related to that. Let me – for example in regards to consciousness you can do experiments where you show things to people that are right about at the threshold like a face and sometimes you see it, sometimes you don't, it's right at the edge, it is shown so briefly and subtly. And people have found pretty nicely that you can see which parts of the brain perk up when you consciously see something and which things are below consciousness, and they can even show you below consciousness, let's say you show a face and the person say I didn't see anything or you show a

car, the person says I didn't see anything, there are studies that show quite nicely that parts of your brain still respond to the face even when you don't think you saw them.

Dave Brodbeck

Right.

Dr. John Gabrieli

So there is a part of your brain and mind that knows what it saw, it is just not talking to your consciousness or allowing you in...

Marc Pelletier

That's dangerous, isn't it?

Dr. John Gabrieli

Yes, that's why people sort of worry about ultimately the – in fMRI used for things like lie detection, what's the ethics of things like that. But, so we can poke at some of these problems of what does it take for a brain signal to be powerful enough to reach consciousness or what can a brain signal know that's below consciousness but how much knowledge might it have?

The binding problem we can talk a little bit about how different parts of the brain seem to collaborate to accomplish something of interest. But again, in many ways those are very modest versions of these – you identified the two holy grail problems, and it's sort of one thing that many of us won't think about in neuroscience, I am sure, I'm guessing you might think this too, it's hard to know that we'll have a like a single solution to that.

It reminds me something like our desire to conquer cancer and it turns out that cancer is not one disease at all, it's many different diseases that we give a common label to. And whether the consciousness will be like that, it's many different phenomena, each unique biologically, call it all consciousness, but they're quite different things or even a binding thing can be very different, binding and memory versus binding and perception. So those are biggest mysteries of how – the mind...

Marc Pelletier

What do you guys mean by binding? I'm going to have to dumb it down a little bit here because I have no background in this area. So what do you mean by binding?

Dr. John Gabrieli

The gist of the binding – the way we understand – make progress in understanding how the brain works is understanding this part of the brain does X, this part of the brain does Y, this part of the brain does Z.

Marc Pelletier

Okay.

Dr. John Gabrieli

And so we break it down into pieces, right. Now, as you're really living there at this moment as we are talking, your mind, your perception, your recall of information and memory, your thinking about timing and so on, it's all happening simultaneously and pulled together. You're not sitting there going, okay, now I will do memory, wait a minute I will do perception, wait a minute I am going to do something physically, move my head. They're all bound together to give us a sort of fullness of experience, integrating all our mental abilities on whatever our focus of attention is.

So how does it – if our brain solves problems by breaking down things into pieces, which is how we tend to understand it, how does it moment-to-moment pull all those pieces together to give us the unity of consciousness? And that's a giant mystery, a beautiful one, very hard to make progress on.

Marc Pelletier

That raises the big question of Tibetan monks that can control various thought processes to extreme levels, or yoga specialists from India that have been able to lower their heart rate consciously by changing physiological function. Has there been any work in that area of using people that have trained and conditioned?

Dr. John Gabrieli

There are several groups, Richie Davidson in Wisconsin is famous for this, looking at brain differences in people who spend many years meditating. And they're understanding it as a skill that you get and one message from the research is that the skill of mediation is not what some people might think, which is that you really get really good at dwelling on your inner thoughts or feelings, because that's what – an intuition that you might have.

But it's really that they are able, the imaging suggests, to shut out the stuff that we normally sit in there. So one of the giant topics of curiosity these days is what is called the default network of the human brain. So if you put a person in a scanner and everything I have been telling you, the science of the field is like the better the task is the more we control the mind the better, but sometimes for various reasons we will just have a person lay there and do nothing.

And the amazing thing is that when people lay there and do nothing, they almost always turn on exactly the same regions of the brain. And the person in the scanner that could be thinking about lunch, they could be thinking about is this really a safe machine, they could be thinking about some sports event coming up. I mean it must be the case that moment to moment and person to person the thoughts are very different as you lay there freely thinking and yet everybody turns on roughly speaking the same parts of the brain.

Marc Pelletier

Are we thinking differently? I mean generally, I hate to say it – I don't want to take it into the gutter, but males tend to, certain age groups 18 to 34, tend to be thinking about one thing, how is that?

Dr. John Gabrieli

That mostly don't have a – that doesn't show up in this kind of imaging. It all looks the same. Whether you're thinking about pure thoughts or things you ought not to be thinking about in polite company, that looks the same. But what's curious about the meditators is they're not going to that place that most of us do. They're actually using quite different parts of their brain as if through training, instead of dwelling on everyday concerns, thoughts, the random stuff that mostly comes to our mind, through training they can really focus their attention quite away from the random clutter that we normally live in. So it's really quite fascinating as the insights, the suggestions from the imaging on the meditators.

Marc Pelletier

That sounds like it could be beneficial.

Dr. John Gabrieli

It is and it's truly a trained skill to be able to shut down the normal flow of consciousness and focus in on nothing but in an incredibly disciplined way.

Marc Pelletier

Could you use MRI to help in the training and then maybe help people with functional recovery of certain parts of – certain functions of the brain that need to be redirected to areas where say they have had a traumatic brain injury or stroke, and you want to sort of guide their brain through MRI? I guess it would be very expensive to give somebody constant MRI.

Dr. John Gabrieli

So let me, let me come back to the expense thing, but let me answer your first question first because this – one of our most fun lines of research is what people in the field call real-time feedback, real-time fMRI feedback and so – or neuro-feedback to use a very simple word. So that person lies in the scanner and we show them something like a thermometer and that shows how active a particular brain region is in their brains. So they are sitting there and seeing in a slightly delayed way because there is a blood signal how much they've turned on maybe this part of their brain and, in their frontal cortex or something like that, and then their job is to use that information to gain voluntary conscious control of how much they turn on or turn off that part of the brain. And working with Christopher deCharms, Stanford originally and other people here currently at MIT, we were able to show in a number of studies that people can learn to selectively push up or push down activation in specific brain regions. So we are very excited about that. First of all, it's such an amazing thing to see the – amazing modern human experience to sit in a scanner and see the activity of a specific part of your own brain in virtually real time; just the thought that you could see – just a slice of your brain kind of, and what it's doing...

Marc Pelletier

Yes.

Dr. John Gabrieli

And then it turns out at first people are not too good at pushing it up or pushing it down. I mean, it's a very weird thing like try and push up your occipital cortex or push down your temporal lobe – and, eh, what you do right. But because they see the feedback, because all the time they're seeing the score, they learn like if I think this it goes up, if I think that it goes down and they get pretty good at it over the course of about half an hour or 45 minutes. And so we are very excited about whether that's a possible way to help people with treatments just in the way that you mentioned, can you help people – we do a lot – we run a lot of imaging of various, for example, brain injuries or psychiatric disorders; we know lots of things about how brains are different functionally in depression or anxiety. Could you get somebody to gain control of a part of their brain that's making them prone to anxiety or depression?

And so now you mention the cost – in that context if it had a real effect and there is a lot of research before we would know if it really does but, it's not that expensive compared to multiple doctors' visits if you just do the costs, or you know, more medications, it's not that expensive and it seems like a very humane way for things to approach, because it's a way you're in control, it's not a medication and it's not something people telling me what to do; you are in control of your own brain and seeking a way to make yourself feel happier and more confident in how you are living your life and – so it's a very appealing thing.

We're very excited about this idea that you can learn to control a specific brain region through this kind of feedback and we don't imagine that it's going to treat by itself complicated difficult psychiatric diseases, but we could imagine as part of a treatment together with drugs, together with cognitive behavioral therapy, other things that do work but not for everybody all time.

So we don't know how far it will go but it's pretty amazing to have the idea that people could voluntarily gain to control specific parts of the brain.

Marc Pelletier

Maybe with neuroprosthetics, some kind of interface you could use to create some robotics or prosthetics that people could use to compensate for a loss of limb or...

Dr. John Gabrieli

Yes, that would...

Marc Pelletier

Paralysis.

Dr. John Gabrieli

The sort of brain-mind interactions that people are pursuing in a – with a variety of technologies to let people be freed of kind of difficulties of these sorts would be beautiful and so we are very excited about this.

fMRI is tough in that way because it's hard for people to cart around a scanner.

Marc Pelletier

They are getting smaller, aren't they though?

Dr. John Gabrieli

Yes, they – but you know, maybe we can translate this to things like EEG that's more available or just the ideas that maybe you could get the scale on the scanner but then you can just use it in your everyday life freely without any machine after that after some practice.

Marc Pelletier

I suspect that the MRIs are going to get smaller. You know, they could be assisted with a wheelchair; if somebody is paraplegic, you could have an MRI that would sit and within the framework of a microphone for example, I have a microphone here, I have a range of audio input I think, we could, if the person always stays or trains himself to okay, I'm going to put my head here, think about the slot, chair goes that way; move my head here.

Dr. John Gabrieli

And then there are some methods like optical imaging which also are able to take advantage of signals from the human brain of the same kind as fMRI that are much more transportable already, so I think you are right the technology always surprises us in – when it advances dramatically and there could be that there could be similar kinds of measures that the equipment will be much more transportable and practical.

Marc Pelletier

[43:28] But, it's clear that MRI is going to be decoding the human brain, right? If I understand this is what the fundamental of your work is to decode the various structures of the brain which are leading to various functions and thoughts.

Dr. John Gabrieli

That's the essence of it and it turns out to be, you know, the brain is just so amazingly – it does such amazing things for us and it's so hard for us to decode it. I mean...

Marc Pelletier

So you have a job – you still have a job.

Dr. John Gabrieli

Yes, it's amazing how we can so naturally take advantage of language or thinking or sight and so hard to understand how the neurons of the brain systems accomplish these amazing things.

Dave Brodbeck

One of the things that strikes me, I mean, Marc's talking a bit about stuff that might be five, ten, fifteen years off but one of the things that really I find fascinating about imaging stuff is how it is starting to give us some insight into things like childhood disorders, things like attention deficit hyperactivity disorder, autism, things like that, and I'm somewhat biased there because I have a son with high functioning autism and there are days when I'd love to be able to read his mind, and then again perhaps not. Do you see that these kind of techniques which I mean, I think they've led to real leaps and bounds compared to some of the ideas that people have had about things like ADHD and autism because I mean, some of the big strides that have been made in the last – just last few years I mean, do you think that these things will really break the lid open on what the causes are of some of these disorders, things like ADHD and autism or...?

Dr. John Gabrieli

Yeah, I think it will big pieces, I mean as you know very well, it's really big – in some ways I would say the huge amount of our progress in developmental difficulties like autism, ADHD, dyslexia, a lot of it has just been clearing away ignorance and misconceptions unfortunately...

Dave Brodbeck

Yeah, exactly.

Dr. John Gabrieli

...that have plagued families and children for decades. And I feel like to a certain extent we've cleared that away, we understand what is in the disorder, that it's a biological disorder that has a genetic component. It's not things like bad parenting and stuff like that, that for decades people misunderstood or used very broad terms like mental retardation which give you no insight into a particular person at all.

Dave Brodbeck

Right.

Dr. John Gabrieli

On the other hand, it's just – these have been just – our understanding of the human brain kind of got pretty good at when there is a big injury, right, a rod through your head like Phineas Gage a big stroke, and we are very unsophisticated despite our best efforts in developmental disorders or degenerative ones at the other end of life where things happen in slow, complicated ways.

Dave Brodbeck

Right.

Dr. John Gabrieli

So there have been a lot of structural brain imaging studies that went in and said 'oh we are going to solve autism, we are going to solve ADHD and things like that'. And although there are subtle differences, especially certain very young ages in autism occur maybe in head size and things like that.

Dave Brodbeck

Yeah.

Dr. John Gabrieli

You can't hold up a brain scan as you know structurally and say, this kid has autism, this kid doesn't, or this kid is ADHD. So it's befuddling, because probably it's a – the developmental differences are very subtle, what we might call wiring differences, how different parts of your brain talk to other, that's an – so there I think functional imaging will be very helpful because that gets at some of how brain parts communicate with one other. But it seems to be really, really challenging. And so I think we have – it's like we have the microscope because we can finally look at brain functions child by child, but we almost lack I think the intellectual categories to work in. I know in autism one hears a phrase "if you've met one child with autism, you've met one child with autism".

Dave Brodbeck

Child with autism, yeah, that's right.

Dr. John Gabrieli

Yeah. And I think that speaks of the fantastic variety of children and the struggles they have, there is patterns of strength and weaknesses in everyday life and we're nowhere close, beyond being able to say well this child communicates somewhat, this child less, in understanding how that plays out in genes or in brains. So we have a huge challenge ahead of us. On the other hand

it feels like we have the tools to do it between genotyping tools, of modern day imaging. I mean we have a chance, whereas before we operated in pure ignorance and confusion.

Dave Brodbeck

I think also one of the things that I mean practically for people that their kid gets diagnosed to whatever it's nice to be able to actually as you are saying, be able to tell parents that your kid has a thing, like it's not – it's not just that he didn't paint his room in the right primary colors and put triangles on the wall when he was a year old. The kid's got a proper disorder or that Johnny isn't just hyper, Johnny has got real issues here, he can't attend to things.

Dr. John Gabrieli

Yeah.

Dave Brodbeck

And I think on that level it's also really important. And I guess also you can sort of segue this from saying that you can understand that we've been doing this in psychology forever, you can understand a whole lot about normal functioning by looking at impaired functioning. As you mentioned Phineas Gage, H.M., K.C., all these people. So I guess as well there is the added advantage there that understanding disorder helps us understand order.

Dr. John Gabrieli

Yes. And so with imaging we are just starting to have enough understanding say of typical developmental trajectories, how does language grow or how does social interaction grow in the brain and then certainly we can understand variety in that. Some short run things where I think imaging might be practical is whether we can talk about biological variation in a way that's related to treatments, even available ones, I mean the Holy Grail ones is to have a treatment that just allows every child to avoid the difficulties that they face. But, for example in ADHD, there's several different medications that are given – I'm not a clinician, but every clinician I talk to is an expert in that and they says it's a crapshoot which drug you give to which child. And the way they figure it out is it doesn't work, the kid has got miserable side effects, bring the kid back in and let's try another one.

So having a deep insight into what causes ADHD, that could be a while away, maybe brain imaging could allow us now to say you – for a given child, we can tell you this is a drug that 90% is going to be the right one for you. There is a lot of evidence in dyslexia, lot of evidence in autism, that early interventions can have much bigger effects than latter ones for many reasons. We don't understand all of them. And will these tools allow us to identify children at a very early stage and have interventions that are you know allow a child to skip a lot of the misery that the – can occur in the developmental disorders. So that's I think imaging, you know, it might be just years away from that, you know, deeply understanding these things, you know, could – you never know when the breakthrough happens but that could be easily a decade.

Dave Brodbeck

Yeah.

Marc Pelletier

That's amazing. So you could basically have three or four visits to an MRI center and design a treatment plan versus years of trial and error with various drugs?

Dr. John Gabrieli

That's exactly what we are...

Dave Brodbeck

You can even look at the effects of the drugs, right. You see, oh that drug doesn't work because it's not restoring function to that certain part of the brain.

Dr. John Gabrieli

Yeah, I'm thinking just predicting, you know, maybe one visit – just in a sense, there's a great hope of personalized medicine, as we understand that these labels we use depression or autism cover a huge variety of people, in terms of the true biology of their difficulty and so that combination of genetics and imaging all of a sudden we could say maybe this group of children for example or adults would benefit a lot from this treatment approach. But they won't you know, but the other ones in another treatment approach. So even current treatments with all their limitations, if we could get people to the right effective ones better, we could make lives better pretty soon I think, so I think that's within sight.

Marc Pelletier

After analyzing brain function at various sub-cellular – well not sub-cellular, I don't want to talk about that, I'm a molecular biologist so everything's sub-cellular.

Dr. John Gabrieli

I agree, we would love to. No, no, just to give you our smallest units of measurement are many hundreds of thousands of neurons; this is just the limitation.

Marc Pelletier

The opposite scale...

Dr. John Gabrieli

I wish it were better, my neuroscience colleagues that's why they laugh at us. Like, amongst psychologist, we're hardcore reductionists. Among neurosciences, we're like ESP astrologer types, you know, we're like – they're like yeah, what could you tell when you measure that many things, we don't – we're down studying particular molecules and particular neurons and so we're in the middle but go ahead sorry...

Marc Pelletier

I am on the other scale, I'm looking at blood-brain barrier physiology and I'm trying to modulate water across the blood-brain barrier for a number of – for stroke and TBI. So I – my understanding of human brain is limited to two plasma membranes, astrocyte and endothelial cells, so it's very, very – two cells, handful of proteins that are of interest to me for the task that I'm trying to deal with.

Dr. John Gabrieli

Can I – I have to tell you this because it turns out astrocytes, which are glia, so-called support cells in the brain, right?

Marc Pelletier

Yeah.

Dr. John Gabrieli

Turns out that if you silence them, the fMRI signal disappears. So this is the great mystery, the fMRI signal is – it's unbelievable what goes into that and we don't think we're measuring what astrocytes do for the human mind. But obviously, they are part of the physiology network, but sorry I interrupted your question.

Marc Pelletier

Oh no they...

Dr. John Gabrieli

I couldn't resist showing off the one thing I know about astrocytes.

Marc Pelletier

[52:55] I think they are important. They are not important of thought and emotion and memory, but so what I was trying to say is when I look at – I think about something, I put it into the context of the cell, I put it in the context of proteins, genes, I'm always looking at the small – small scale. So when I think about memory I think about the synthesis of various proteins at a certain time, that the half life of those proteins might modulate certain synaptic activity which relate to possibly memory. But your – the way you feel or you think about the global picture of the human brain and its function, do you see thought as different from emotion? How would you – how do you define thought versus emotion? How do they differ side-by-side?

Dr. John Gabrieli

So partly we do what everybody does, we just have a sense of thought as when you're trying to think really hard, rationally and emotions are when feelings you have of different properties. I mean, we start – like psychology, divides it up that way, right. And it goes with our everyday intuition about these things.

In the brain, we get some degree, as you may well know, I'm sure you do actually, people are deciding that it's harder and harder to tell them apart in real life and we know this like when people make a hard decision but so often they kind of know in the first second through emotion what they're really going to decide. There's a lot of...

Marc Pelletier

Well, that's a difference between Captain Kirk and Spock, right?

Dr. John Gabrieli

Yeah, yeah, well that's pulling them completely apart, right. In the prequel as well as the mature TV series. So one of the fun things about imaging is that we know some parts of the brain seem to be very tied to thinking, so-called dorsolateral prefrontal cortex patients with injuries there, have tough times on classic problem solving tasks where you have to think hard, and we know that other parts of the brain apart are very influenced by emotion, such as amygdala in the limbic system and so you get the chance to ask you know how these things interact and so one line of research is what people call emotion regulation how thinking interacts with feelings.

And we show people pretty disturbing pictures and sometimes they just look at it, and then there is a big amygdala activation, sometimes their job is to reinterpret the picture to reappraise it and say okay, there is a lot of women sobbing in front of a church, how do I reinterpret it, well, maybe they are tears of joy, maybe they're coming out from a wedding. And you can see, you know, in these imaging studies the thinking part of the brain turn up and the amygdala or the emotional part of the brain turn down as people find a way to reinterpret an emotional experience.

So we get to see some of this interaction between emotional circuits and thinking circuits, but we know that in real time, there is a incredibly subversive role of emotional thinking, that very often you know, when people think they are operating purely rationally, emotions are playing a shocking part, it's human nature.

Dave Brodbeck

Most of your, I mean, when you think about sort of the amount of brain, if you, for the lack of a better way of putting it, I mean amygdala is a little tiny thing, it's called amygdala for a reason, it's shaped and the size of an almond, right, I mean, it's not a big thing.

And cortex is huge, as I always call it in class, the wrinkly bits, where you're doing all the processing. If emotion is and I think we all accept that emotion is something that's well, I mean, it's in the limbic system, so it's evolutionarily older. If it's so important to us, yet so basic, sorry, I'll reword this – it's so important to us obviously. But it's also basic, do you think looking at something what's – like how – what's happening in amygdala can give us ideas about how thinking, complex cognition in cortical regions, works or are they pretty darn separate things?

Dr. John Gabrieli

You know, again there is this localization thing, it's easier for us to make progress, the more separate they are in a given experiment the easier we have a progress, better progress we make just in understanding stuff, but they're just so interactive and there is so much psychology, so this is where fMRI for example, with its very poor or modest temporal properties, we would love to know, you know, if you're sitting there and thinking you're making a rational decision, at one moment is that amygdala really firing up? It's a decision made so to speak, you know, before your rational part of your brain rationalizes its way to the decision you already decided in your heart or your amygdala, but we don't have that temporal resolution. No, we don't have it with fMRI and we don't have another brain measure, we have ones with great resolution EEG, MEG, but they don't tell us – they don't tell us, they're not very good for knowing when the amygdala is really firing way. So...

Dave Brodbeck

Right.

Dr. John Gabrieli

I think, a lot of this is going to come from animal work and then we'll see correlates of in humans but the drama will be in the animal work because there they can see millisecond by millisecond, you know, when neurons are firing in the amygdala and when they're firing in the frontal cortex. The only limit of animal work is we won't get their opinion about Star Trek because even monkeys that are evolutionary close to us just live in a different world socially and don't have some of the properties that we have certainly and so you know, it's going to be a very interesting interplay between the hardcore biology you can get in animals and the other kinds of stuff we can do in people.

Dave Brodbeck

[58:30] Do you think, I mean, you said something it's interesting that you sort of – monkeys for example or chimps live in a different world than we do. And I'm sympathetic to that I think that's true too. I have colleagues and friends who have different attitudes about that, they are looking for things like evidence of metacognition and you know, morality, consciousness in chimps, in monkeys. When we see the similarities, do you think imaging is going to be able to play a role there, we can actually take a look and say look it's the same or the roughly the same places in a chimp brain that is lighting up in a human brain. And the behavior looks similar and then the only step we have to make is sort of – we have to make an inference. Do you think that's going to be a – you think it's a sensible thing to do make that inference?

Dr. John Gabrieli

Yeah. Well, the last step about guessing about the internal mental life of animals has always been very tough. You know, it's just hard in people, but we've shared that, we can talk about it, but I agree with you that, that's going to influence us a lot because if we think the monkey is making a moral decision of a kind, thinking whether something is fair or unfair and the activation looks the same as it does in the human, that's really going to push us to really think carefully about what mental life is occurring in the animal.

So by different worlds I just meant this real world we live in within being on the Internet and that kind of stuff, but in terms of the internal mental life, I agree with you it could be a very fascinating way to line-up the human experience and what might be the internal experience of other animal species.

Dave Brodbeck

My friend Rob at – Rob Hampton of Emory, he actually has a system where, in fact, his monkeys are on the Internet, when it's done the experiment, it emails Rob the data file, the monkey. It's actually the gear that does it but you know the email looks like it says that it's from monkey@robslab, which is pretty cool.

Dr. John Gabrieli

Yeah, I think I've been getting a bit of spam from that monkey.

Dave Brodbeck

I'll talk to him.

Dr. John Gabrieli

Okay, thank you.

Dave Brodbeck

This sort of leads me to something that, you know, philosophically and I'm no philosopher, I took one philosophy course in first year – that's '78, but one of the things that's always struck me about whenever I read, whenever I'm teaching, you know, intro neuroscience courses is in all the books it thanks, it gives Descartes all this credit saying, you know, without René Descartes we would not have the reason to study the brain, to study the mind rather, but Descartes of course is a dualist, right, or was that the mind and body are separate things and when you – studies show when you go and ask the average person out on the street, are your mind and body separate? They almost, you know, 80, 90% of people go, yeah of course and usually when you ask, you know, psychologists, neuroscientists, they go, what kind of question is that? You know of course that the mind is a function of the brain. Do you think that perhaps, I mean, this is sort of the selfish thing because I get tired of debunking this in class, you think it's possible that at some point all these imaging data were going to eventually be able to explain to people that their mind is just in their nervous system and they should get over it?

Dr. John Gabrieli

I like the way you said that. You know yes and no, I think that is a fascinating social effect, not all at once everywhere but of imaging itself, I mean, I think maybe this is what you're saying, as people see more and more topics of all kinds, everything from marketing to diseases, you know, study by imaging I think there's a – there will be a societal shift to comfort with the idea that the mind is what the brain does, the physical extension.

Dave Brodbeck

Yeah.

Dr. John Gabrieli

So I think what will happen you know, then you have the legal excuses or the parental or the child excuses, 'oh my brain made me do it', so that will – but you know – so I think that – I think imaging is driving that in many ways because people just say, okay, a certain pattern of activity, I'm having a certain thought or feeling, that's fine. To me, that's a fascinating topic but the – almost the more disturbing for me is where free will falls in any of this because –

Dave Brodbeck

That's where I was going next by the way.

Dr. John Gabrieli

Yeah because you can get people to agree okay, genetic – genes are important, environment is important, mental life is important, it's the stuff – the brain that makes the mental life is important. I have no idea how, you know, we're going to think about free will in that context and yet, you know, everything about our society depends on treating people in the way in terms of responsibility that they have free will. It feels to us like we have a choice to do certain things that there's bad things, wise things, silly things, you know it'd be hard to imagine our life for us if we really believed that everything was sort of a preordained, probabilities, we get the right environment and things fire and they happen, so I think free will is going to be giant challenge. The more we understand about the physical basis of mental life, the more it's going to push us, where's the free will piece in this? And yet we have to live our lives day to day in our society as if

there were free will because it just feels like there is and we don't know how else to live our lives I think.

Dave Brodbeck

Yeah, I mean that's what I'm always saying in class, I try to be provocative in first year to get them interested or scare them away, one or the other, and you know one of the things that I tell them on one of the first couple of days is, you have no free will, it feels like you do so I wouldn't worry about it.

Marc Pelletier

Dave, Dave. Devastated.

Dave Brodbeck

Well, no, you have no free will, Marc, just get over it.

Marc Pelletier

I know I don't, I'm just a biochemical machine.

Dave Brodbeck

That's right. You're a very complicated machine.

Dr. John Gabrieli

And we knew you're going to say that too.

Dave Brodbeck

That's right. Exactly. On the other hand, I mean, I think that's an interesting sort of physiological cognitive neuroscience question is how does free will work?

Marc Pelletier

It's the subject of another show.

Dr. John Gabrieli

Day after tomorrow we're submitting a paper explaining all of that so you know, it's – I am not sure we'll ever get to some issues like that in any deep scientific way and they may be beyond science to address.

Dave Brodbeck

Shame on you.

Dr. John Gabrieli

Okay. Really? At the same time, you know, I think we will gain some senses of things that – brain conditions or situations that strap us of free will. I mean certainly if you give somebody unbeknown to them a drug that has a huge effect on their brain and they do something. You know we would certainly say that person was not operating at free will and the more we understand about biology the more we are going to understand some factors that make – that really bias you to behave in certain ways and I think that will push us in our sense of what is the line between biological destiny, as it interacts with the environment on the one hand and free will and free choice on the other, because the more we understand about brain mechanisms and how they come to be through genes and through experience, you know the more we will see, it will be harder and harder to leave that little piece left over for free will. So it will make us more understanding of people, but maybe it will make responsibility a harder thing to define.

Marc Pelletier

Yeah. We just scratched the surface here of the human brain and humanity, right, what makes us human. So we're going to have to certainly dig deeper in future shows and we could also have

Dr. Gabrieli back in some time, a little bit of time, give him a break from us. Thank you very, very much for coming on the show.

Dr. John Gabrieli

It's been delightful. A lot of intellectual fun. Thank you.

Marc Pelletier

So that was Dr. John Gabrieli, who is the Grover Herman Professor of Health Sciences and Technology and Professor of Brain and Cognitive Sciences at MIT.

Dave Brodbeck

And really the other thing, besides all the titles and all that stuff, Marc, he just seems like heck of a guy and I don't know about you but one of the things that I've always noticed is that people that are really, really, really good, they're so humble and cool and pleasant, it's the fair to middling people like you and I that are really jerks.

Marc Pelletier

I agree and what an opportunity. You know I do this podcast as a way to extend my education...

Dave Brodbeck

Yeah.

Marc Pelletier

...since I finally finished college after 19 years. Literally I was in college from 1989 until, oh god, until 2007. But hey so wow he's fantastic and...

Dave Brodbeck

Yeah.

Marc Pelletier

...extremely thoughtful and what an amazing thing to do to go into the human mind with an MRI and...

Dave Brodbeck

Yeah.

Marc Pelletier

...try and make sense of it all.

Dave Brodbeck

And I mean when we touched a bit on the stuff, I mean, this really – this is everything from hi-tech stuff to you know, it does get at even you know thinking about our audible pick, it does get too philosophy to a point which I usually get frightened and run away when I see things that look like philosophy but we're getting close to discovering things like consciousness and how it works and if any of my students are listening, yes, you just heard Dr. Dave Brodbeck say, we can maybe study consciousness someday and John Gabrieli is one of the people that's going to allow this to happen.

Marc Pelletier

Well, it was a pleasure to have you on as a co-host, Dave, we're going to have you on to help us cover everything revolving around the human mind.

Dave Brodbeck

Thanks.

Marc Pelletier

We cannot neglect that biotech and the human mind are coming together. So I need someone who can – who understands the human mind a lot better than I do this and to really get everything we can from this – these interviews. So again I'd like to thank John Gabrieli and Dr. Dave Brodbeck who's an Associate Professor and Chairman of the Department of Psychology at Algoma University in Sault Ste. Marie, Ontario, Canada. Thanks, Dave, for coming on.

Dave Brodbeck

Thanks a lot, Marc, always a pleasure.

Marc Pelletier

Just before we go there are few more people that I'd like to thank, but I need to mention that I'm doing the post production for this episode on the road and I don't have a mic other than the one underneath my keyboard so I apologize for the audio here.

I'd like to thank Tom Price from Pods in Print for making the transcripts available, you can download them at futuresinbiotech.com. If you need transcripts done, the folks at Pods in Print are really exceptional at even the most technical stuff.

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For Futures in Biotech, I'm Marc Pelletier.