Future of Health Technology Symposium

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Kevin Warwick:
The robots that are looking up there, those are the bodies of the robots that we saw but the brains of the robots are not computers. The brains are biological tissue, neural tissue that is growing. And all the neural tissue knows these as a robot. It only knows the sensors of the robot, all it does is move the robot around. So the brain is a robot, brain being biologic. But there is other research going on. From this you can get ideas as to what is possible as far as humans are concerned. Now one set of research I want to share with you, this is from John Chapin from New York and is actually taken from Korean television. …….

So what John has done is put implants in the brain of the rat in order to control the rat to move to the right, to the left from the computer. So, literally press a button on the computer and off the rat goes. So, you have to think not so much in terms of a rat here but perhaps your husband or your wife or boyfriend/girlfriend, and you can press a button. And whereas he's pressing a button, the rat goes right or left, you can press a button: stand up, sit down, fetch me some coffee, that sort of thing. So you get the idea, looking at the possibilities here. I can see that some of you see the commercial opportunities on this one anyway. And of course, some politicians already have this sort of implant in I'm told. What they've also done with the rat is put a camera on the head of the rat so they can see where the rat is going. So this is like a telly-operated rat. They can take it to a bomb or another dangerous area or weapon.

(inaudible) (Video). There are some other examples with animals. I'm not sure why it is when animals volunteer for these experiments rats always seem to be front of the queue. I'm not sure why that is. But I want to stick really to human machines, human technology links. What I've talked about so far are the possibilities of enhancement. If any of you thought that was science fiction, it's not. You'll see; stick with it, it's not. I've mentioned about five things that maybe you thought, well this is way into the future. Two of them we've already got a big tick against. It's not science fiction; it's very much science fact as you will hear. But just for a moment, rather than look at enhancement, because in some of your minds, maybe you think, well, ethically, I'm not sure about this enhancement. If I've got the extra sensory input, that's alright. But if this person next to me has got it, and I haven't, I don't know that I fancy that so much. What is perhaps clearer maybe is when we look at therapeutic uses of this technology. Some of you are familiar with this, maybe most of you, but it's just to get us into this a little bit more. What I'm going to show is a video of an individual with Parkinson's disease, and they've received the deep brain stimulator produced by MedTronics, amongst others. So what

you are going to see is the person with Parkinson's disease, how they are, and then you will see them when the stimulators are switched on in terms of the power packs. The power packs are positioned at the top of their chests, and then are wires going up to control, to power the electrodes that are positioned into the central area of their brain, all fully implanted. What you are going to see is the person with Parkinson's disease. The stimulators are switched on, and then you'll see them with purely electronic stimulation. There are two things to say here: if you haven't seen this before, this is a genuine patient who has Parkinson's disease. This is not an actor. The other thing to say is that this was originally filmed at a Christmas party and maybe some people have had a little bit too much to drink because its got some laughter at the end that might not seem appropriate. So, that's just explaining where that comes from.

(Video).

Now this type of implant has so far been very successful. A lot of people received it. The surgeons we work with at Oxford put a new one in every week. That's just one hospital in the UK. But there are a couple of problems with it. One is that it operates in open loop. It is just putting a stimulating signal into the brain; there's no feedback there. And anybody that is into cybernetics or control systems, you need some sort of feedback to regulate or provide better performance. The other is more immediate. When people have this implant, they leave it on 24 hours a day, 7 days a week. You are stimulating all the time. Hence, it overrides a lot of other effects going on in the brain. People want it on all the time because when it's on they don't have Parkinson's diseases to all intents and purposes. They can live a regular life, drive their cars and so on, in most cases. This uses up power quite considerably and after a couple of years, the person has to go back to have a new power pack to put in place which needs more surgery, and even looking at recharging devices through induction externally, it only lengthens the life of the battery such that maybe it's surgery after three years instead of two. What we are doing is working with the surgeons at Oxford to provide the next generation, we hope, of this type of implant. Just to give you some idea of what is going on, what we are doing is using what is called an artificial neural network, if you like, a computer system, an artificial brain, dependant upon how you want to look at it, to monitor what is going on in real time in the human brain in order to provide stimulation when it is needed. So what the system is doing is predicting when tremors are going to occur before they occur and is only stimulating before the tremors occur. If you like, it's trying to out-think the human brain before it does something and then stopping it doing it before it does it. The first element of it is successfully predicting what the human brain is going to do before it does it in terms of the tremors. Here are some brief plots taken from a patient's brain. What we see along the bottom line, just to see what's happening, at about the 45-second mark…the bottom line is EMG, muscular data, movement if you like, the tremors. Up to about 45 seconds, there is no movement. This is a regular person, no problem at all. What we see at the 45-second mark are the tremors. This is what all this is on the bottom plot. This is muscular movement showing the tremors are occurring. When we look at the plot above, this is local field potential from the subtholamic nucleus. This is the third plot down, the one up from the bottom if you like. If you look at that, you can see the variation, the standard deviation of the signal, is quite large, and

then at about the 45-second mark, it diminishes at about the same time the tremor start occurring. Now, our artificial neural network is sitting looking at this electrical data. If it doesn't see the mechanical data (that really happens later on), it sees the electrical data from the central area of the brain. If we look at the very top plot, what that is showing is the output from our artificial neural network. Just to be clear on what we see, at about the 45-46 second mark, you see the plot goes high and stays high. What that is doing is indicating that tremors are actually occurring. It's not predicting; it's just saying yes, we've got tremors. The network has been trained to recognize tremors. It is saying there are tremors. More importantly, at about the (this is the top plot we are looking at) 14-second mark and again at about 19 seconds, the output goes high. This is indicating that tremors are going to occur. It is some sort of prediction. If we look at the bottom plot, we can see there are a few little things. It is as though the tremors are starting to kick in but don't get going. The network is picking up on that.

Most importantly, if we look at about the 30-second mark, again there is another spike. The network is again saying something is going to happen here; tremors are about to occur. This is what we are looking at to provide what we are about. Now, a feedback loop in order to just apply the tremors at that time. It doesn't matter if we apply the signal too often to counter up the tremors; it's not a problem, but it must reliably provide it before tremors occur. That's what we're about now, applying the feedback loop and starting to test it out so that we've got an intelligent feedback stimulating mechanism rather than just this open loop stimulating mechanism. Of course, it has all sorts of other potential uses. This is for Parkinson's disease therapy; all very nice. In the future, of course, it doesn't have to be. Maybe you could put it into the brain of your husband and wife, and when you are going away for a few days, it's a sort of an anti-fancier person of the opposite sex device so that if they look at somebody else, you can predict they are going to look at somebody and TING! Stop them. No. No. It's just to point out that when we are looking at devices like this there is, perhaps, an immediate potential therapeutic use but the same technology can also be used for other purposes. So if we are looking at making some ethical decisions, therapy is ok. Enhancement, we're not so sure about. It's a very naïve point of view. What is therapy for one is enhancement for another. A device that could be developed for one thing can clearly be used for another. That is shown even more with this. This is Campbell Edd. Campbell lost his original arm due to cancer. He has been given this articulated arm but you'll see him controlling the robot arm with his left hand, his good hand. He's flipping a switch in order to control the robot hand which we've seen. It's very silly. It would be much better if he could control the robot hand directly from his brain so that his neural signals move the hand, move the arm, and when the hand touches an object, signals go back from the hand to his brain. That is really what my research has been about and is about, mainly, at the present time.

But here we have a quandary. While we can provide an interface to link the human brain and the wires of this robot arm together in a bi-directional way, ok, if this person's hand is not as powerful as our hands….well that's alright and it will help him, but what if the hand is much more powerful than we have. What if it can crush a car? Is that appropriate? More importantly, we've been hearing about the Internet. We're talking

here about brain signals not just staying within the human body or the nervous system but appearing on wires on this arm. Anybody into technology knows if you've got signals appearing there, we can send them where we like. We can send those brain signals across the internet to another continent, maybe by satellite. We're talking here about having the technology. We can have a reliable interface to have this technology so that your body does not have to be physically where it is now but by linking your nervous system to the internet, your brain signals can control not just your fingers but they can control pieces of technology on a different continent. Your body can go where the Internet takes it. Think about what that might mean.

Not only that. Maybe an infrared scent picks up some signals on a distant continent. Those signals can be passed back down onto the wires up to your brain so your senses don't have to be on your body; your senses can be wherever the network is connected to. You can have senses on a distant planet if you like.

So, my own research. This is the last big plan, so far, that I have. This is me on the operating table; two hours of neurosurgery. I'm working with a team of four consultant neurosurgeons. Two of them there. One on the left, Amjad Shad, we're working very much with at the present time. Peter Teddy, too, but Amjad very much in the next development stage. This is what I had implanted, 100 electrodes. Each electrode is 1-1/2 millimeters long, and this was fired into the median nerve fibers of my left arm. Now, the median nerves are the main bunch of nerves that run from your brain down to your thumb and your main fingers to take motor neural signals in that direction. And then if you touch your fingers, sensory information goes back up to your brain in that way. And there is also temperature and all sorts of other signals that we don't fully understand. But this was fired into my neural system. Just to be clear, I wasn't wearing this in my top pocket or anything like that. This was fired in, pneumatically into my nervous system to make a direct electrical contact. If the nerve fibers, there are about 10,000 of them, and altogether they are about 3-1/2 to 4 millimeters in diameter. I like to think mine are 4 millimeters in diameter. It's a guy thing, I guess. But 1-1/2 millimeters fired into about 4, so it's not quite halfway, to make direct electrical contact bi-directionally. So, if I move my hand, my neural signals, my brain signals could be picked up via the implant, transmitted off wherever we wanted via the Internet and also back the other way. We could pick up signals; play them down onto the array onto my nervous system to stimulate my brain.

I've got a little clip here from Discovery TV to give you some idea what we've got up to.

(Video)

Just to say if you want to find anymore of this, coincidentally today on MSNBC.com there is an interview in the video section. I'm not sure how long it will stay there. I think it was on NBC Today today as well, a brief bit. What we are doing is working with the National Spinal Injury Center in the UK and looking at could this technology be useful for people with spinal injuries. Hopefully, you can see with all of the things we are looking at there that there are two aspects to all of them, the robot arm potentially for

people who have had their hand amputated as we saw with Campbell Edd but also looking at the enhancement to controlling things like that over the technology of the internet or whatever it happens to be, the therapy enhancement aspects for both times.

Now one or two holiday snaps just to finish with if that's alright, Renata. Renata has a little daughter called Irina, and I have a little wife called Irina. I shouldn't say little. She's smaller than me anyway. Irina is fantastic; she helped with the project in many ways. Here she's wearing some jewelry that a student at the Royal College of Art put together, and the jewelry changes color from red to blue. I think you were looking earlier at wearable computing and in a way, this is one aspect of that but potentially for health purposes. So, she's wearing jewelry but it is linked to my nervous system via the implant, and there are two ways that we could potentially operate it. One, just with my hand closed, the jewelry was red; hand open, her jewelry turned blue. But on the nervous system, it was Picard earlier talking about looking at anger and stress and getting indications of those sorts of physical emotions as you could describe them, and clearly by monitoring the nervous system, you can get other signals of that time. For example if I was to go "Loud Noise" – shock. This is audience participation. Sorry if I woke anybody up or if any of you just peed yourself, I'm even sorrier. If you did, please leave now. But the point is that if I'd have been monitoring your nervous system then, clearly, we would have got distinct signals that yes, this person is shocked. That is what I was trying to point out. Excitement is another thing. If you are nice and calm, you'd get one set of signals. If you get excited, the signals look completely different. So if you can imagine that. My wife, Irina, is wearing the jewelry connected to my nervous system. When I am nice and calm and relaxed, the jewelry is blue. When I get excited it starts flashing red. So she is in her office walking around; the jewelry is blue. No problem; he's not doing anything he shouldn't. The jewelry starts flashing red…what is he doing? And more importantly, who is he doing it with? Possibilities.

This is taken at Columbia University, New York. The guys there helped put my nervous system live onto the Internet. We did the experiment with the robot hand, so I was in New York, and the robot hand was in Reading in the UK. I moved my hand in New York, my neural signals were sent across the Internet to move the robot hand, pretty accurate following by the robot hand and my hand. But, when the robot hand gripped an object, signals were sent back from fingertip sensors on the robot hand across my hand to stimulate my nervous system. So what we were doing was, as the hand gripped more and more, my brain received an increased frequency of current pulse. So the force in the fingertips was translated into an increased frequency of stimulating current for my brain. And I was able to get pretty fine control of the robot hand on another continent getting feedback from the fingertips of the robot hand.

This is one of the five things I mentioned at the start. I've got a baseball cap with Computer Associates who was one of our sponsors on the baseball cap but also ultrasonic sensors, sonar sensors, and the output from the ultrasonic sensors was fed down by the implant to stimulate my nervous system. Again, if an object came close by, my brain received an increased frequency of current pulse. Any object further away, the current pulses died away. So, with a blindfold on what I was doing was moving around

and I could detect objects. I didn't know what they were but I could detect them and, hence, avoid them. So, clearly it has a potential role for somebody who is blind, not to repair the blindness in any way but to give that person a different sense. So, it has a therapeutic purpose but also for anybody it is an extra sense, an ultrasonic sense directly. We were avoiding the normal sensory route. We weren't conducting ultrasonic signals into vision or tactile or the normal 5 sensors. We have commandeered nerve fibers and are opening a new sensory input in that sense. There are questions as to how the brain adapts to that but, certainly, ultrasonics work. Ian, the assistant, would move the board towards me and what I was trying to do was to stay the same distance away from the board using the ultrasonic signals. If he moved the board away, I was trying to follow it purely on the ultrasonic signals.

The final bit of the experiment with Irina again…what she had were electrodes pushed into her nervous system from the outside. This is something you can try tonight if you like on yourselves or if you have a friend. Whether they will still be a friend afterwards is more the question. But if you push electrodes into a nervous system, you will find it is extremely painful. We thought she was going to get some anesthetic but the doctor said no, I need to make sure I've made good contact here. So he pushed the electrode in and she screamed. The doctor said, oh, I think we've made a good contact there. We went back to the lab and linked our nervous systems together. Essentially, when she moved her hand, her neural signal that did that was sent across a network within the lab and stimulated my nervous system. So every time she moved her hand, my brain received a pulse. So we communicated telegraphically directly from nervous system to nervous system. Quite clearly I can see the next step on that research is to do it brain to brain, telegraphic communications.

Still, a few questions. It's coming clearer now but a few questions as to exact positioning and the nature of bi-directional signaling but brain to brain communication I would within the next 6 to 7 years in a telegraphic sense will be brought about. The basis of thought communication. As to how far we can go in terms of parallel signaling, and ideas, and colors, well there's research. We've got to head there. But it is a tremendously exciting opportunity. Clearly, it opens up possibilities for people with Loftin's Syndrome and patients who have difficultly communicating allowing them to communicating in a new way. But for all of us, it opens up the possibility of communicating by thought alone, ultimately, from brain to brain.

To conclude, though, a note of caution in this. Clearly, if we look at upgrading and having extra memory, if that's possibly, and extra mathematical abilities, certainly extra sensory input, communicating in new ways, maybe thinking in new dimensions, all of these are intellectually important aspects that would put cyborgs as being far superior to regular humans. So if there are those of you who feel that no, you don't want to have anything to do with these implants, fine, it's your choice. If you want to be part of some subspecies in the future, that's up to you. But as far as I'm concerned, just to conclude,

I did mention that very imminent politician Arnold Schwartzenegger earlier, and I'd like to conclude with some very profound words from him, and that is, that I have been a cyborg in the past, and as far as being a cyborg is concerned in the future: I'll be back. Thank you.

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