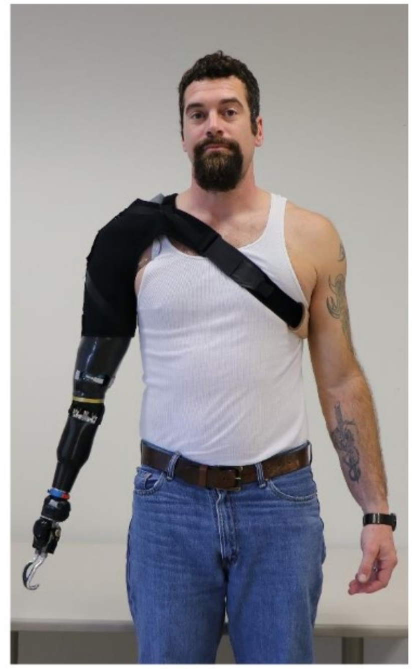
The future of RIC Rehabilitation Institute of Chicago | Shirley Ryan AbilityLab

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

LEVI HARGROVE, PHD
CENTER FOR BIONIC MEDICINE

- 4 interrelated labs
- ~75 people
  - Clinicians
  - Scientists
  - Engineers
  - Students
- Focused translation research
  - Prosthetics
  - Orthotics
  - Exoskeletons



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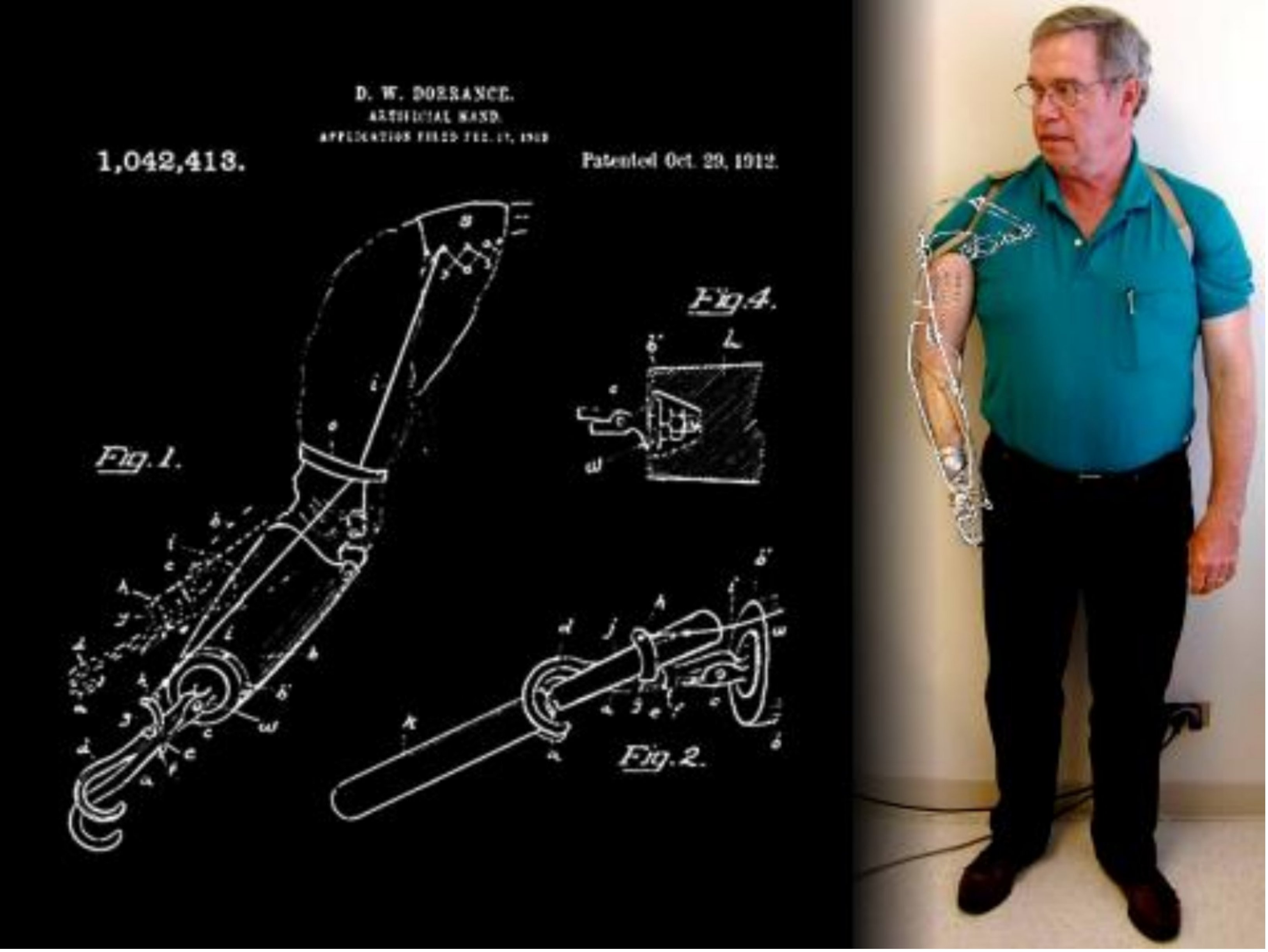
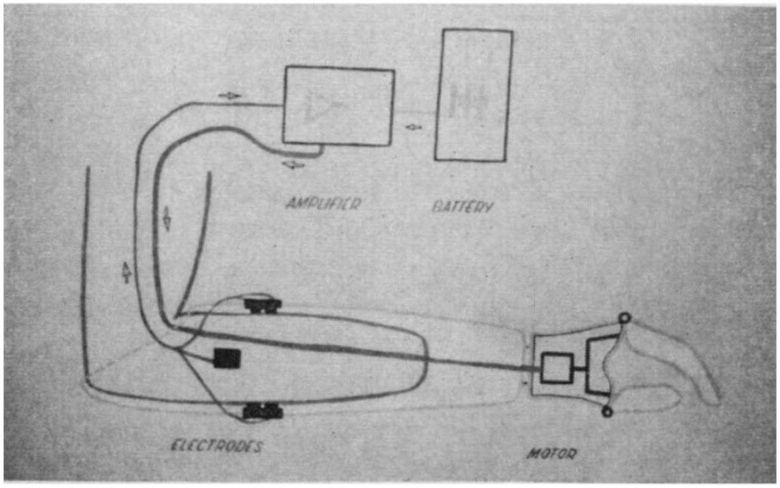

D. W. DORRANCE.
ARTIFICIAL HAND.
1,042,413.
Patented Oct. 29, 1912.
Fig. 4.
Fig. 1.
Fig. 2.

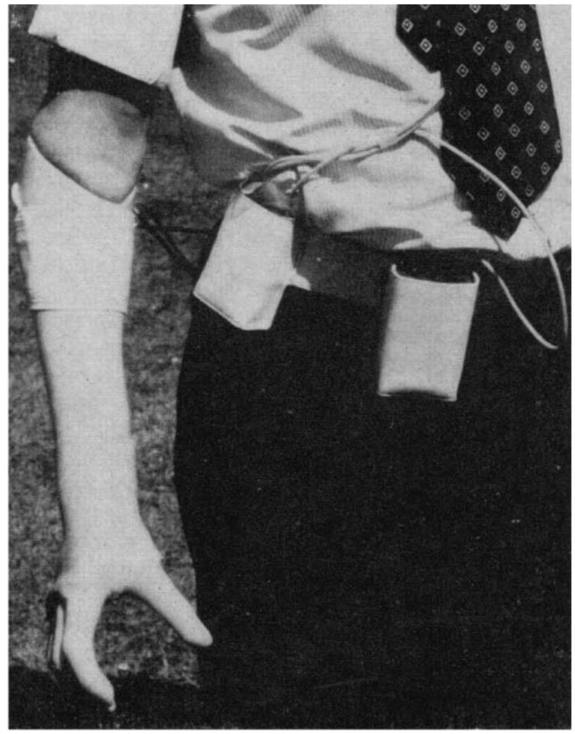


SPECIAL REPORT

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*



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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.

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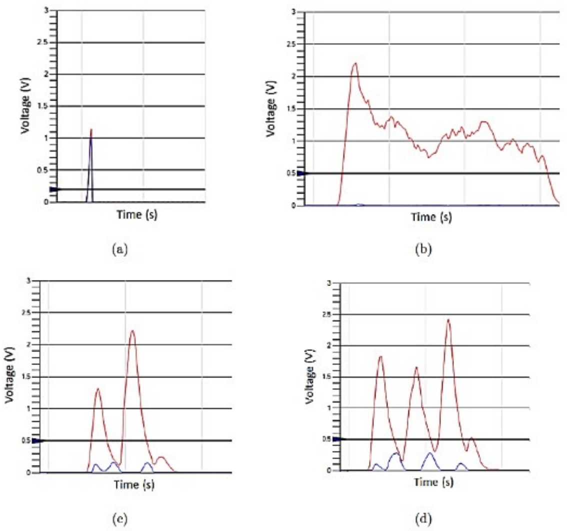
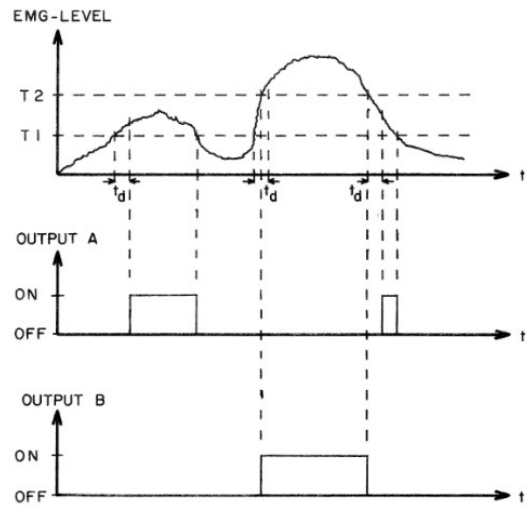
There are many flavors of amplitude based control that typically rely on one or two strategically placed EMG sensors. Prosthetists have been very successful in combining these approaches with switches to create functional Morse-Code control systems for patients.

Myoelectric Mode Switches



M. Vilarino, The Academy Today, 2015

Three State Control



L. Philipson, BPR, 1981

Commercially Available Arm Systems

<u>Control Limitation</u>: Current commercially available arm systems have more degrees of freedom than can be reliable controlled using direct control methods.

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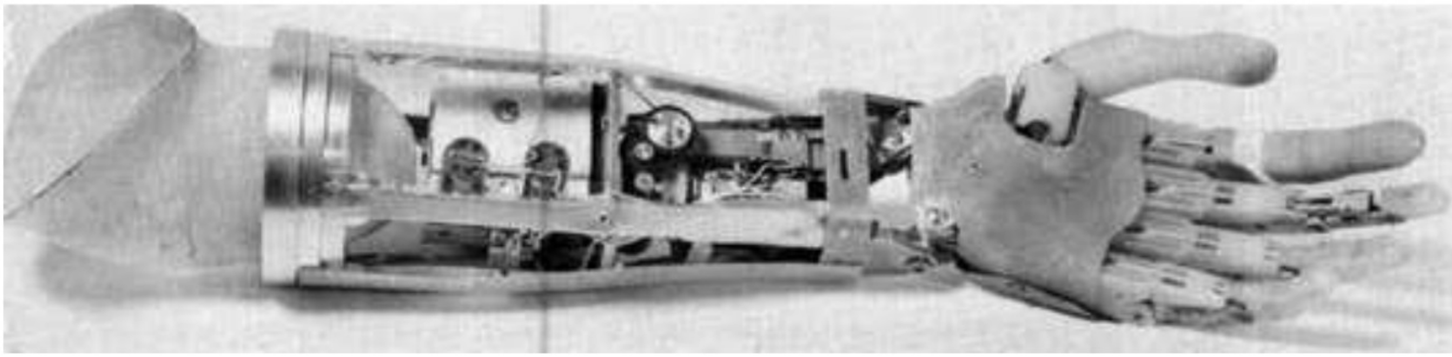
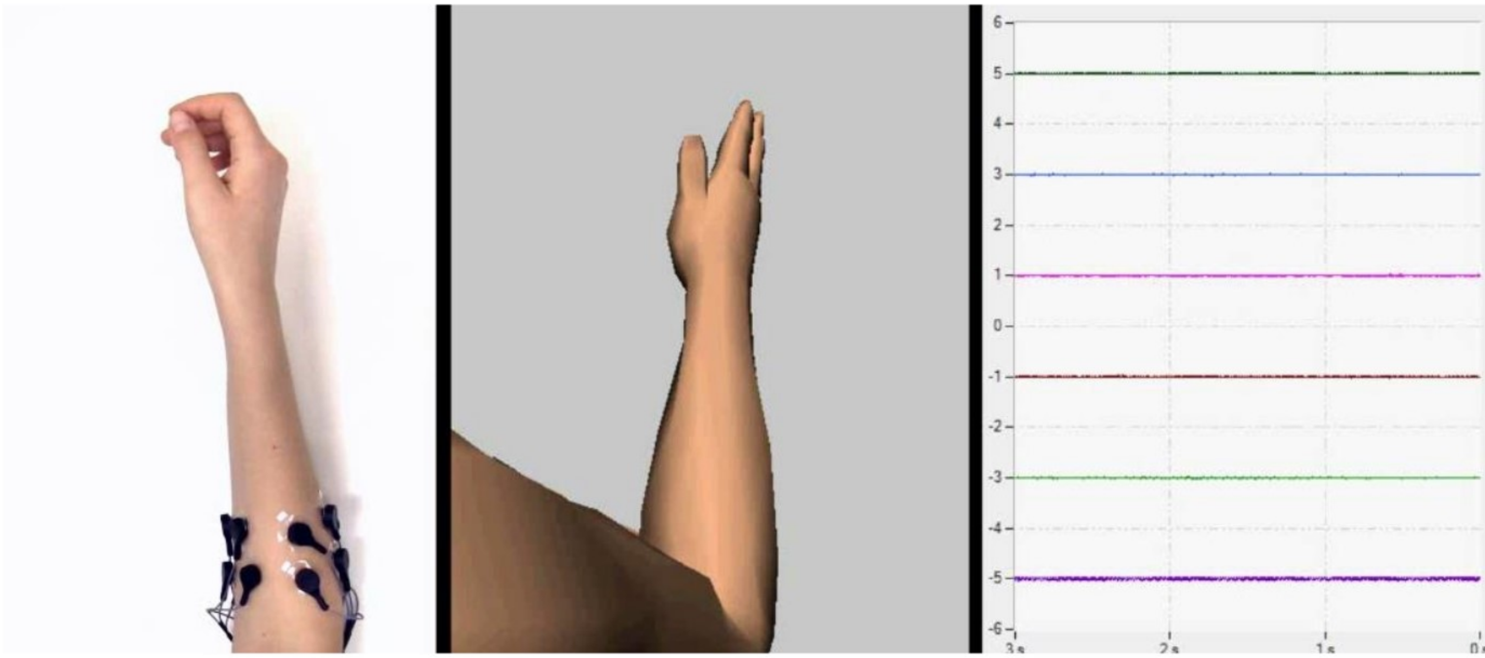
Experience with Swedish Multifunctional Prosthetic Hands Controlled by Pattern Recognition of Multiple Myoelectric Signals

C. Almström[1], P. Herberts[2], and L. Körner[2]

[1] Department of Applied Electronics, Chalmers University of Technology
[2] Department of Orthopaedic Surgery 1, University of Göteborg, Göteborg, Sweden





Pattern Recognition: Does not require placement of electrodes of agonist/antagonist residual limb muscle pairs and eliminates the need for mode-switching. However, it does require algorithm training data and currently limited to learned sequential control.

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Prosthesis Construction

- 2 DOF Wrist prototype from Otto Bock
- Michelangelo Hand

Outcomes

- SHAP, Clothespin Relocation Test, Box and Blocks, and a customized Cubbie Test
- Testing completed pre and post a 4 week home-trial

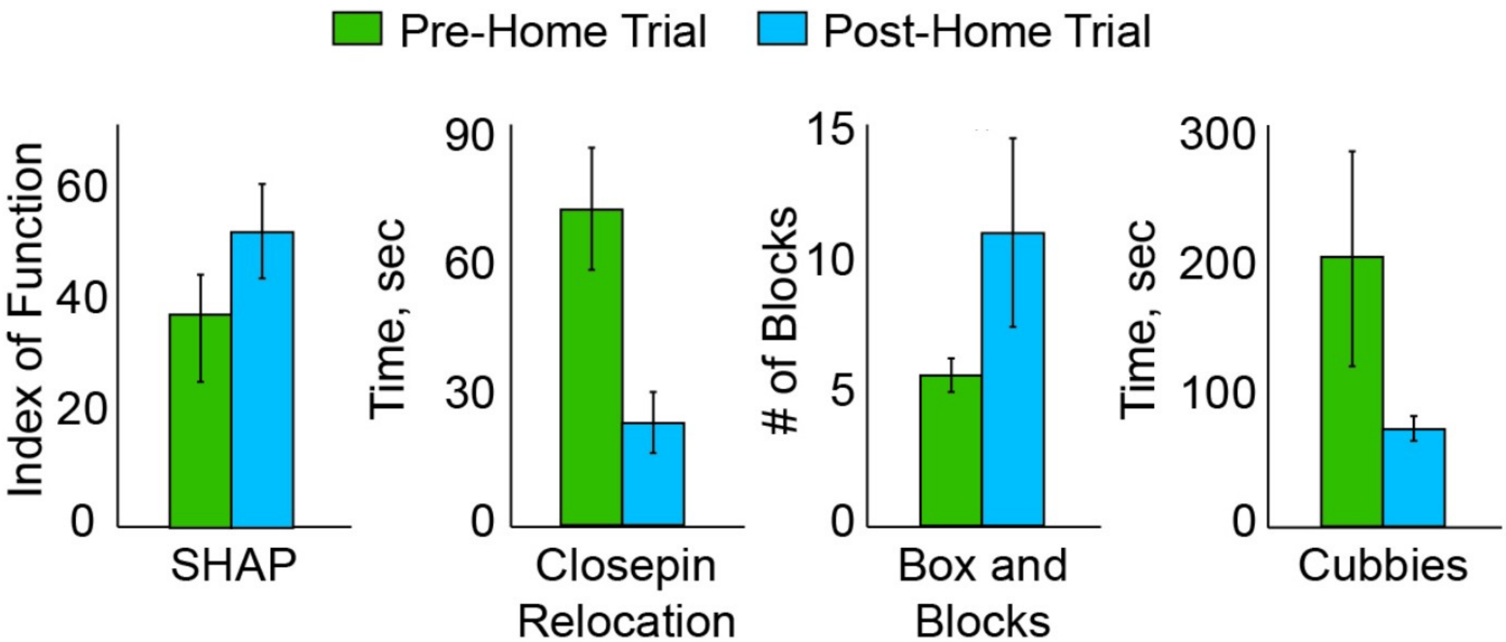
Control

- Pattern Recognition Control

Subjects

- 3 Transradial non-TMR

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.

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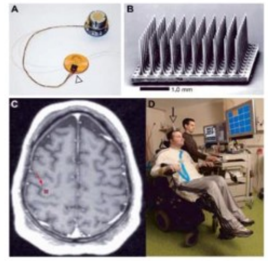
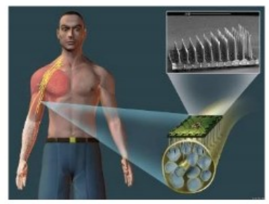
Targeted Muscle Reinnervation (TMR)

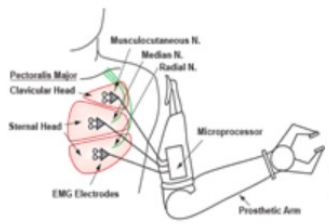
Invasiveness



Brain Machine Interfaces



Peripheral Nerve Interfaces



Targeted Reinnervation

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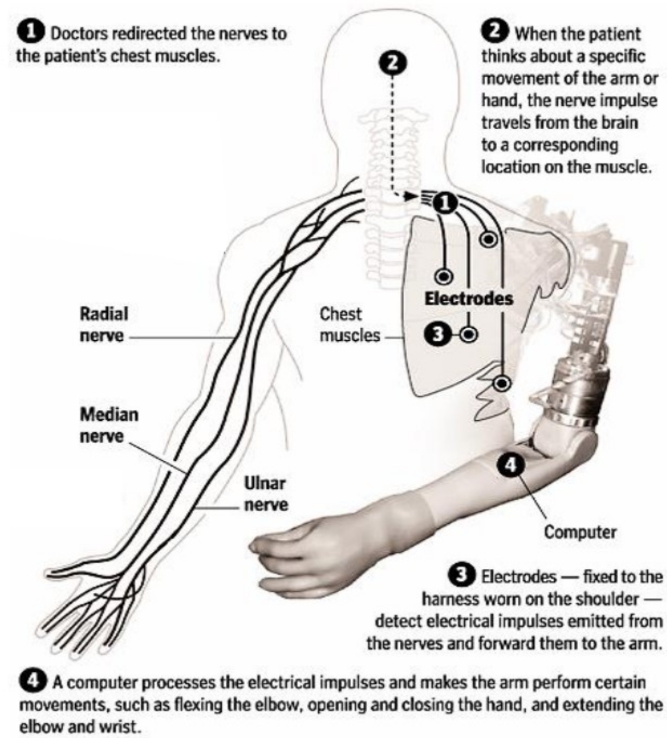
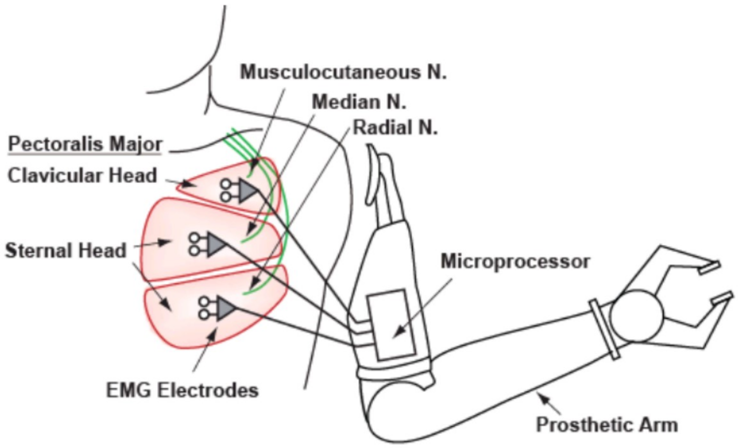
Targeted Muscle Reinnervation (TMR)



Targeted Muscle Reinnervation (TMR)

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)

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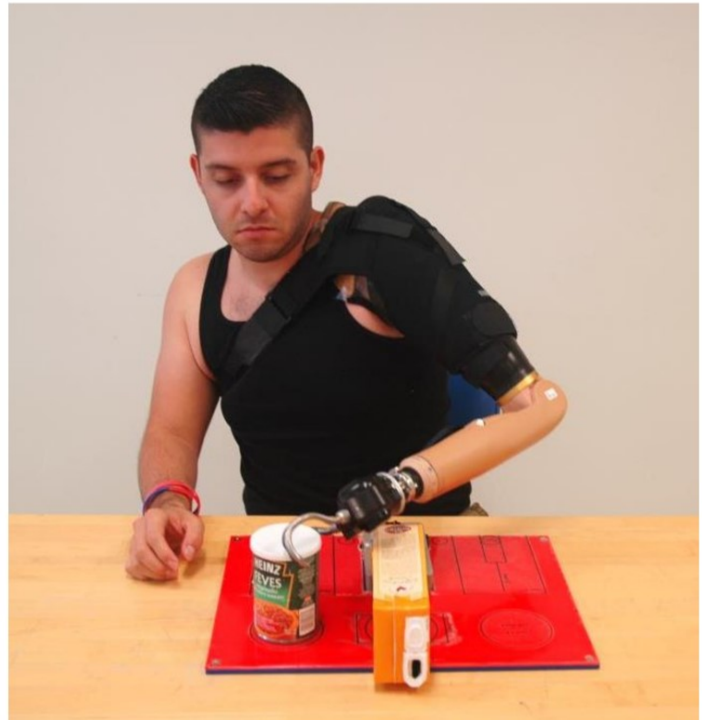
Objectives

- Determine if virtual-reality assessments are correlated with physical prosthetic usage in TMR transhumeral amputees.



Prosthesis Construction

- Boston Digital Elbow
- Motion Control wrist rotator
- Single DOF terminal device

Control

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

Outcomes

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

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

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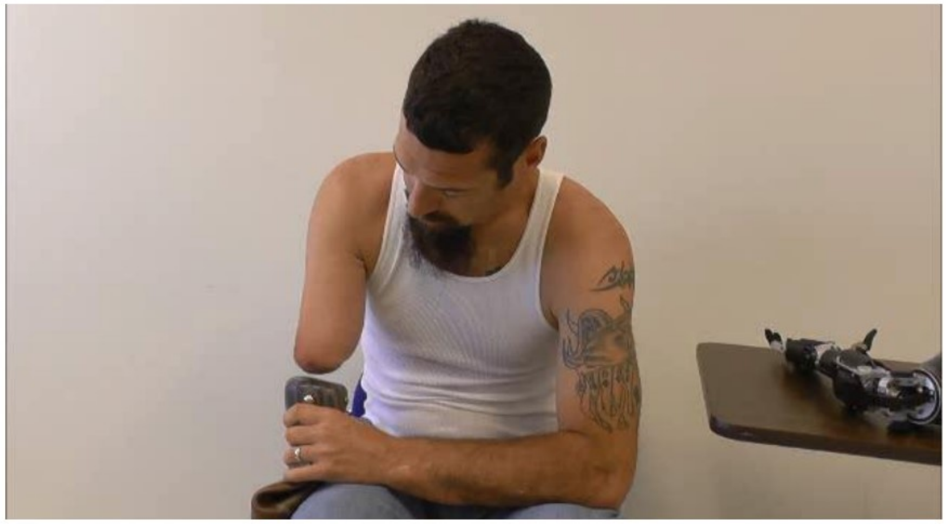
Innovative gel liner interface

- Embedded electrodes, lead wires, and amplifiers



Magnetic Electric Interface (MEI)

- Polarized magnet orient the limb when donning
- Latch is engaged to ensure robust electric connection

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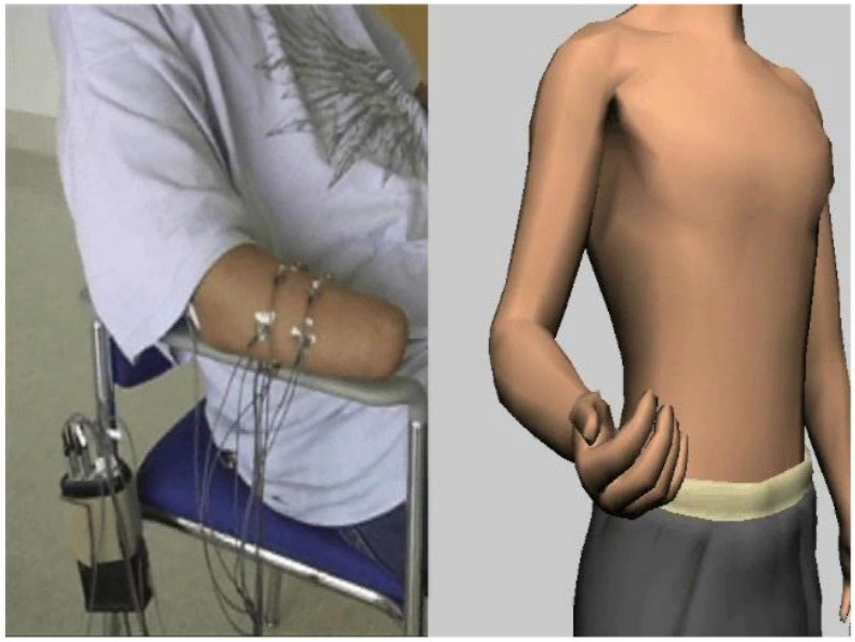
Target Achievement Control (TAC) Test

- 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)



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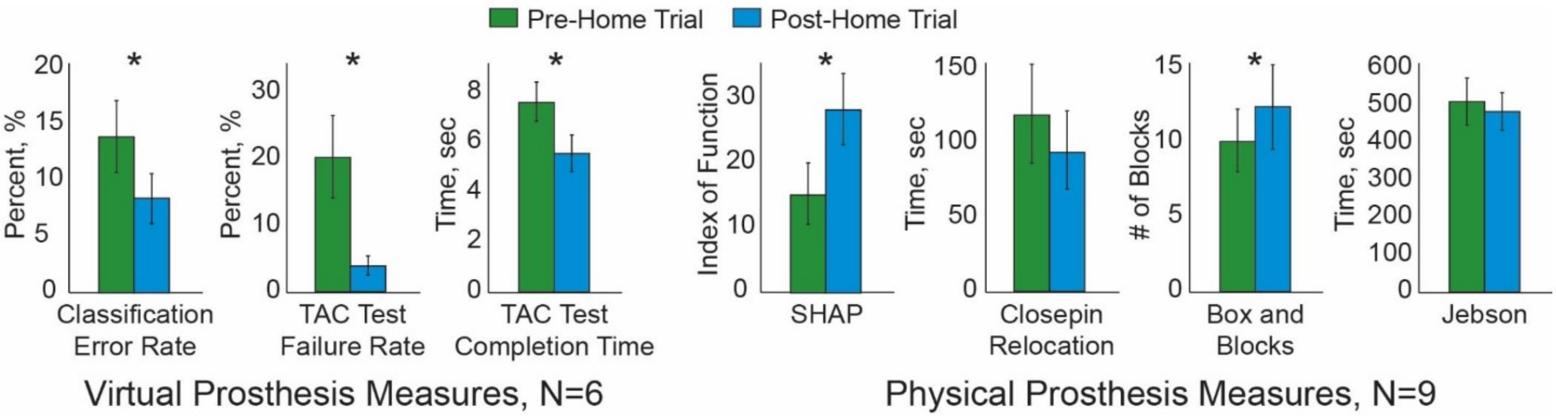

Key Point: **1) Patients have improved outcomes using both virtual and physical prostheses post a minimum 6 week home-trial.**

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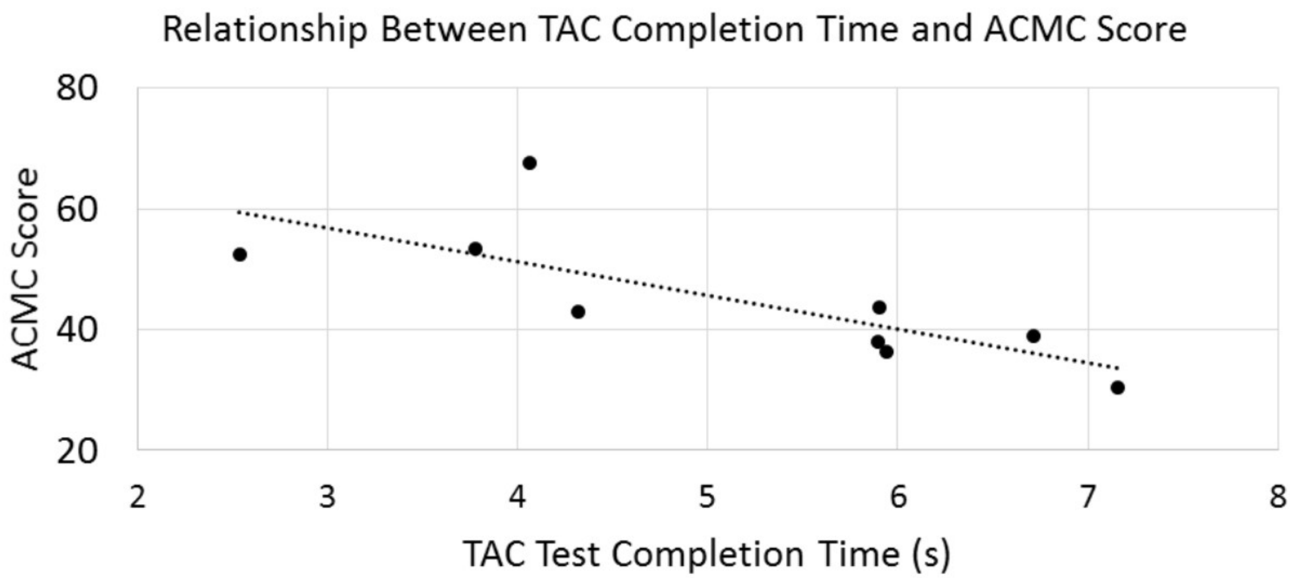

- The ACMC is a validated outcome measure. Scores higher than 37 have been suggested as being appropriate for myoelectric control users.
- Significant ($p<0.05$) strong correlation between ACMC and TAC Test completion time.

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

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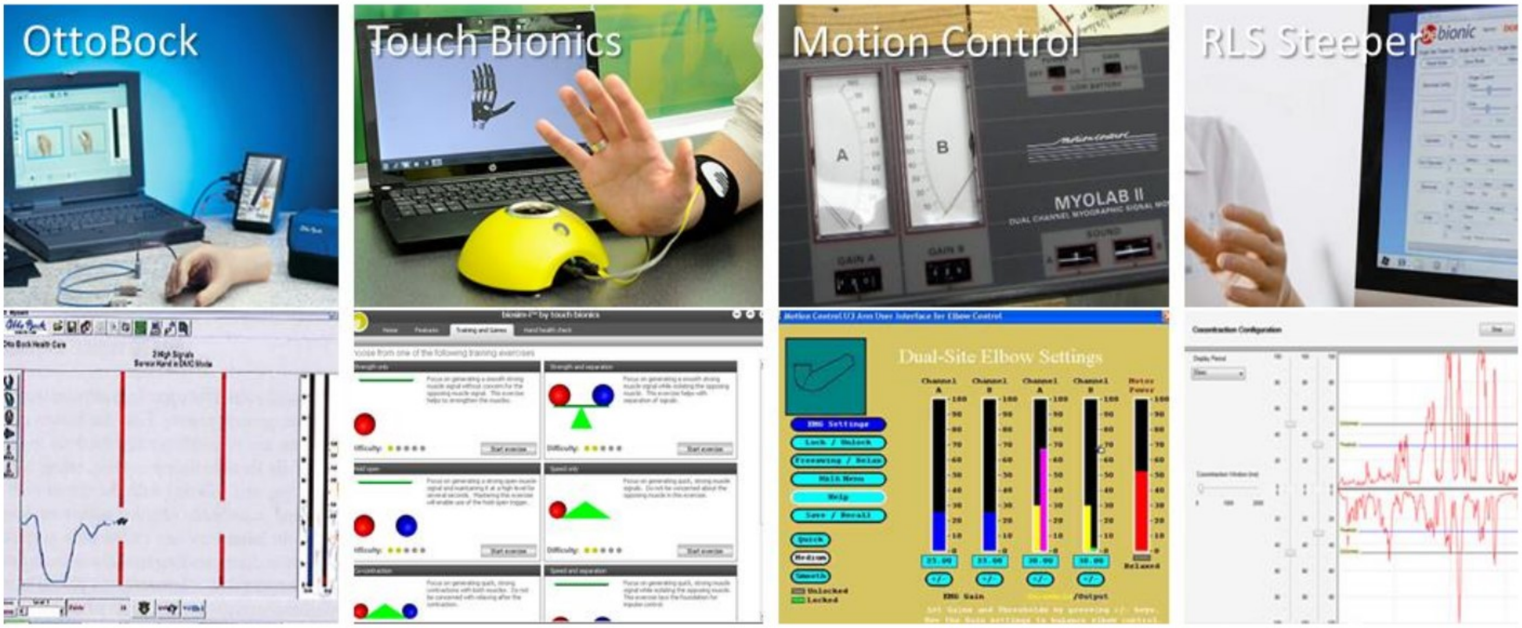
Current Commercially Available Tools

- 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



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Consumer Virtual Reality

- Highly immersive
- Some are capable of positional tracking (eg. Occulus Rift, HTC Vive)
- Some are mobile (eg. Google Daydream, Samsung Gear)
- Relatively inexpensive (<$1,000)

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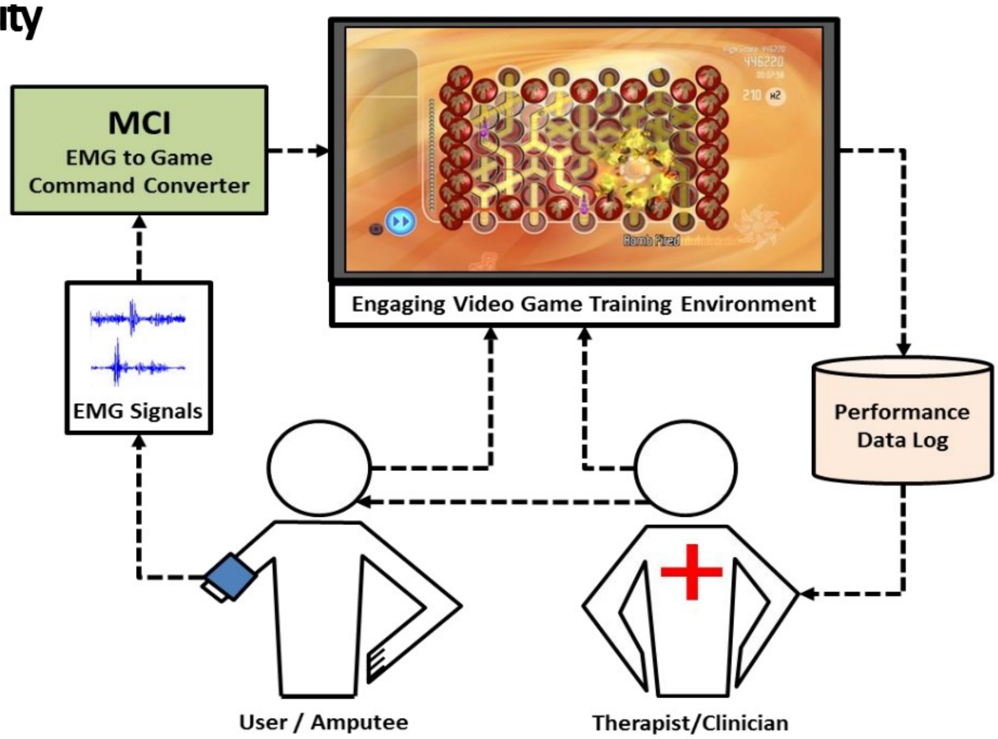
Emerging Research Systems

- Myo armband coupled with Mobile phone

- Myo armband coupled with immersive VR

Virtual Coach

- Center for the Intrepid
- Carnegie-Mellon University
- Shirley Ryan AbilityLab



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

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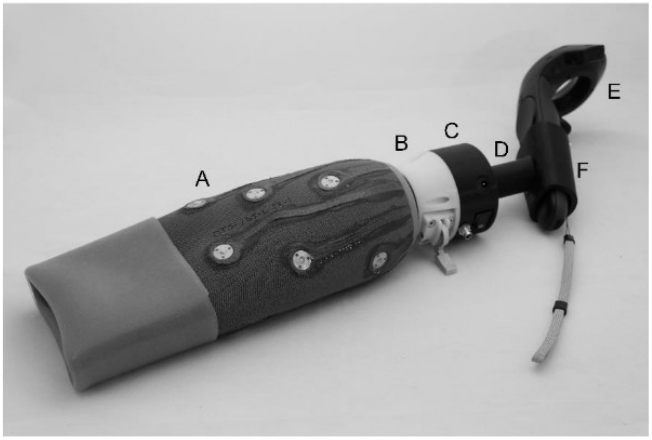
Virtual Coach – Immersive HTC Vive Experience



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: CDMRP, (W81XWH 12-02-0072)

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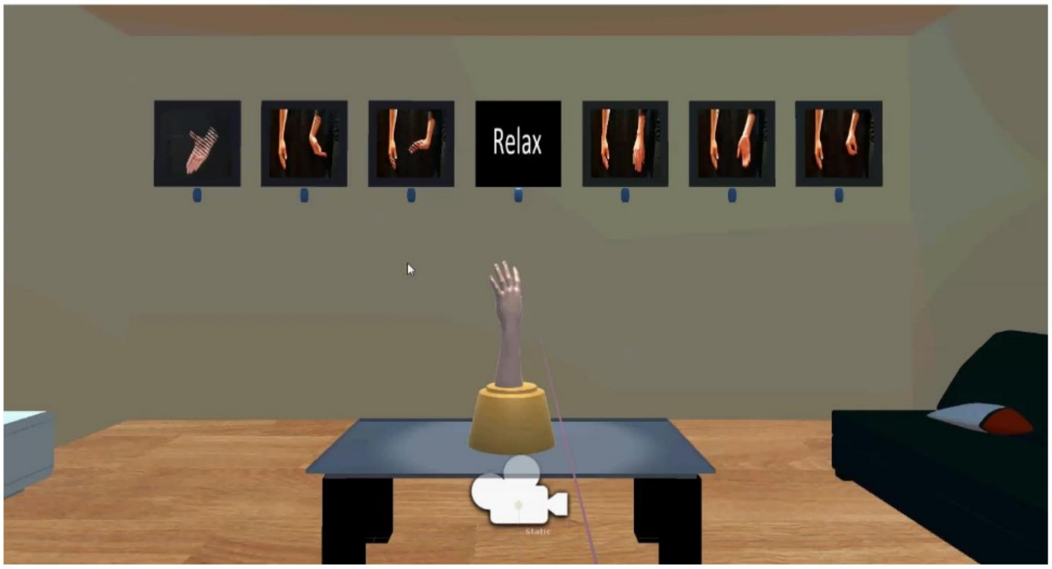
Virtual Coach – Customized Training Environments



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

Virtual Coach – Immersive Google Daydream Experience

- The VR application can communication seamlessly with the embedded controller inside the prosthesis.
- Effectiveness of the virtual training can be tested immediately with the prosthesis.

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

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Acknowledgements:

US Army: CDMRP, (W81XWH 12-02-0072, W81XWH 12-02-0072)

NIH: (1R01 HD 058000-01)

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