CONTROL WITHIN A VIRTUAL ENVIRONMENT IS CORRELATED FUNCTIONAL OUTCOMES WHEN USING A PHYSICAL PROSTHESIS

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CENTER FOR BIONIC MEDICINE
• 4 interrelated labs
• ~15 people
  • Clinicians
  • Scientists
  • Engineers
  • Students
• Focused translation research
  • Prosthetics
  • Orthotics
  • Exoskeletons
SPECIAL REPORT

A Russian Bioelectric- Controlled Prosthesis:
Report of a Research Team from the Rehabilitation Institute of Montreal

E. DAVID SHERMAN, M.D., F.A.C.P.,* Montreal
Direct Control: Intuitive to control when electrodes can be placed on physiologically appropriate agonist/antagonist residual limb muscle pairs. A mode switch (co-contraction, force sensitive resistor, etc) is required to control more than 1 degree of freedom.
There are many flavors of amplitude based control that typically rely on one or two strategically placed EMG sensors. Prosthetists have been very successful in combining these approaches with switches to create functional control systems for patients.

**Myoelectric Mode Switches**

![Myoelectric Mode Switches](image)


**Three State Control**

![Three State Control](image)

L. Philipson, BPK, 1981
Control Limitation: Current commercially available arm systems have more degrees of freedom than can be reliably controlled using direct control methods.
Experience with Swedish Multifunctional Prosthetic Hands Controlled by Pattern Recognition of Multiple Myoelectric Signals

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Pattern Recognition: Does not require placement of electrodes or agonist/antagonist residual limb muscle pairs and eliminates the need for mode-switching. However, it does require algorithm training and currently limits to learned sequential control.
Prostheses Construction
- 2 DOF Wrist prototype from Otto Bock
- Michelangelo Hand

Outcomes
- SHAH, Clothespin Relocation Test, Box and Blocks, and a customized "Middle"
- Testing completed pre and post a 4 week home-trial

Control
- Pattern Recognition Control

Subjects
- 3 Transradial non-TVRK

Funding: NIH, (1R01 HD 058000-01)
Key Point: 1) **Patients have improved outcomes after 4 week home-trial.**
2) **Pattern recognition control outperforms direct control after the home trial.**
Targeted Muscle Reinnervation (TMR)

Brain Machine Interfaces

Peripheral Nerve Interfaces

Targeted Reinnervation
**Targeted Muscle Reinnervation (TMR)**

1. Doctors redirected the nerves to the patient's chest muscles.

2. When the patient thinks about a specific movement of the arm or hand, the nerve impulse travels from the brain to a corresponding location on the muscle.

3. Electrodes — fixed to the harness worn on the shoulder — detect electrical impulses emitted from the nerves and forward them to the arm.

4. A computer processes the electrical impulses and makes the arm perform certain movements, such as flexing the elbow, opening and closing the hand, and extending the elbow and wrist.
**Targeted Muscle Reinnervation (TMNR)**

**TECHNIQUE**
- Residual nerves transferred to spare muscle and skin.
- Muscle acts as a 'biological amplifier' of the motor command.

**ADVANTAGES**
- Additional control signals for simultaneous control of more DOFs
- Control signals are physiologically appropriate
  - More natural feel
  - Easier, more intuitive operation
- Shoulder still available for controlling other functions
- No implanted hardware required
- Can use existing myoelectric prosthetic technology
- Pattern Recognition Control is possible

**DISADVANTAGE**
- Requires additional surgery (unless it is done at time of amputation)
Objectives
- Determine if virtual reality presence correlates with physical presence in lower-limb transhumeral amputees.

Prosthetic Construction
- Boston Digital Elbow
- IV Motion Control Wrist Rotator
- Single DOF terminal device

Control
- Direct Control system equivalent to their daily use prosthesis
- Pattern Recognition Control

Outcomes
- SHAFT, Clothspin Relocation Test, Box and Blocks testing pre and post a 8 week home-trial.
- Assessment of Capacity for Myoelectric Control (AGMC testing post home-trial).
- Pre and post virtual environment testing using the Target Achievement Control Task.

Funding: CDIMRP, (W81XWH 12-02-0072)
Innovative gel liner interface

- Embedded electrodes, lead wires, and amplifiers

Magnetic Electric Interface (MIEI)

- Polarized magnet orient the limb when donning
- Latch is engaged to ensure robust electric connection
**Target Achievement Control (TAC) Test**

- Control a virtual limb to various target postures and maintain the target for 2 seconds

**Outcomes**

- Number of targets successfully acquired (Completion Rate)
- Time to acquire and hold the posture (Completion Time)
- How much the virtual limb moved when acquiring the posture (Path Efficiency)
**Key Point:** 1) Patients have improved outcomes using both virtual and physical prostheses post a minimum 6 week home-trial.
• The ACVIC is a validated outcome measure. Scores higher than 37 have been suggested as being appropriate for myoelectric control users.
• Significant (p<0.05) strong correlation between ACVIC and TAC Test completion time.
Virtual Reality Training Applications for Improved Control

- We have shown users become more proficient using their prosthesis after using it in their home environment.
  - Improved muscle strength and endurance
  - Capability to make more distinct contractions
  - Better understanding of the limitations of their prosthetic limb
  - Development of compensatory strategies to come complete functional activities
Current Commercially Available Tools

- Focused on providing assistance with initial fitting to the patient
- Developed for in-clinic based use
- Manufacturer specific
- Not engaging enough for long-duration use
**Consumer Virtual Reality**

- Highly immersive
- Some are capable of positional tracking (e.g., Oculus Rift, HTC Vive)
- Some are mobile (e.g., Google Daydream, Samsung Gear)
- Relatively inexpensive (<$1,000)
Emerging Research Systems

• IViyo armband coupled with IViobile phone

• IViyo armband coupled with immersive VR
Virtual Coach
• Center for the Intrepid
• Carnegie-Melon University
• Shirley Ryan AbilityLab

Funding: CDL-RP, (W81XWH 12-02-0072)
Virtual Coach—Immersive HTC Vive Experience

A: Silicone Gel Liner
B: Magnetic Locking Connector
C: Battery Powered Myoelectric Decoder
D: HTC Vive Connector Mechanism
E: Commercially Available Vive Controller

**PROS:**
- Extremely engaging
- Wide variety of games available (first person shooters, job simulators, etc)
- Positional tracking of body and limb

**CONS:**
- Not all games are suitable for use
- Requires empty space to configure play area

Funding: CDIRRP, (W81XWH 12-02-0072)
Virtual Coach—Customized Training Environments

Funding: CDIRbP, (W81XWH 12-02-0072)
The VR application can communicate seamlessly with the embedded controller inside the prosthesis.

Effectiveness of the virtual training can be tested immediately with the prosthesis.

Funding: CDMIKP, (W81XWH 12-02-0072)
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