Reassessing myoelectric control: Is it time to look at alternatives?

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"The future is bright for myoelectric prostheses", proclaimed a 1985 review on the subject.[1] "Progress in the next five years will exceed all past accomplishments [and] artificial elbows and knees, under natural control of the human, will become commonplace", said a 1977 review.[2] But has the second prediction come to pass? There are those who assert that it has not.

From the time of its arrival on the rehabilitation scene, some 20 years ago, myoelectric control has been presented as a tremendous success story in the making. "Myoelectric control was so exciting when it first came out", recalls Micheal D. O'Riain, PhD, director of rehabilitation engineering at the Royal Ottawa Regional Rehabilitation Centre. "It seemed such a simple thing, that you could tap right into [the neural signals to] muscles that were no longer functional. All you had to do was train the person to make coordinated muscle contractions and it would become automatic." So promising was it, in fact, that the ultimate success of the new control strategy was taken for granted. Consequently, says O'Riain, efforts were focused on refining the technique "rather than examining whether or not it was a good idea in the first place".

Has myoelectric control made that much of a difference?

The first myoelectric prosthesis was developed in Germany in the early 1940s. A decade later the concept was being "rediscovered" in England, the Soviet Union and the United States. The "Russian hand" became the first somewhat practical myoelectric limb to be used clinically; it was built under licence in Canada at the Rehabilitation Institute of Montreal during the 1960s. Later the Montreal institute and the Bioengineering Institute at the University of New Brunswick, Fredericton, were among the first in North America to develop their own myoelectric mechanisms. By 1967 myoelectric hands had become commercially available,

O'Riain: using an intact joint to give the position proprioception lacking in myoelectrically controlled prostheses.

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and 10 years later they had achieved some measure of clinical importance.[3]

A lot of people who work in the field do think that myoelectric control is a good idea. Their surveys show that people prefer myoelectric limbs over conventional harness-driven prostheses, feeling perhaps that the electric hand is more nearly a part of them.[4] But O'Riain contends that this preference is really based on good cosmesis rather than usefulness; what is made to look like a hand, he points out, is in reality pincers covered by a skin-resembling glove, which clumsily gets in the way when there is work to be done. "Myoelectric hands are probably the least functional prostheses [and] are used simply because there are people who will not wear hooks."

Any prosthesis, conventional or state of the art, is likely to seem heavy and cumbersome to the wearer. Prostheses are noisy and limited in what they can do; it can take five times longer to do something with the myoelectric hand than with the normal hand.[5] If a person still has one good arm he may well prefer to use it instead of the prosthesis, no matter how awkward this may be. "I've seen above-elbow amputees who just decide they're going to go around without an arm", says O'Riain. "Myoelectric control has not made all that much of a difference." He says that even people providing myoelectric limbs would admit that the majority of the people they fit ultimately reject the limbs.

And yet O'Riain was initially 100% behind myoelectric control and laughing at the early sceptics. He first became involved in myoelectric research at the University of New Brunswick in the early 1970s. But while there he began to see that few above-elbow prostheses were being used. He later went to Montreal, where he was further disturbed to discover that prosthetists were strangely indifferent to fitting above-elbow myoelectric devices. He recalls his gradual disillusionment: "It was slow, but I began to think that maybe the people who had sensed that myoelectric control wouldn't work were right."

It was while O'Riain was in Montreal that he first made a careful study of a paper by D.C. Simpson,[6] of Edinburgh, that made a lot of sense to him. With great clarity Simpson explained that while a prosthesis for the complete arm must necessarily be an intricate machine with a great many separate axes of motion, the continuous conscious control of even two such "degrees of freedom" is a fatiguing challenge to the person's intellect and powers of concentration. O'Riain says that with myoelectric control the person ends up having to look at where the hand is. This can be done, but having to consciously steer an artificial limb is a considerable mental load.

O'Riain acknowledges that myoelectric hands do work for people with below-elbow amputations but explains that this is because with an intact elbow the person already knows where the hand is; however, when the elbow is artificial and the person uses myoelectric control to position the hand in space, there is no feedback: "It is totally open-loop."

Closing the feedback loop using other joints

There have been many attempts to provide the person who has a prosthesis with feedback, mainly through various forms of cutaneous sensation. That may be suitable for appreciating how strongly a myoelectric hand is gripping something, O'Riain says, but it does not provide position sense. The obstacle, as explained by Simpson,[6] is the need to present moment-to-moment information about artificial-joint angles to the central nervous system. Says O'Riain, "We cannot by stimulation of skin or nerves give the same sensation as you get from the positions of your own joints". Simpson drew a parallel between these substitutes for proprioception and "the long list of unsuccessful, electronic aids for the blind [that give] information in an *unnatural code*", which he contrasted with "the acceptance of the long stick".

Simpson saw the stick as a mechanical extension to a natural system, with the brain using proprioceptive information from the distal joint to accurately tell the blind person where he is making contact with the environment. He applied this principle of extension to the design of a control system for artificial limbs. In his system, movement of an intact joint is translated through harness cables and gas-powered actuators into motion of the prosthesis. The proprioceptive knowledge of clavicle position is used, movement for movement, to activate the prosthesis and to represent its position. This technique has unknowingly been used all along with conventional prostheses, whose movement is governed by a harness that measures rounding of the shoulders. Simpson, however, is generally credited as the first person to recognize the importance of feedback and to use the term "extended physiological proprioception" (EPP).

To keep the shoulder movements from outrunning the capacity of the prosthesis, Simpson installed a cable that constrained the shoulder. While the harnessing required to measure joint movement in EPP is a step backward from the self-contained, self-suspending prostheses made possible by myoelectric control, the method should allow movement comparable to that of the natural elbow and wrist.[7] Simpson's Unbeatable Servo, says O'Riain, "is a very elegant system".

What Simpson is doing with EPP, O'Riain says, "is closing the loop using other joints. At the moment this is the most perfect way of doing it. The absolutely perfect way would be to feed into the sensory nerves using the proper codes. . . . If we learned how to do that, then EPP would overnight become irrelevant." But neither the codes nor the means of appropriately stimulating the proprioceptive nerves seems within our grasp.

O'Riain doesn't believe that people will learn how to transmit proprioceptive information to the sensory nerves in the foreseeable future. In the meantime, workable prostheses have to be supplied.

Can the brain handle the flexibility the microprocessor offers?

While still at the Rehabilitation Institute of Montreal, O'Riain decided that Simpson's concept should be taken further. With funding from the Natural Sciences and Engineering Research Council he and colleague David T. Gibbons, PhD, came up with a proposal to replace the cable-operated control mechanism with a microprocessor.[8] This, they saw, would free their device from the rather limited range of motion imposed by the fixed 1:1 relationship that was the key to Simpson's system. By programming the microprocessor they could create the best possible linkage between shoulder and prosthesis movements for each person and for each task. What is more, the person would be able to change the linkage by flipping a simple electric switch. "We can store several input/output relationships in our microprocessors", says O'Riain. He envisages one setting for general activities and others for repetitive actions, such as eating at a table and working on an assembly line.

Some people, says O'Riain, have misunderstood what he and his coworkers are doing and charge that they are fitting people with robots. But he insists that they are not providing preprogrammed movements: "We are programming an input/ouput *relationship.*"

The microprocessor would also be used to implement Simpson's Unbeatable Servo concept by warning the user with a vibratory stimulus that the shoulder is moving too fast or too far for the artificial limb.

Shoulder flexion, extension, abduction and adduction would be measured by electrogoniometers instead of cables. O'Riain recognizes that there are advantages inherent in Simpson's gas-powered actuators but for practical reasons intends to use electric motors in the prostheses for movement. He favours the use of a myoelectric signal to control the prehension of a hand or hook, because feedback as to the gripping force can be provided satisfactorily.

Simpson's work established that a single 1:1 relationship can be learned, but O'Riain doesn't yet know for sure whether people with prostheses can handle up to eight, as he is prepared to offer with a microprocessor. "A single linkage will give very good performance. With two the person will be able to do more, but he will lose something. Does he gain more than he loses? . . . There is a danger that the brain may not be able to adapt. . . . We have spoken to experimental psychologists and they are not sure either."

O'Riain's work on EPP was interrupted in 1981. In 1984, when both he and Gibbons had joined the Faculty of Engineering at the University of Ottawa, they resumed their collaboration. PhD student Sebastien Philippe-Auguste will make the problem of multiple linkages a major part of his thesis.

EPP becoming a recognized alternative

O'Riain and his associates have constructed bench-top prototypes of their prosthesis and have carried out tests with the device strapped to the side of a normal arm. They plan to proceed with programming the microprocessor and ultimately will build a complete artificial limb.

"Nobody can yet simulate position proprioception other than by using the position of another joint", reiterates O'Riain. "We started in 1979, at a time when people were very, very sceptical. Now they are coming around to the idea of using body movement instead of myoelectric control." He points to recent articles and events showing a shift away from absolute reliance on myoelectric control but notes that most researchers have had difficulty rationalizing why it wouldn't work. It seems that the fundamental problem has been obscured by the mechanical — and presumably correctable — drawbacks common to all prostheses. Simpson was first to see the need for extended physiological proprioception, O'Riain says, but Simpson "had the advantage of never having used myoelectric control".

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