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The Past, Present and Future of Rehabilitation Robotics: *An Ethical View from Pioneers of the Research*

ED Note: The following is a transcript of a roundtable discussion during the 9th International Conference on Rehabilitation Robotics [ICORR] held in Chicago in June 2005. This year, for the first time, ICORR was sponsored by the IEEE Robotics and Automation Society. ICORR 2005 Proceedings are available on [IEEE Xplore](#).

[See more photographs of the latest devices demonstrated at ICORR05](#)

Participants and Titles:

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Neville Hogan, PhD (NH) – Professor of mechanical engineering and professor of brain and cognitive sciences, Professor of biological engineering, Director of the Numan Lab for biomechanics in human rehabilitation at the Massachusetts Institute of Technology.

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Tariq Rahman, PhD (TR) – PhD Head, Pediatric Engineering Research Lab Senior Research Engineer at DuPont Hospital for Children in Wilmington, Delaware and Research associate professor at Drexel University.

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H.F. Machiel van der Loos, PhD (MVH) – Biomedical Engineer at the Rehabilitation R&D laboratory at the Palo Alto VA Health Care System and Consulting professor in mechanical engineering at Stanford University. *Moderator of the RoundTable.*

William S. Harwin, PhD (WH) – Director of the human robot interface laboratory, University of Reading Department of Cybernetics.

Dudley S. Childress, PhD (DC) – Professor of biomedical engineering at Northwestern University and professor of physical medicine and rehabilitation at the Feinberg Medical School, Senior Scientist for the VA.

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Images of Rehabilitation Robotics. [All photos courtesy of the Rehabilitation Institute of Chicago] *Click on photos for larger view.*



Gernard Fulton trains on the Lokomat robot-assisted walking therapy system.



Jesse Sullivan and Dr. Todd Kuiken of the Rehabilitation Institute of Chicago. Kuiken

created the nerve reinnervation technique that makes the Bionic Arm possible for Jesse Sullivan.

A patient trains on the KineAssist robot-assisted walking therapy system (3 photos below).



JP – ICORR, this year, is being hosted by the Rehabilitation Institute of Chicago and Northwestern University. It's by far the largest ICORR that has ever taken place.

TR – ICORR, an international conference on rehab robotic, was first held in 1990 in the DuPont Hospital for Children and now alternates between North America, Europe and Asia. When it first started off, there were only 50 participants, now it's up to 350. Since then, the conference has diversified quite a bit, for it started off as rehabilitation engineering conference with a concentration on assistive devices for people with physical disabilities. Today the conference addresses not only physical rehabilitation, but it also covers therapy and brain controlled robots, which is a major development. So that is the state of ICORR today. It has changed a lot and it has diversified over the years, but it has been for the good.

JP – Now we are going to start the discussion. I'm going to defer to our incoming president and chair, Machiel Van der Loos.

MVL - There are a number of provocative questions we are prepared to talk about today as they relate to robotics and their use in society in the realm of rehabilitation. The first question is the following:

Robotics have been quite a boon to manufacturing in general in terms of increasing productivity but have "replaced" a great deal of jobs. Should physical therapists be afraid of their future livelihood or more important, what role will robots play in physical therapy in the near and long term future?

NH – First of all, this statement is incorrect because industrial robotics and manufacturing did not replace jobs. One of the reasons that robotics took such a long time to establish



themselves in the '80s was because what really happened was robotics changed the color of the workers collars. Originally you had a number of people who were blue-collar workers doing manual assembly but after the robots came, they were not displaced. Instead they were retained to become the operators of the robots. If you go and look at the history of robotics in the automotive industry you will find this to be an accurate summary. If you look at whether therapists should be afraid of the technology, unless you take a Luddite perspective, I don't see how you can be afraid of new tools. It's like a typist being afraid of computers; it doesn't make sense to me.

PD – I understand these concerns and the answer is that there is a need for rehabilitation, which is much larger than what currently can be provided. Many types of illness require intensive procedures and families/patients want to have more cycles of therapy that are intensive, every day. Therapists alone are simply not enough to do that, therefore with their collaboration, I think this requirement will be widely accepted and they will overcome their fears.

MVL –The demographics are such that the workforce is decreasing and the percentage of elderly people, who tend have more disabilities in the population, is going up. So who is going to be doing the therapy? It could be really great if a therapist can be in charge of the therapy for more than one person and use the tools, like these robots and smart exercise machines, and be able to do the physical work and required strength and so forth. And on the flip side, what does the therapist get out of it? The quantification of the interactions between the machines and the patient. The therapist gets the information “for free “if you will, for patient charts. In the whole, I think we are all looking at robots as enablers for the therapists.

HK – To some extent, robots might represent the mental piece to help therapists bring needed evidence to the field. Maybe in the last ten years there has seen a significant change from what I might call eminence-based therapy to evidence-based. That is done significantly via new tools that are used to quantify the recovery that they observe. So I don't think they would look to robots interacting with therapists as threats to their livelihood. They look to it as the other way around – what is the potential to justify what they are doing. I think this is perceived clearly by the elite users in the therapy community, which are the ones that form the opinion.

JP – There is an awful lot of intimidation here, but I don't think anyone is trying to replace a therapist with a robot. What we are trying to do is discover an entirely new use of robots that are going to expand the entire picture of therapy available for a patient. What we have is a whole new world that is yet to be fully explored.

DC – Basically, it's not just physical therapists or occupational therapists that can be

available for help around the home and helping people become independent citizens. People may not need a robot, but they may need a van and all the modifications for a physical disability or they would need it for nursing help. I think it's horrendous that if anybody ever dies of a pressure sore. I know of several people now in the past few months that have died pressure sores. That should never happen when we have technical equipment like we have today. It shouldn't even happen without the equipment, but it does. And so it goes well beyond just physical therapy or all the therapies and nursing. It also goes beyond the social element, which you talked about.

MVL – Actually, that runs nicely into our next topic that was suggested about the redefinition of the word robot, as when you talked about a van and we talked about sensors. It was mentioned in a few of the talks that this notion of the smart home environment, that a robot doesn't just look like one with arms and legs and wheels but it behaves in the sense that it takes sensors from people. The robot actually acts within its environment and improves the quality of life and the ability for a person to be independent. So the next question is:

Ethics have become a major focus for both the media and general public when it comes to biomedical advances. What are the ethical implications of the integration of robots into these various therapies or their regimes? And perhaps more important, given the directions of the advances on display at ICORR, where is the integration of components into the bodies of patients actually happening and what are the implications for man machine interfaces with diagnostic and with implantable systems?

HK – I think that technology can be used in different fashions. In our particular case, we look to this technology to help people with disabilities to cope with their environment. Very few of us would have difficulties thinking about the possibilities of using neuro prosthesis or other implantable devices to ameliorate the disabilities of our fellow citizens. Therefore, in this side of application, I don't perceive the ethical dilemma that might be extended of using the same type of technology for other objectives. But I think it is always something to be clearly defined and discussed within the rehab community.

WH - I think one thing is very often we are making up the rules as we go along because we are digging in a new area and we have to make allowances for the fact that the ethical implications that have not been fully considered. That said, I don't think that there have been any major concerns. I think we have been very responsible as a community in dealing with anything that we feel could be an unethical issue in a reasonable way.

NH - My impression is that the research community has been very careful, but I wouldn't make little of the ethical problem. My impression is that with the way people behave, a lot of the things that I have concern for is that as we continue to develop robotics and tools that work with people and treat them, making it so that the robots may become scapegoats. So there's a transfer of responsibility from the clinician who may ultimately be responsible for making decisions about the treatment to the machine. I am concerned about how people behave as groups more so than with the machinery. And that I think is a more difficult topic and I'm glad to see that some of us are actually tackling it.

WH - I think it's something we have to manage extremely carefully and I would agree with that, Neville. We're all very happy to blame computers, but in fact what we should be doing is looking at the person responsible for programming the computers. I think we need to make sure that we take the same position that it is still the person behind the system that's going to take the ultimate responsibility.

MVL - The issue is control: who defines ethical policy is actually through the thought leaders in the society we live in.

So the philosophers, religious leaders and judicial leaders and all the people who are actually defining help compromise who we are as a moral society. Therefore it's not the technologies that are pushing these solutions, it is that they are going to grow into the fabric of the society that some of live. And as such we need to understand how society has made decisions about other technologies, like stem cell research and genomics, which are hot areas of research that is exemplifying what we should be doing and what we shouldn't be doing. Robotics is going to be able to reform itself from the lessons learned from those areas. So I think we have to bring up the questions and we have partial answers based on the technology, but we don't have a lot of the culture-based answers. It's a very cool area to be working in because we have some of the tools that are going to be moving out of research into clinical practice if they haven't already, so it's a topic that we should keep open for the time being and bring other people into it to discuss some of these areas at greater length.

TR - I'm not sure where we're divorced from defining some of these issues. I think we have a role here as we develop technology and we define how you evaluate that. If you give a person with a disability a robot are you trying to make them look normal or are you trying to improve their life incrementally?

MVL - I think we do have some answers, but I think our perspectives are from the medical side and there are more pieces that need to be brought into the puzzle. And as to what constitutes normal and what does the person want to achieve in adopting the technology? Perhaps more independence or quality of life.

PD - I believe that so far as we consider just the issues of; let's say restoring the capabilities of disabled persons, most everybody would not argue or would not make any objections. But the point is the misuse of the technology. The same technology that can be used to connect the brain to some prosthesis could be used for other applications. I think we should take this as an opportunity rather than as a problem, to grow as a community. I always say that scientists, basic scientists, like physicists and biologists are used to dealing with ethical issues for decades. Now it is the turn of engineers because we are asked to consider the implications of our research, even those implications that we don't have in mind. And as it is it is a fascinating challenge for us. It is a way of growing as a community. It is a way of discussing, as we do with other communities, that we are discussing with philosophers, with physiologists with anthropologists, theologians.

NH - It seems to me that Dudley made one of the operative points that there is another side to ethics: it's not just the responsibility of those of us who develop technology, but it is the responsibility of those who deploy it. We were fortunate a couple of years ago to get to the position where in the use of the robotic tools for treatment, we had established a positive effect. We had established no additional risks. As a result, our clinical colleagues felt that they were ethically in a position where they could not deprive their patient's treatment. And I think that's another side of the development. If we can show that it works and that there are side effects, then really we have an ethical obligation to at least make it available as an option.

MVL - Fortunately, there are a number of technological domains where we can learn lessons. If you look at the automotive industry, they have developed seatbelts, ABS system and other kinds of computer-based augmenters for drivers. But these weren't immediately adopted and they did have to prove some kind of efficacy over and above

what a car provides by just sitting in a parking lot. Indeed I think sometimes the ethics of deployment almost comes out to when can you and when do you have to do it in order not to advance people's well-being and quality of life?

With robotics like the brain gate and the bionic arm that are linking people directly up to computers, in the long run who is going to control whom? Where do we draw the line between robots, computers and people? The question was how and where do we draw the line, but from an ethical view you can ask the question how do we draw the line or even do we draw the line. Do you have any comments on the bionic twist?

RW - I think that it may be based on your comments on enhancement versus augmentation for age or for disability, and where it seems to me that enhancement is viewed as a bad thing. As soon as these arms get to the point that they are better than your physiological counterpart, then that's when things will get to be very interesting. But that's still a while away.

WH - Don't you think that's really a perception thing because, not me personally but certain people go out and drive these digging machines that certainly enhance the strength of their arms, and help them to build buildings and dig trenches.

RW - I think it's the intimacy of the interface that may be a defining factor there.

WH - But where do we draw the line? I think that we have a very nice cop out position here because I think that the line is going to be drawn from a legal point of view and we don't need to deal with that. We'll let the lawyers deal with that when the question becomes a legal issue.

MVL - I don't think we can let ourselves off the hook that easily because guess who the lawyers are going to haul in as expert witnesses?

You, and all of us around this table. Our responsibility is really to do the best we can, just like all the consumer products that are out there and medical products that try to make everything as hack free as possible and with the ethical mores of the day. It might not be today, but it might be ten years from now when the issue might not be in front of us but on all sides of us.

PD - These concerns are certainly true. What I'm saying and insisting, in a way, is that through a connection between the brain and the artificial we are entering a very difficult area that, of course, we approach from a mostly technical point of view. We want to solve the problem. But we should consider again the implications of misuse. Some communities, especially in Europe, are very sensitive to this kind of argument. And it also goes to anthropological issues and the value you attribute to human beings. Of course, I personally believe that a human person should always be at the center of our technology, and so, always be empowered in respect to, for example, any bionic device. It's certain that applications can go in different directions, so we should be careful about that or at least be aware of this. I think the strong message is, so far, that many of us have been only involved with industrial robotics, engineering or prosthetics and so on. We are entering an area in which we will be forced to investigate issues that are not only technical, and I'm very happy that people are asking us. Bionics really goes beyond just rehabilitation robotics and ~ robotics in a way is even far from that. For example the question, will a robot ever be able to say "I"? This is a very basic question that people are asking us. Are you able or willing to make a robot, let's say an assistive robot, one day like in the film "I Robot"? Is this possible, is this feasible, is this desirable? Those

are, I think, are very fascinating issues for robo-ethics.

MVL - Issues of moral agency and how do you build some kind of a moral engine into your robot?

I'm not talking about bionic arms, but we're talking about personal or assistive robots where the "I" issue comes into play because then it has an identity and it has identity in our world, so these are interesting questions and ones that I think the A.I. community will be working on for quite some time. I have one final question, but I think we may have discussed much of this. What are the ethical implications of integrating things like bionic devices into people as an elective procedure? I mean we've got hip implants that send out sensor information; we have capsules that we put into our body for drug metering and people have injected RFID chips into themselves for various things. And then there are some test subjects who are living with, like the brain gate interface for months at a time. So what are the ethical implications of integrating things like this as an elective procedure? Either for enhancement or to stave off things like being able to diagnose a stroke that hasn't happened yet-- I don't know if the answers are any different than the previous ones.

HK - I'm glad that you brought this up because I was thinking about the difference between an individual decision and a collective decision. There are a lot of things that we might look and have personal opinions about when it comes to elective procedures that should be avoided, but some people prefer and decide to do it. I'm not so fully sure that we will be able, as a collective, to define the rules. I think that a lot will be coming from individual decisions, people electing to have procedures, even including augmentation, which makes it very hard for us to predict. But, I believe that it is elective procedures that would drive the ethics and not a collective decision. I think the decision makers are going to be running behind to try to legislate what is being done outside by people electing individually.

TR - We talked about enhancement, I just thought of cosmetic surgery and people are doing it in millions, they are being enhanced already. Some might have ethical dilemmas, but tons of them are doing it. We are trying to improve the function of someone that is physically lacking in something and that's a little nobler to me than maybe plastic surgery to me.

MVL - Well, I think from a nobility point of view you're right but I guess one question would be "is cosmetic surgery actually functional?"

I mean, in many cases when it's corrective, of course it is. In the cases you were referring to I think it was mostly aesthetic surgery. So it goes into, what do we do with our disposable income? But there are people who do enhance themselves with all kinds of stuff already. I guess the question is, when these things become robotic, does anything change in terms of how we need to deal with the technology or deal with the ethics of it?

RW - I guess it's kind of like steroids that have now been swamping the sports world, where people are taking these things to give them an edge and that's viewed as unfair. So going off and getting a robot implant to give you an edge one day may be viewed to be unfair as well.

NH – There may be some difference though because, to the extent that this class of technologies is or will become capable of some degree of autonomous behavior. There are things like sequences of action; normally we would associate it with somebody's will

or somebody's decision. But now, the explanation would be "no it wasn't me who decided that, it was the robot who decided how I would walk or how I would turn." I think that gets you into a slightly different area than using augmentative chemicals or any type of those things. And I don't know how that will be dealt with, but there may be a qualitative difference.

DC – I'd just like to say that working with people who have artificial hands and arms prosthesis, many of them are quite interested in their appearance and they classify the appearance as a function. Though I don't particularly share this view, appearance is considered to be a function by many people with disabilities.

MVL – Well, I guess it certainly is a function if you look at the broader picture of quality of life. I think for all of us, even for people who do elect to have cosmetic surgery, they live better lives presumably as a result of it, so in some sense that quality of life is important for one's functioning in today's world. So, I agree with you from that point of view anyway.