BRAIN SCIENCE PODCAST

With Ginger Campbell, MD

Episode #28

Interview with Dr. Edward Taub, Pioneer of Constraint-Induced Movement Therapy

Aired January 11, 2008

[music]

INTRODUCTION

This is the *Brain Science Podcast* – the podcast for everyone who has a brain – and I'm your host, Dr. Ginger Campbell. On the *Brain Science Podcast* we explore how recent discoveries in neuroscience are unraveling the mysteries of how our brains make us who we are. For more information including Show Notes, links to previous episodes, and information about how to subscribe please go to the website brainsciencepodcast.com. We also have a Discussion Forum at brainscienceforum.com and you can send me email at docartemis@gmail.com.

[music]

"It is hard work. But if you put the work in, over a period of time there is almost no limit to the amount of recovery that you can have. And this is predicated on the fact that the brain remains a very plastic instrument throughout the lifespan."

[music]

GC: This is Episode 28 of the *Brain Science Podcast* and that was today's guest, Dr. Edward Taub from the University of Alabama at Birmingham, where he has pioneered a revolutionary approach to stroke rehab that taps into the brain's plasticity. I guess I should mention that one reason why I decided to interview Dr. Taub is that he has been working at the University of Alabama at Birmingham since 1986. UAB, as it is known locally, is where I went to medical school, although I was never aware of Dr. Taub's work. I graduated in 1984.

When I was editing this interview I struggled with how much clinical detail to leave in vs. editing some of it out, and I decided to leave most of it in. There is one section where I will let you know where you might want to fast-forward. In Episode 26 when I was interviewing Dr. Doidge I promised to give you the follow-up information about my friend Dr. Bernstein's rehabilitation experience, and that is near the end of this interview.

I'll be back with a few announcements after the interview, but let's get on in to Dr. Taub's interview.

INTERVIEW

GC: Dr. Taub, I want to thank you so much for coming on the *Brain Science Podcast* today. You're probably the first person that I've had on my show so far who's actually somewhat of a clinician, actually doing work with patients. And the reason I wanted to talk with you is that we've been talking on the show a lot about neuroplasticity, which my listeners are very interested in, and I know your work relates to that directly. Would you tell us a little bit about how you got involved in your current area of work?

ET: Sure. Actually I wasn't originally a clinician; I was a basic researcher working with monkeys. And we found that there was a particular surgical procedure that abolished all sensation from one forelimb in a monkey—and that's important; just one forelimb in a monkey. And the classic observation by Sir Charles Sherrington and his collaborator, Mott, was that if you deafferent the monkey—that is if you sever all of the dorsal roots of spinal nerves associated with a limb—then the limb is never used again.

Sherrington, who was a brilliant scientist, asked why should this be when the motor innervation had not been interfered with at all. And the answer that he came up with is historically important. He decided that the answer was that movement is based on spinal reflexes, and severing sensory roots or dorsal roots of spinal nerves does abolish all spinal reflexes from an arm. And that observation was the basis of what is called Sherringtonian reflexology, which was the dominant position in what we now call neuroscience.

And I'm a psychologist—a kind of psychologist who focuses on brain behavior relationships, or central nervous system behavior relationships—a behavioral neuroscientist. We decided to reevaluate this historically important observation, which had been replicated quite a number of times, using behavioral techniques. And we found that it was possible to overcome the non-use of the deafferented limb by one of two techniques.

Those techniques were training of the more affected arm—or the deafferented arm—by a behavioral method called shaping in which you ask the organism, whether it be an animal like a monkey or a human being, to improve its performance in very small steps by what are called successive approximations on a trial-by-trial basis. So, there's this bringing the organism along very slowly but steadily so that there is a steady and progressive improvement in motor capacity.

And the other technique was prolonged restraint of the intact arm, so that if the animal didn't use the deafferented arm this would render the animal virtually helpless. It couldn't ambulate, it couldn't climb, it couldn't feed itself. And this increase in the motivation to use the limb induced the monkey to use the limb.

That's where we started. This series of experiments took place over a substantial period of time. At some point I wondered whether the same two techniques wouldn't be of use in human beings after stroke. And I wondered about this for a long time.

The point is that in neuroscience at that time virtually no one had done any translational research from the bench, as it were, to the bedside. That isn't the sort of thing that one did in neuroscience. It hadn't been done. None of my mentors had done it. No one suggested that this be tried. However, as time went on the question kept growing in my mind until finally I did try it here at the University of Alabama at Birmingham.

GC: Was there work by anybody in particular that inspired you to move forward into actually trying this in people?

ET: Just the work that I and my collaborators had done. It was at that time just out of left field. It wasn't the way that you did neurorehabilitation. What you did at that time—and still do in many places—was to attempt to get the more affected arm to be used more. This was usually in the early subacute period when the patient was being treated in a hospital, say, one to two months after stroke onset.

And when a plateau was reached, then the therapist would move on to the arm that had not been affected by a stroke and try to train the person to use it so that it did the work of both arms. This had the unfortunate consequence of stamping in the non-use. But that was what was done.

I, when I came into this area, knew nothing whatever about rehabilitation; literally zero. So, fortunately I didn't know the way rehabilitation was supposed to have been done. And just based on our data with monkeys I formulated a rehabilitation therapy that also combined what I had learned as a graduate student in the behavioral laboratory.

GC: Your method that you use now is called Constraint-Induced Movement Therapy. Is that the right name?

ET: Right on the button. It's a rather long name, so we usually shorten it to CI Therapy.

GC: OK. And that involves both the idea of the shaping—the small increments of improvement—and the idea of keeping the person from using their good limb.

ET: That's right. Now, we've also worked with young children from ages two to six years old who have cerebral palsy. And we've worked with monkeys, and we've worked with adults. With monkeys, restraining the limb is very important. And for young children restraining the limb is also very important. With adults it's much less important. We don't do that; we really don't feel comfortable doing it. But we've experimentally demonstrated that you can get virtually the same treatment effect without the restraint, just with the intensive training and a third component, which was transparent to me for many years.

In the behavioral laboratory when you were trying to effect a behavior—in this case a movement change—in a person, these are the techniques that you normally used: behavior techniques. And we have found that these behavior techniques—which we now consider as a group to be what we call our transfer package—that really is, it turns out experimentally, the most important therapeutic factor in CI therapy. It's more important than the intensive training, for example, and the shaping.

GC: Could you maybe give us an example to explain what you mean by that?

ET: Sure. The first thing that we do when a patient comes in to the laboratory or the clinic—and we do have a clinic here at UAB—is to do what we call a behavioral contract, where we take down what a person's normal routine during the day is. And then we come to an agreement with the patient on what he is permitted to do with the restraint off, like toileting and use of water, or anything that involves safety, like walking up stairs. Or if they use an assistive device like a cane or a walker, then they take off their restraint device and carry out that activity safely. But aside from that—and these are specified—the patient agrees to do specified, and most, activities of daily living using only the more affected arm. The patient signs it, the therapist signs it, and a witness signs it.

GC: So, that's kind of like when you tell everybody that you're going to quit smoking, you're more likely to do it.

ET: That's right. There are other components that are like quitting smoking. After doing that we administer a structured interview; a questionnaire that is administered in a very specified way. Every morning when the person is in therapy they get the MAL—the Motor Activity Log—administered to them. And there are 30 activities of daily living which are both frequently carried out by virtually everyone and which are important in the life economy of most individuals; like using the utensil for eating, using the arm to brush the teeth or the hand to wash their hands, to shave or put on make-up, and various other commonly carried out activities.

And the person is supposed to, when they're at home, use the hand for this purpose. Now, adults will typically try to do that. And if they haven't done a specified number of these activities of daily living the therapist will ask them why. And there will frequently be a perceived barrier to carrying out the activity that can be circumvented—sometimes very easily. And the therapist is very experienced at handling these perceived problems and enabling the patient to overcome them.

For example, the patient says no, they didn't try to drink water from a glass, they were afraid of spilling the water. So, the therapist will say, 'That's fine. Why don't you try just filling the glass up one-quarter of the way, and then you won't be in any danger of spilling the water.' Same thing for drinking coffee. The point is, once you can get a patient started doing these activities, the more they do it the easier it is for them to do. And the objective is to get the use of the arm habitual in the life situation.

[music]

GC: I want to thank those of you who have come to the website at brainsciencepodcast.com and made donations to help support the *Brain Science Podcast*.

[music]

GC: Do you have any idea in your own mind about why this works? Not the psychological, that's not what I meant; I meant neurologically how it works.

ET: Well, there's a fine line between the two. The nervous system produces behavior and behavior in turn feeds back onto the nervous system and can change it profoundly. And that in fact is what we have found occurs. We think that there are at least two mechanisms that are responsible for the efficacy of CI Therapy. The first is largely behavioral and it is called 'learned non-use'.

Initially the belief was that what you're dealing with is a learning phenomenon: a learned inhibition of movement. And now we have considerable evidence that this is in fact a mechanism that occurs both in monkeys and in human beings. After any substantial damage to the nervous system there is a period where there's a reduced excitability of the nervous system. And during this period—which has been referred to as cortical shock, or spinal shock—during this period of reduced excitability the individual, whether it be a monkey or a human being, really cannot use the affected extremity.

During this period the individual tries to use the extremity but he can't. This represents a failure of an attempted objective, and failure produces an inhibition of movement. Not an abolition, rather simply an inhibition. Its pattern remains in the central nervous system and it can be activated very rapidly, but only by the application of an appropriate technique.

One of the mechanisms of CI Therapy is overcoming learned non-use. There is a related mechanism which is independent, but the two operate together. And that is an entirely neural mechanism, but as I said there is a fine line dividing the two. And one of the things that we found back in the late 90's is that lack of use of an extremity after stroke produces a contraction of the cortical representation of the affected extremities. The cortical representation, for example, of an affected arm shrinks by about a half.

People who have had a stroke frequently report how effortful it is to make a movement, even when they can make it. And that isn't surprising, because now they're trying to make that movement with about half the neurons that they used to use before they had the stroke in order to make that movement. And so, it's effortful. Now, what CI Therapy does is increase the use of the limb—motivate the person to increase the use of the affected extremity. And when the person does that there is a corresponding increase in the size of what we call the motor output area to specific muscles of the arm.

You can determine the size of the motor output area for a particular muscle of the arm, for example. You can tell how excitable a particular part of the brain is for producing a movement or a contraction of that muscle by a technique called 'transcranial magnetic stimulation', or TMS. That involves focusing a strong magnetic field non-invasively through the skull onto a small area of the brain until you hit a spot that will produce a response in the target muscle. And then you map the brain around that area for the section which, when stimulated, will produce a response in that muscle. That's called the motor output area.

Now, we did this back in 1996. We published our first paper in 1998. This was in Germany; I had a number of German collaborators. The senior author on that paper was Joachim Liepert. What we found, again, was that after stroke but before CI Therapy the motor output area for APB—abductor pollicis brevis, which abducts or extends the thumb away from the hand—had shrunk by a half. And that has since been replicated by an Italian group and other groups a well. After CI therapy the motor output area had doubled in size. It was back to normal size. That doesn't mean that it was normal, but it was of normal size. There was still a deficit.

That has since been replicated by other groups using other techniques like FMRI, functional magnetic resonance imaging, and PET, positron emission tomography. We also found in a study with a group from Berlin that I was working with—this was published in 1999—that there also was a recruitment of the motor areas on the healthy side of the brain.

GC: Was that a surprise?

ET: It was all a surprise. It really was. Except that – I mean the reason that we did the experiment was that I thought that it was distinctly possible that this was occurring. From the 1970's I had been operating very naïvely under the belief—which seemed obvious to me—that the nervous system produces movement. So, if you see a change in movement it implies that there must be a change in the nervous system, which you could see if you went looking for it and had a technique that was appropriate for enabling you to see where that change was. That informed a great deal of my research, including the research involving CI Therapy.

You remember I said that I was trained as a psychologist but I was also trained as a neuroscientist. So, I had really been working between the two areas from the very beginning of my career. And this was a naïve point of view. A good friend and collaborator at the time, when I tried to use this as the basis for a grant application, said, 'OK, do the research, but let's not talk about the hypothesis very much. It's the kind of thing that a psychologist would come up with.' But in any case, not withstanding my colleague's sarcastic remark it seemed obvious to me that this would be the case.

At about this time I was stopped from doing research for a period of years. But fortunately an investigator named Dr. Michael Merzenich[1]—and Dr. Jon Kaas, and several others, but mostly notably Michael Merzenich—was able to demonstrate that in fact the central nervous system is highly plastic and is responsible for alterations in afferent input and to behavior, so that when this was changed substantially the nervous system had a corresponding change. I had already been working along those lines before these very dramatic demonstrations.

GC: But people probably started paying more attention to your work once they had a reason to believe that it worked.

ET: I had been publishing for several years what I considered to be pretty good clinical data—well controlled, with the kind of attention to control and detail that you use in basic research, which is what I had been doing. Nobody exactly disagreed with the effects of CI Therapy, but nobody paid any attention to it either. Well, a few people did; but mainly it was ignored. We began publishing these papers showing that CI Therapy produced a change in the brain, and all of a sudden everybody started believing that there was something there; or at least something worth attention because it produced a physical change in the brain.

I was delighted that that happened. But I was always also faintly annoyed that the clinical data wasn't good enough to convince a large number of professionals. Clinical evidence, when it's well controlled, is scientific evidence, and it's as

---

[1] Dr. Merzenich was interviewed for [Episode 54 of the Brain Science Podcast]

significant and empirical as a demonstration that a treatment has a physical effect on the body—in this case, the brain.

GC: Yes. They certainly seem to be happy with clinical evidence when they want to convince us to prescribe a new expensive drug.

ET: That's exactly right. And it may be that what was the problem was that the treatment that we had developed was just very different than treatments that had been used in rehabilitation before, so that the level of evidence needed before people would pay attention was much higher. In any case, all that's in the past. As a result of the demonstration that the therapy had an effect on the brain, in addition to the clinical evidence, we were able to get funded by NIH to do a multi-site randomized clinical trial; which is what you were referring to before.

And it was recently completed and written up, and it was published in the *Journal of the American Medical Association* in November. It was accompanied by a very positive editorial and press releases by the AMA and NIH. And I believe that it is now the first rehabilitation therapy that has been validated by what is generally considered to be the gold standard of evidence in the medical field.

[music]

GC: The next section, which is about ten minutes long, is a discussion of the application of CI Therapy to a number of different clinical conditions including traumatic brain injury, cerebral palsy, multiple sclerosis, spinal cord injuries, hip fractures, and focal hand dystonia. At the end of the section there is a question that came from one of our listeners. However, if you're not interested in these clinical issues you can go forward about ten minutes to the rest of the interview.

[music]

ET: We have recently—by recently I mean very recently; this Monday, for example—submitted a grant to do a parallel multi-site randomized clinical trial for traumatic brain injury.

GC: My next question was going to be where are you going next; and I guess you're answering that.

ET: Well, no, we've already been there. And we've worked with perhaps 50 people with TBI, and we get exactly the same results. This, however, has become a very critical, sensitive, hot-button issue with the large outcry in the media of mothers of brain injured veterans of the Iraq war who felt that their sons and daughters were not getting sufficient treatment. And so, the finding among 50 civilian TBI patients was not viewed by people in the medical and materiel command as sufficient evidence to make this a standard of care for TBI in military and veteran affairs hospitals, and it was necessary to carry out a multi-site randomized clinical trial, which we have applied to do. I don't know whether it will be funded. We'll know in April.

But we have worked with a variety of other conditions. You remember that I said that one of the mechanisms was learned non-use. And the formulation says—and this formulation goes back to 1977—that any substantial damage to the nervous system which gives rise to a temporary inability to use an extremity or a reduced ability to use an extremity which will eventually recover to some extent, sets up the conditions for the development of learned non-use. So that most of the work that we've done and other people have done—and this has been replicated many times; there are well over 200 publications on CI Therapy applied to stroke in the literature now—but the formulation from the beginning directed attention, not to stroke, which just was accessible to me here at UAB at the time, but to any type of neurological damage that resulted in a motor deficit which would slowly recover.

And so, we have used CI Therapy for cerebral palsy in children two to six years old. Other people have used it in children eight to eighteen years old. With young children we have even greater success than with adults, presumably because it's a more plastic nervous system. We've got our clinic for that at the Children's Hospital of Alabama, which is right here in the UAB complex. We have worked most recently with multiple sclerosis—that work is spearheaded by Dr. Victor Mark, who is a neurologist here at UAB and part of our group—the kind of multiple sclerosis that progresses slowly without remissions and relapses; because then you'd need really large groups.

We've worked only with what is called progressive multiple sclerosis where you can get remissions, but they're relatively rare. And we get just as good results with progressive MS as we do with stroke. We developed a therapy for the lower extremities with just some modifications of the basic CI Therapy approach, and we get results with the leg that are just as good as with the arm. We started with stroke and then began working with spinal cord injured patients, and then patients with fractured hip who never recovered the ability to walk normally, though there appeared to be no physical reason why they shouldn't. And there are a lot more people like that than one would anticipate.

We've also worked with some other conditions where the connection with the original paradigmatic CI Therapy approach to upper extremity stroke isn't quite so apparent, but it's there. One condition is focal hand dystonia, where the person loses the ability to independently use a single finger.

GC: That happens in musicians.

ET: It tends to happen most in musicians, but also it seem to be related to writer's cramp. But, yes, it has terminated the careers of many musicians. It frequently occurs with kids in conservatories where they're frequently practicing six hours or more a day; and professional musicians don't quite practice that much. So, if you're going to get focal hand dystonia you frequently get it in the conservatory when you're a student; but not always. There are some well-known cases of professional musicians who had major reputations and came up with focal hand dystonia. And we do have a treatment for that.

GC: Would you say focal hand dystonia might be an example of the downside of plasticity?

ET: Yes. It definitely is. I've worked on this problem in Germany at the University of Konstanz with Professor Thomas Elbert and a young man who was a graduate student at the time, named Victor Candia. And the first thing that we did was look at the brains of musicians with focal hand dystonia. And we found that the representation of the fingers in the brain had fused. We used a technique called magnetic resonance imaging, but not the traditional MRI.

GC: Is your treatment directed towards getting those maps to be separated out again.

ET: It wasn't directed to that, but that's what happened. So that the ability to make independent movements with the fingers without having co-contractions of other fingers, when this had occurred and you looked at the brain again there was now a separate representation for each of the digits. It had broken apart this fusion. At about the time that we demonstrated this—which was I think about 1992, 1993—another group at NIH led by Mark Hallett and a foreign fellow named Bara-Jiminez also demonstrated this. But that was without having therapy that would break the digital representations apart.

GC: I'm going to ask you a question that might seem like it's a little bit out of left field.

ET: Those are the best kind.

GC: Yes. One of my listeners wrote to me about his son, who I think is about eight years old and had a stroke—I think it was some kind of vascular origin—and he has made some recovery. But he was asking me a question I didn't know the answer to, and I don't know whether you will. But apparently his son had a lot of damage to the area of the pons—which of course is not directly related to motor, it's a lower area—and he was wondering do we know if the pons is as plastic as other parts of the brain.

ET: Well, I don't know of any experiments that relate to the pons directly. There has been quite a bit of research on plasticity in the thalamus and the midbrain. The pons sort of wraps around the bottom of the midbrain but isn't directly a part of it. And there's a great deal of plasticity lower in the nervous system. There have been some experiments on the spinal cord.

We've worked with—this was before we were routinely doing MRIs with all of our patients—but we have worked with many patients that had so-called pontine strokes, and they recovered motor function just as well as people who had subcortical and cortical strokes. That would suggest that there was a considerable amount of plastic reorganization going on in the pons. But we didn't demonstrate that experimentally because we don't have any MRIs pre-treatment and post-treatment from the period when we were working with these people. But I would assume that there was. In terms of there being a deficit eight years after stroke –

GC: No, the little boy is eight years old.

ET: Oh. Yes. When did he have a stroke?

GC: I'm not sure that he told me that. I have another listener who said he was a year out, but as I understand it your method works many years after the stroke.

ET: Many years. There's no correlation whatever between length of time since stroke and treatment effect. The record is 50 years. We worked with a man who was 55 who had had a stroke when he was five years old. We got excellent results with him.

[music]

GC: Is there a central place that people can contact when they want to learn about this? I mean I know you're not the only one doing it now. Do people just contact you, or is there a link I can put up for people that are interested? Because I'm sure that I'm going to get a lot of people wanting to know how do they get this treatment—which I'm sure you're used to being asked.

ET: Sure. There is no central registry of facilities that offer CI Therapy. There are quite a few. I think they can be reached if you do a web search under the name CI Therapy, or Constraint Induced Movement Therapy. But many of these facilities have not been trained. As a result they get positive results but they're just one-half to one-third of what we get here. We have a training program for therapists now. We give it twice a year. And we've just not too long ago completed our fourth five-day workshop. And those people do know how to do CI Therapy. A lot of people reading the papers that we published from the laboratory decided they could do it themselves.

The problem was that this isn't traditional physical rehabilitation; there are a number of behavioral techniques which are foreign to the armamentarium of traditional therapy. Until the last two years or so we weren't even aware ourselves of how important they were, though we did them all the time—our transfer package. And we believe that this is the reason for the difference in the results that we get and the results that people who we have trained get, and people who have been and are therapists but who have not received our training.

GC: Well, I'm glad to know you're training people. I actually have quite a surprising number of listeners who are involved in aspects of therapy. So, who knows; you might get a new student.

ET: I'll be glad to email you the website address of our clinic and also of our training program.

GC: Yes, and I always have Show Notes up for every episode, so I'll put those in there.

[music]

GC: I appreciate you giving me so much of your time. Before we say goodbye I thought we might bring this down to the sort of human level by maybe talking about one particular story that is a connection between us. And one of the reasons why I decided to contact you was because I read in the book, *The Brain That Changes Itself*, about my friend Michael Bernstein's experience. Would you tell my listeners about that?

ET: I'd be very glad to. And we're very proud of Dr. Bernstein, but he is not an atypical case. To understand what happened with Dr. Bernstein perhaps I should give you a little background. Our therapy is intensive. It lasts for either two or three weeks, depending on how severe the motor deficit is.

For what we call mild moderate motor deficit we give three hours a day for two consecutive weeks—or at least, 10 weekdays during two consecutive weeks. For moderate motor deficit and for moderately severe motor deficit we usually give three hours a day for moderate, and seven hours a day for moderately severe deficit, for three weeks. And recently we've developed methods for working with people with completely paralyzed hands—plegic hands. And there it's seven hours a day for three weeks.

Now, we have chosen those times—actually they were lucky guesses at the beginning. That's what we chose to do at the beginning. And it turns out that for people with mild moderate deficits they start to level off in the middle of the second week. And so, we stop treatment at the end of the second week.

That doesn't mean that there's no potential for continued improvement, by any means. It just becomes a cost-benefit type of calculation. A therapist's time is costly. And how much is it worth to keep working with people for progressively smaller amounts of improvement as contrasted with working with someone where you can get a very rapid and large change?

The usual treatment effect that we get for people with mild moderate stroke and with moderate symptoms after stroke is on a particular measuring instrument that we use—the Motor Activity Log—they go from about 9% of the amount of use of a more affected extremity compared to before stroke, before they start CI Therapy, to 52% after CI Therapy. So, you've got a very substantial change—there's an approximate five times improvement—but it's not a cure. The people are not normal afterwards, they've just been substantially improved. Which we were very satisfied with.

For someone like Dr. Bernstein, when he came he had, I think it was moderate—what we call here grade 3—and when he left he was substantially improved but he was very far from normal. Again, I think the criterion of like 9% to 52% is about characteristic of where Dr. Bernstein was.

Dr. Bernstein is an ophthalmologist and after he had a stroke he gave up his practice. And the improvements that he made were so great that immediately after treatment he went back to his practice and he was using a microforceps with his more affected left hand, and he decided that may be he would try ophthalmic surgery again. And we tried to convince him, I think successfully, that maybe that wasn't a good idea. But he was doing ophthalmic examinations manipulating his instruments with his left hand.

But Dr. Bernstein was a very determined person, and what he really wanted to do was not just practice medicine but to play tennis. And he started to do that right away. What he would do is throw up the ball with his more affected left hand, and then stroke with his racquet with the right hand. But he was just deliriously happy that he could get back on the tennis court.

But he was just very determined, and very disciplined, and so he kept on doing the exercises that we'd had him do when he was here. And even more important, he decided that whatever he could do with his left hand he would do with his left hand. And so, he kept practicing using that hand and it got better and better.

A few months ago I was invited to a birthday party. He told me that he wanted me to come because he had a surprise. The surprise was truly surprising. He gave a concert for a half hour, and the pieces were not easy. There was a Brahms piece and some Mozart.

GC: Piano?

ET: Piano. One of the things that pianists have to learn early is to get their left hand as strong as their right hand—or at least their non-dominant hand as strong as their dominant hand. And that takes a lot of work and a lot of practice. As far as I could tell his left hand was just as strong as his right hand, and I would say that this was a dextrous performance.

Dr. Bernstein is not the only person like this. And we don't really like talk about them. We had one person who came with a mild moderate deficit; closer to the mild side. He had been a commercial pilot and he lost his license after the stroke. After CI Therapy, and then continuing to practice at home and use the affected hand, he was able to go in and take an examination and get his license back. We had one young lady who left here playing simple tunes on the violin. As a matter of fact, the person who got his license back played the piano—like "God Bless America"—very simple tunes. After the person leaves here if they will continue working hard for a year or more there's almost no limit to the plasticity of the nervous system. But you've just got to keep working on it.

GC: I have to tell you one thing. I called Dr. Bernstein to ask for his permission to talk about his story. And we were talking; and I happen to take lessons from the pro who he was with the day he had the stroke, so I had heard that story a few times. I talked to him about the piano concert. He was more proud of the fact that he's playing tennis again, I think, than anything else.

ET: Yes. Playing tennis or playing the piano.

GC: No, playing tennis.

ET: Playing tennis. Yes. I mean I'm just delighted for him.

GC: There's no substitute for motivation.

ET: There's no substitute for motivation. This is very tiring for the patients. It's very effortful. They haven't used their arm, their cortical representation of the arm has shrunk, and now we're asking them to use the arm three hours a day. And they are very tired. They've usually read something about the therapy. And we remind them they didn't come here to have a vacation. Right? And they all say, right, and laugh. It is hard work. But if you put the work in, over a period of time there's almost no limit to the amount of recovery that you can have. And this is predicated on the fact that the brain remains a very plastic instrument throughout the lifespan.

The axiom of neuroscience used to be that you have plasticity when the nervous system is immature, and after maturity that's it: you get an injury to the nervous system, it cannot repair itself; it can't reorganize. That was virtually an axiom in neuroscience with very little evidence in back of it. And that frequently happens with axiomatic beliefs. But it isn't true. The adult nervous system has less plasticity than the young nervous system, but it doesn't have none.

GC: Which means those of us who are healthy really don't have any excuse for not learning new stuff. Right?

ET: That's absolutely right. That is absolutely right. And this applies not just to movement, but also to cognitive functions. It may be more difficult as you grow older, but it is always possible with the application of an appropriate amount of effort.

GC: Dr. Taub, I really want to thank you for talking to me today. And since you are so close by at UAB I hope that someday soon we will get a chance to maybe meet in person.

ET: Oh, sure. You'd be very welcome to visit here.
GC: Well, I'm going to let you go.
ET: OK.

GC: Thank you very much.
ET: You're very welcome.

GC: OK. Bye.
ET: Bye now.

[music]

GC: I hope Dr. Taub's interview gave you a feel for what it's like to do this kind of research down in the trenches. He was describing to us over two decades' worth of his work. And I will have information in the Show Notes about how you can learn more about CI Therapy in case you or anyone you know has been affected by any of the conditions. It really does seem to offer hope for continued improvement.

As always, I'd love to hear your feedback on the episode. The best place to leave feedback is at the Discussion Forum at brainscienceforum.com. You can also send me email at docartemis@gmail.com or at the website brainsciencepodcast.com. I appreciate anyone who blogs about the podcast and puts links on their websites.

The next episode is going to be out in two weeks and it will be an interview with Dr. Maryanne Wolf whose book, *Proust and the Squid*, about the brain and reading was discussed in Episode 24. I hope that you will tune in for that interview.

I think this is going to represent several episodes in a row in which I've done interviews rather than book discussions. And I have gotten feedback that there are many of you that like the book discussions, and I am going to continue those. I'm hoping that I will be able to do one on the study of the evolution of language, maybe in February.

Thanks again for listening. I'll talk to you again soon.

[music]

[music]

Transcribed by Lori Wolfson
All errors or omissions responsibility of the transcriber