< Small Movements: New Devices Help the Paralyzed

Heard on Talk of the Nation

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July 14, 2006 - JOE PALCA, host:

This is TALK OF THE NATION: SCIENCE FRIDAY from NPR News. I'm Joe Palca, sitting in for Ira Flatow.

Mind readers are usually those guys in circus sideshows who tell you what you had for breakfast or how many coins you had in your pocket. But there's a company in Massachusetts called Cyberkinetics that's built a real mind reader.

In the current issue of the journal Nature, a team of scientists from the company and several additional academic institutions demonstrate how their device could essentially read the mind of a paralyzed man and allow him to open an e-mail and move a robotic arm simply by using his thoughts.

Several research teams are working on these so-called brain-computer interfaces. Also in this week's Nature, scientists at Stanford University report they've got a prototype system that may someday allow even more sophisticated actions.

We start this hour with the latest work on turning thoughts into action. So give us a call. Our number is 1-800-989-8255, that's 1-800-989-TALK. If you want more information about what we'll be talking about this hour, go to our Web site at www.sciencefriday.com where you'll find links to our topic.

And now let me introduce my guests. John Donoghue is the chief scientific officer of Cyberkinetics Neurotechnology Systems, and the Wriston Professor in the Department of Neuroscience and the director of the Brain Science Program at Brown University in Providence, Rhode Island. He joins me today from the studios of WRNI in Providence. Welcome back to the program, Dr. Donoghue.

Dr. JOHN DONOGHUE (Founder, Chief Scientific Officer, Cyberkinetics Neurotechnology Systems,; Wriston Professor, Department of Neuroscience; Director of the Brain Science Program, Brown University): Well, thank you, Joe...

PALCA: And...

Dr. DONOGHUE: ...thank you for having me.

PALCA: ...oh, well, it's great to have you here.

And Krishna Shenoy is the head of the Neural-Prosthetic Systems Laboratory and an assistant professor in the Department of Electrical Engineering and the neurosciences program at Stanford University in Stanford, California. He joins me today from the campus there. Welcome to the program.

Dr. KRISHNA SHENOY (Director, Neural-Prosthetic Systems Laboratory; Professor, Department of Electrical Engineering and Neurosciences Program, Stanford University): Thank you, Joe.

PALCA: So, Dr. Donoghue, let's begin with you. You were on the program the last time and you talked about a system similar to this one, or it sounds similar to this one, where a monkey was able to move a cursor just by using its thoughts. Are we talking about the same kind of machine here?

Dr. DONOGHUE: Yes, this is very much the same system, one that takes signals out of the brain, decodes them, and displays basically the output of the brain as a cursor on a computer screen.

PALCA: And how are these brain signals recorded?

Dr. DONOGHUE: Well, what we do - which I think is something that's a coming breakthrough in the way we can record brain signals - is record many cells at the same time by putting a small baby-size - baby aspirin-size platform onto the surface of the brain. And it has about a hundred electrodes, sort of hair-thin electrodes that go just into the surface of the brain and pick up the electrical impulses from neurons in the brain.

PALCA: And so this is the thing I'm curious about. So how does this differ from recording from outside the brain? What more information do you get?

Dr. DONOGHUE: Oh, you get lots more information. The impulses or the spikes that brain cells put out are really the brain's language, the messages of the brain, the details of what's going on. And from outside the brain you can listen in on sort of general brain states.

A way to think about it is, for example, if you were a hundred feet above a football stadium and you wanted to listen to a conversation, really what you'd hear is the roar of the crowd. You know that something's going on but you don't know the details. But if you had a couple of microphones you could drop into the front row, you could listen to the conversation between, say, two young men discussing what the play was all about.

PALCA: Right, but to take that analogy one step further, the cells aren't actually saying to each other, move my arm or turn the cursor to the left or something like that. So you're doing something with their output that's different from that.

Dr. DONOGHUE: Right, that's the decoding problem that both we are dealing with and the paper that Professor Shenoy has published. It's the challenging problem of taking the complex information that comes out of the brain - so it's sort of like a foreign language - and translating it into a language that we understand, one that can be transformed into a control signal that can be used to operate devices.

PALCA: Okay, well let's turn to Dr. Shenoy now. Your paper talks about something similar, but you say that you've taken this a couple steps further. Is this a refinement or a completely different paradigm that you're using?

Dr. SHENOY: Well, it is a variation on a theme and what we set out to do - and by we, I mean the wonderful students and post docs on this paper as well -Gopal Santhanam, Stephen Ryu, Byron Yu and Afsheen Afshar - we set out to systematically investigate the performance limits of these systems. In other words, how quickly, how accurately, can you select keys and how many keys you can select?

And as Professor Donoghue mentioned, we think this is important because we do need to clearly demonstrate that these systems relying on implanted electrodes can outperform those that are not implanted.

So what we did was, as I mentioned, a variation on a theme. Instead of decoding neural activity moment-by-moment and guiding a computer cursor, which is so appropriate and important for guiding real arms, we simply accrued neural information for a brief period of time, predicted where you wanted to go, and then could leap the cursor to that final destination point.

PALCA: So it's sort of like - yes, I see, sort of I know you've just knocked the ball toward the outfield, so I'm going to hit the ball - I'm going to put the ball in the outfield with my computer program.

Dr. SHENOY: Exactly. If you really, you know, if you care about moving your arm, as we so often do, out to pick up a fork and bring it back to your mouth to feed you, then you need to be guiding that motion continuously.

However, and what we were focusing more on, is if you are sitting in front of a keyboard, you really simply care about which keys you hit, how quickly you can hit them and how many keys might be on your keyboard.

PALCA: I see.

Dr. SHENOY: (Unintelligible)

PALCA: Were the monkeys in your experiment paralyzed or were they fully intact?

Dr. SHENOY: No, they were fully intact, normal, unimpaired monkeys. And a wonderful theme that appears to be emerging here both in the laboratory of Professor Donoghue and several others around the country as well as our lab, is that this is really an appropriate animal model.

One of the most wonderful and striking things about Professor Donoghue's recent report is how well the mathematical algorithms and lessons learned in intact monkeys really translate into humans that are paralyzed.

PALCA: Huh. And so the idea is that you're not just, I mean, it's not - cause what I - the reason I asked the question is, I was wondering whether there is, you know, whether a paralyzed individual would behave differently than a non paralyzed individual. Do you have any experience with that, Dr. Donoghue?

Dr. DONOGHUE: Well, we can compare what goes on in the intact monkey and in humans, and as Krishna just pointed out, it's striking how many similarities there are. Of course, you know, we're still at the early stages of looking at the differences. But the similarities mean that the advances that we're making in this non human primate model can be directly applied to the paralyzed human.

And it is striking and I think one of the important advances in the information we've gathered is that even though the brain has been disconnected from the arm for years, in the case of our patients, that the activity of the brain is still readily called up and readily modulated when there is thinking about movement rather than actual movement performed.

PALCA: We're talking about using brain signals themselves to drive computer programs which in turn drive cursors on a screen or robotic arms and we'd like to hear your thoughts. Our number is 800-989-8255. And let's take a call now from Mike(ph). Mike in Saint Louis. Welcome to SCIENCE FRIDAY.

MIKE (Caller): Hi, thanks. Yeah, I always speculated about - when I was a kid I always felt that someday we would be able to plug wires into each other's heads and read each other's minds, but more recently I've been speculation about the idea of the downloadability(ph) of visual images, and I wonder if you have any comments on that, if it's much more complex and less useful or just what you might have to say about that.

PALCA: Interesting. Maybe, Dr. Donoghue.

Dr. DONOGHUE: Yes, I think we're talking more about taking signals out of the brain rather than putting them back into the brain.

MIKE: (Unintelligible).

Dr. DONOGHUE: Right. So downloading - so in the case of removing or distracting visual images we have less experience. We do know something about the brain's code, which is quite similar in that it's these electrical impulse spikes, and we know that if we captured them we could reconstruct pieces of images, at least, that are present in the brain, but that hasn't really been done on a big scale yet.

PALCA: Do you have to - when you're recording the signals that the brain is sending out, do you have to go to a particular part of the brain to get the -for example, the movements to the arm or can you record in one spot and get the arm, the leg, the mouth, the feet, whatever?

Dr. DONOGHUE: No. The brain was one of the, you know, the advances over the past hundred years neuroscience is that we know a lot about the structure of the brain and what's called functional localization. It means that there's a place for vision and hearing and moving, and the part that's related to moving is broken up into places that are dedicated to the leg or the arm or the face, and we know exactly where to go to get information about the arm.

PALCA: All right. Let's take another call now from Jason(ph) in Cleveland, Ohio. Jason, welcome to the program.

JASON (Caller): Thank you, Neal. I have a question actually about what sort of research has there been for sensory things? I've heard - I just turned on my radio, actually. I heard that the research so far was about movement and stuff, motor skills, and I was wondering what sort of research has been done for sensory stuff because I'm deaf in my left ear and I was wondering like what sort of research was applied to that sort of thing.

PALCA: Okay, Jason. Thanks for that call. Dr. Shenoy, do you want to take a whack at that?

Dr. SHENOY: Sure. So what we're specifically talking about today really is reading signals out of the brain, but, in general, what we're really talking about are electrical interfaces with the brain, so the caller's question is quite on target, which is that we can think about in a sense writing signals into the brain to restore lost hearing or sight and in particular, the cochlear implant has been a wonderful success in restoring some sense of audition to severely deaf over the past few decades.

New systems are coming along that are attempting to write visual signals directly onto the retina or into the cerebral cortex, the outer layers of the brain, and it really is an unfolding story to see how many different types of sensory and motor and even cognitive modalities we might be able to address.

PALCA: So you think there will be a time when it might be possible to decode language, for example.

Dr. SHENOY: Well, I think that that is definitely being talked about around the community, but as John mentioned, really what we are standing on is the shoulders of many, many decades of basic systems neuroscience research that's come before us. Specifically, for us to read out how the arm wishes to move -how we wish to move our arm, moment by moment, or how we're planning to move our arm, we really are relying on wonderful research that has told us how different neurons respond. We first need to know how different neurons respond to language before we can build those types of systems.

PALCA: Okay, so we have a ways to go. Dr. Shenoy. We have to take a quick break and we'll continue talking about decoding brain signals and perhaps using them to control things. Stay with us.

(Soundbite of music)

PALCA: This is TALK OF THE NATION from NPR News.

(Soundbite of music)

PALCA: From NPR News this is TALK OF THE NATION: SCIENCE FRIDAY. I'm Joe Palca.

We're talking this hour about brain-controlled devices. My guests are Krishna Shenoy, head of the Neural-Prosthetic System Laboratory and assistant professor at Stanford University; and John Donoghue, Chief Scientific Officer of Cyberkinetics Neurotechnology Systems. And, Dr. Donoghue, I want to - I think we sort of have to step through how this BrainGate machine, or I guess it's not just a machine, it's a system…

Dr. DONOGHUE: (Unintelligible) system.

PALCA: …but maybe you can just step through it on how it goes from the patient's brain to whatever he is controlling.

Dr. DONOGHUE: Sure. In the pilot device, what you have is a sensor that's implanted into the brain and then a cable that leads out from the - really through the skin - to a cartful of electronics where the computers that process these brain signals and turn them into a control signal are located. And then that signal is then displayed on a computer screen that the individual can see this net output of their neural signals. The sensor itself, as I said, is just a small platform that comes from a cable to percutaneous pedestal. That means it actually goes through the skin and requires the cable to be attached each day when we want to record. Of course, we're aiming towards making that fully wireless, but in this version we connect the cable that goes out to this big external cart full of electronics.

PALCA: And how - I mean, the paper you present in Nature this week talks about one person, who's identified himself so I guess we can say his name is Matthew Nagel, who was injured a few years ago and his spinal cord was severed. How long does it take for someone to learn to control this system?

Dr. DONOGHUE: Well, it really doesn't take anymore time to learn to control it than it would to, say, when you get up in the morning how long does it take you to learn to control your arm to reach over and grab your toothbrush. Now, the part that does take time is building what we call a decoding filter, the translator that takes the pattern of activity that's coming out of the brain and relates it, say, to cursor motion. Now, that takes about a half an hour each day to build that translation filter when we look at brain activity and try to relate it to a motion of a cursor on the screen.

PALCA: All right. Well, let's take another call now, and perhaps we can go to Jennifer(ph) in Brattleboro, Vermont. Is that right, Brattleboro?

JENNIFER (Caller): Yeah, that's right. Actually, I'm almost to Marlboro but...

PALCA: Close enough.

JENNIFER: I had a - this is a fascinating topic, and it sounds to me - I'm wondering if when taken to its full extreme is this something that is, you know, a hundred years from now people will have chips in their brains that are wireless that can turn on the coffee pot in the morning and turn on the shower and close the door behind you and, you know, do all these little odds and ends throughout your day?

(Soundbite of laughter)

PALCA: Well, maybe Dr. Shenoy - that seems to be some of the direction that you're heading. What do you think about that possibility?

Dr. SHENOY: Well, it certainly is imaginable, however, it's important to remind ourselves and everyone that we're really strictly focused on medical devices at the present to restore a lost function. We're talking about individuals like Christopher Reeve, who are severely paralyzed, and offering them some simple sense of independence to interact with the world - control their wheelchair, turn on and off the room lights, type in a key - is really what we're after, so while we can, of course, envision a day where it might become more elaborated, that's really what we're focusing on at present.

Dr. DONOGHUE: (Unintelligible)

PALCA: Sorry. John Donoghue, go ahead.

Dr. DONOGHUE: I was just going to add, I think that, you know, the fact that the sensing requires an implant into the brain, I think that that will remain a fairly substantial barrier for the near term at least.

PALCA: But I'm wondering - maybe you can say - do you see a day for paralyzed people where this will just be a device that works around the clock and could drive a motorized wheelchair or, you know, take care of the things that someone would need throughout his day?

Dr. DONOGHUE: I think that day is coming very, very quickly. I think we're at the edge of a new era of neurotechnology where there's a whole armamentarium of devices available to physicians to interact with the nervous system. Just like the cochlear implant, which has been implanted in 50,000 or more people to restore hearing, we're going to see a range of devices like this that will be able to couple the brain to the outside world and we hope someday coupling it up to paralyzed muscles and letting people move their muscles again.

PALCA: Let's take another call now and go to Cheryl(ph) in St. Louis. Cheryl, welcome to the program.

CHERYL (Caller): Hello?

PALCA: Hello.

CHERYL: Oh, I'm in Saint Paul.

PALCA: Saint Paul. Sorry, misread.

CHERYL: That's okay. First of all, I'm on my way to one of my student's houses. I teach grade school. I'm a computer teacher, because he has cerebral palsy and he's just coming to our school and I'm supposed to be learning about his DynaVox. And I'm just fascinated that this is coming on right now, so I have two questions. Could this brain implant work - because they mentioned you can relearn - what if you've never had the ability to move your arm before?

PALCA: Oh, that's interesting. Dr. Donoghue?

Dr. DONOGHUE: Yes, that's a very interesting question. You know, the technology could potentially be available to a range of people who have a brain that can issue motor commands but that can't get them to work because their arms and legs don't work for a variety of reasons. Cerebral Palsy is certainly one of those where it's just the mechanisms that control the limbs don't work, so we don't know the answer to that. There is an enormous amount of plasticity. It might possibility take a lot longer to learn how to control a device if you've never had that experience. That's something we just don't know right now.

CHERYL: Okay...

PALCA: And your second question. Go ahead, Cheryl.

CHERYL: Well, so as a child thinks - you know, he's not going to think E-A-T. He's going to think eat. Is there a way that that idea just is transferred so that it comes out that he wants to eat then? I always wonder about this kid and other people problems when they can't get their hands. If you have an itch somewhere on your head or something that must drive you nuts. So anyway, is there a way that just simple words can come out from (unintelligible) be taught from that little thing in the brain? Ideas I guess is what I'm saying.

PALCA: Tough question, I think. Dr. Donoghue, do you want to try?

Dr. DONOGHUE: Krishna's working on it. Maybe...

PALCA: Okay.

Dr. DONOGHUE: Maybe, Krishna, do you want to start?

(Soundbite of laughter)

Dr. SHENOY: Well, we're certainly not working on reading ideas, but we are -and what John was referring to is that we are much more focused on reading out just the plans to make movements as opposed to perhaps the detailed moment-by-moment instructions that actually guide the arm. So as with a previous caller which was interested in reading out language, this particular question of reading out ideas I still think is very far in the future and would really require us to understand much better on the basic system's neuroscience front how those concepts are even working in the brain to begin with before we can start interacting with them and building systems that might read them out.

PALCA: Dr. Shenoy, it's making me wonder, how much computing power do you need to make these things work, or is it mostly figuring out what the pattern is and then the computing isn't that hard?

Dr. SHENOY: Well, it is definitely challenging on multiple fronts. Once you do have a basic idea of how individually cells or neurons in the brain are representing the information that you wish to read out, you then have to set about really writing down a computer algorithm, basically, that can interpret that neural language into the control signals that you wish to deliver to a computer cursor or an arm. And if you go through all of these algorithms and count them very carefully, as engineers are fond of doing...

PALCA: Mm-hmm.

Dr. SHENOY: ...what you find is that basic systems can be made fairly streamlined and that really is a very promising sort of finding in that what we'd really like to do is implant along with the electrodes all the computational power and the wireless systems that John mentioned so that everything is self contained.

On the other hand, at present, when you really need very flexible systems to really explore new areas, new types of algorithms, then more computational power is indeed needed and that's where the types of carts that John mentioned are currently in place, will continue to be needed for some time.

PALCA: But I'm wondering now, when you reach for something, I mean, you pick up a coffee cup differently than you pick up an aspirin, let's say, but they're still the same motion of reaching out to and grabbing. And part of the difference is your eyes are telling you something about the difference and then your touch tells you something about the weight and how much stress it is. It seems like there's a lot of steps that are incoming as well as outgoing in terms of making a system work. Dr. Shenoy.

Dr. SHENOY: Yes, that's absolutely correct. It's an enormously complex system and there are, you know, thousands of researchers working on tens if not hundreds of different aspects of that exact problem.

When we reach out, we see where that object is and have to relate that to where our arms are at, how to get your arm there, how to apply the proper force and grip and how to sense how tightly you're squeezing it. All of these things have to be understood to replicate - if that's the goal - completely natural movement.

But the near term opportunity for severely disabled patients is to simply guide an arm out to the coffee cup and grab onto it in some form and bring it back to your mouth. Perhaps you don't need to reconstruct all the fine details, in other words, to still offer a tremendously useful, you know, life-enhancing benefit to these patients.

PALCA: Let's try another call now. Oh, sorry, Dr. Donoghue, did you have something that...

Dr. DONOGHUE: I was just going to add that this problem is called sort of a closed loop problem, that is bringing sensation back into the system. And engineers are wild about making sure that the system gets feedback. It's a, you know, part of training in being an engineer.

And I think that there's some very exciting work now at the animal stage that, in fact, a tiny electrical stimulation of the sensory areas of the brain can, in fact, give rise to perceptions of touch. And I look forward to the days when that gets transformed into humans, and I think we really can close the loop.

PALCA: Let's take another call now from Ted in Jackson, Michigan. Ted, welcome to the program.

TED (Caller): Thank you. I'm a certified (unintelligible) to make artificial limbs and braces. And obviously this stuff is fascinating to me because it's the next generation of what we do. How does the direct neural interface off the central nervous system relate to a direct neural interface on peripheral nerves? Particularly, I'm thinking of amputees there. And how difficult is it to control electromotive device in terms of maybe locking in the brace for somebody with lower limb paralysis or something of that sort?

PALCA: Dr. Donoghue.

Dr. DONOGHUE: Well, of course, nothing like that has been done with a brain signal and we're still looking to refine the brain signal to make it as accurate as possible. But there are a number of people working at bio interfaces at the brain, nerve and even muscle level to try and get these commands out.

It turns out that coupling to the nerve is a pretty challenging problem. If we could get simple commands out of the nerve then we could do things like lock a joint. And there have been some exciting findings coming out of the Rehabilitation Institute of Chicago that have shown that using muscle commands, you can move an arm and do some pretty impressive things with a mechanical arm.

PALCA: Let's take another call now from John(ph) in Cameron, North Carolina. John, welcome to SCIENCE FRIDAY.

JOHN (Caller): Thank you. I was curious from a human brain to a human brain, the signal that the brains put out are they the same or would you have to re-decipher from brain to brain? And if you do, do you have to re-decipher from, say, a human brain to a monkey's brain also?

PALCA: Dr. Shenoy, I was wondering...sorry, John, you were saying? I'm sorry.

JOHN: Like, for the same action to, say, lift the arm up, is the signal the same from brain to brain or would you have to re-decipher from brain to brain that signal?

PALCA: Right. So, Dr. Shenoy, is that something - do you have to tune the system to every individual monkey that you use it for?

Dr. SHENOY: A little bit, but the big picture is that you don't. As John mentioned, this functional organizational principle means that from monkey-to-monkey, or presumably from human-to-human, you should be able to know exactly where to put the sensor.

Now, once you put the sensor there, you are certainly not able to hear or listen in on the same neurons as you might have in the previous patient or the previous monkey. But because all those neurons in that area are doing similar things within this few minutes or up to a half an hour training period that John mentioned, you can learn rapidly how each neuron is responding for desired hand movements in certain directions or at certain speeds or at certain end point locations.

And that fine-tuning or relearning is really rather straightforward it's turning out.

PALCA: We're talking about using brain signals to direct actions through a computer interface.

I'm Joe Palca. And this is TALK OF THE NATION from NPR News.

Dr. Donoghue, I wonder how far away reasonably we are from something like this coming into common medical practice?

Dr. DONOGHUE: I don't think we'll see something that's the finished end product fully restoring many, many complex actions for some time. But I do think that within a short timeframe, within a few years, we'll begin to see products available that will have substantial impact on the quality of life of individuals with spinal cord injury and other movement disorders.

So at Cyberkinetics, we hope to have something available within a couple of years.

PALCA: Okay. Another call now from Danielle(ph) in San Francisco. Danielle, welcome to SCIENCE FRIDAY.

DANIELLE (Caller): Hi, how are you?

PALCA: Good.

DANIELLE: Great. My question is about the patients that the system is practiced on. Like, how simple it is for them to just think something and have the system work for them. Or did they have to, you know, change they way they're thinking about something or what - is their delay time on a system like that?

PALCA: Danielle, thanks for that. John Donoghue.

Dr. DONOGHUE: Sure. So I somewhat anticipated this kind of question. I thought it would be best to take a quote directly from Matt Nagle that has appeared in the press the other day as this came out. And so if I can quote from a telephone interview.

He said, it was cool. After a while it was almost like I didn't have to think about it. I would just look at it and it did it.

So I think that pretty much captures what happens. It's pretty much like when we do anything. We don't think the details of, you know, grabbing onto our toothbrush or our telephone. It just sort of happens. And I think that's what happens as you begin to use this brain computer interface.

PALCA: And so it's not especially fatiguing in any way?

Dr. DONOGHUE: Well, it's no more fatiguing than it would be to use our own arms and hands, at least that's not the report.

PALCA: I see. Dr. Shenoy, maybe I'll pitch that question to you. I mean, obviously Dr. Donoghue is hoping that this goes quickly. What do you think about the timeframe before this becomes a useable technology more broadly than a few experimental subjects?

Dr. SHENOY: I think, you know, John framed it very nicely, which is to say that to restore full functionality may be many years away and that there may be some short-term opportunities. There are a few hurdles, of course, that we're all working on as a community to help assure that we're really providing, you know, considerable benefit to the patient population.

The lifetime of the electrodes, many people are working on to help extend them from a few years out to a decade or more so that there aren't repeated neurosurgical procedures that are required. And the wireless system to help escape this connector sitting on their head is another major area.

Of course, continuing to understand how well these systems can perform, which is one of our particular points of focus, so that physicians can have meaningful risk/benefit discussions with their patients. How well can you expect this to perform?

When you add all this up, I think that there's going to be an increasing number of patient segments that would drive near-term utility from what we can offer them. And hopefully that will just continue to increase through time.

PALCA: Okay. Well, I'm afraid we're going to have to leave things there. Thanks very much.

I'd like to thank my guest Krishna Shenoy. He's the head of the Neural-Prosthetics Systems Laboratory, and assistant professor in the Department of Electrical Engineering at Stanford University. And John Donoghue. He's the chief scientific offer of Cyberkinetics Neurotechnology Systems.

Thanks very much today for joining us.

Dr. SHENOY: Thank you.

Dr. DONOGHUE: Thank you, Joe.

PALCA: Thank you. And when we come back, we'll be talking about languages and saving them from a complete distinction. So stay with us.

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