Cortical Activation During Tool Pantomime with Upper Extremity Prostheses

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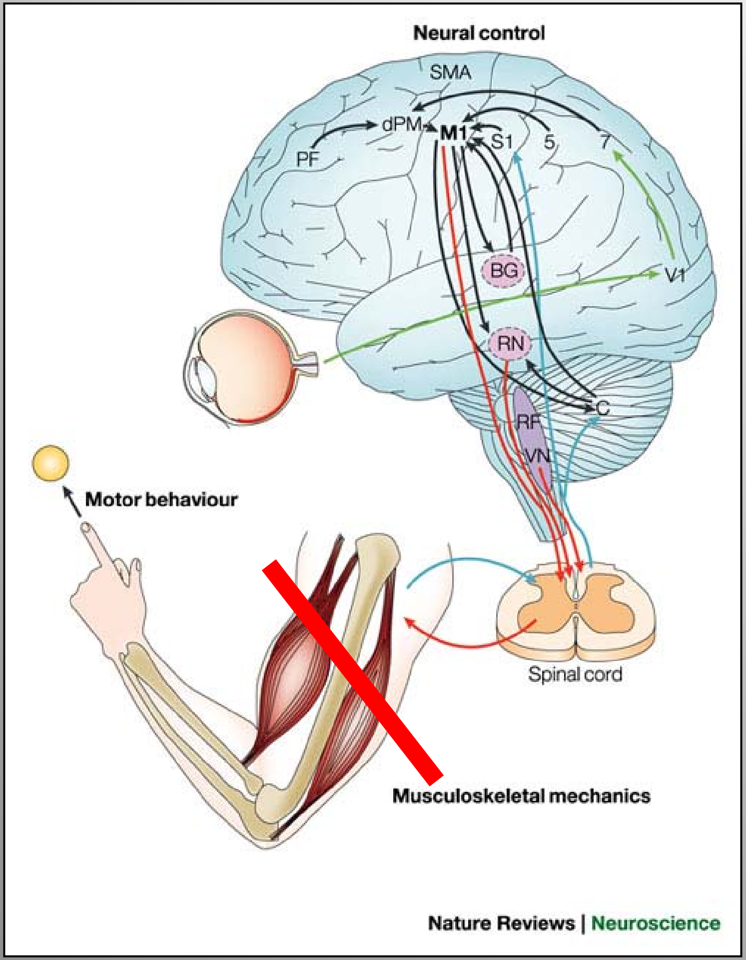
Introduction and Background

- This study explores:
  - Upper extremity amputees
  - Cortical activity during motor planning
    - Praxis is action:
      - Initiation
      - Organization
      - Performance
    - Tool use
  - Comparing brain activation
    - Sound vs. affected side
    - Simple movements vs. tool pantomime gestures

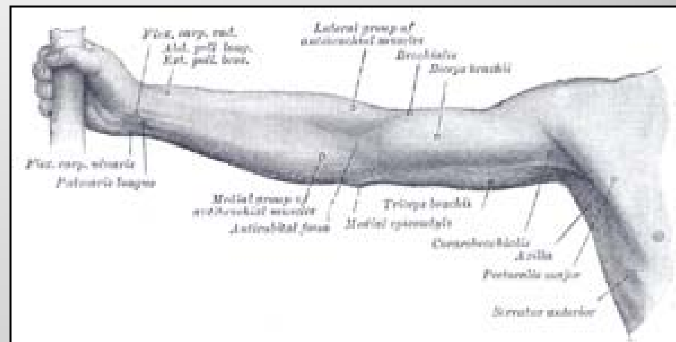
Introduction and Background



- Why expect differences?
  - Amputees lose muscles, nerves and skin
  - The normal pathway between muscles, nerves and the brain is disrupted.
  - Effects motor output and sensory input
  - This peripheral, external loss can lead to reorganization in the brain (Schwenkreis, 2001)

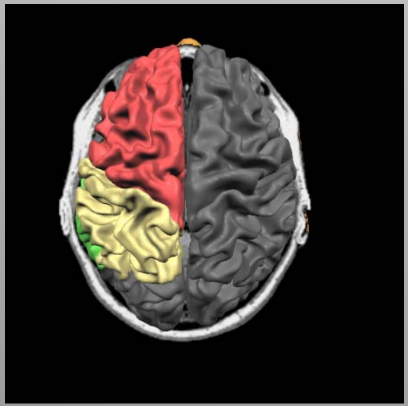
Introduction and Background

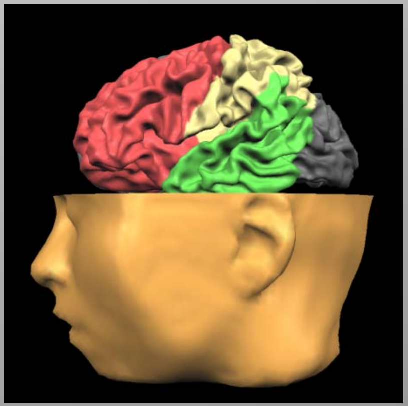
- Why expect differences?
  - Prosthesis vs anatomic arm/hand
  - Mechanism of device movement
    - Expect to see cortical changes in motor planning and execution
  - Feedback



Introduction and Background

- Normal tool use control requires activation of widespread cortical areas
- **Left Temporal areas:** tool familiarity (Vingerhoets, 2008)
- **Left Frontal areas:** how to grasp objects (Buxbaum, 2006)
- **Left Posterior Parietal Cortex :** representation of tool characteristics (Vingerhoets, 2008; Tsuda, 2009)
- Together, these areas make up the **“neural tool network”**





Introduction and Background: Why is this study important?

- 588 new upper extremity amputees in 2007 (http://hcupnet.ahrq.gov)
- Only about 50% use prostheses. (Alley, 2004)
- Lack of prosthesis use has been attributed
  - Lack of education about options and care
  - Lack of training
  - Discomfort
  - Poor cosmesis
  - Cost (Nielson , 1991; Melendez 1988)
  - Adapting to one-handed life

Aim

- To determine if there are differences in brain activity during prosthetic and sound side movements
  - Better understand how prostheses are processed
  - Guide prosthesis design and training paradigms

Introduction and Background

Hypotheses:

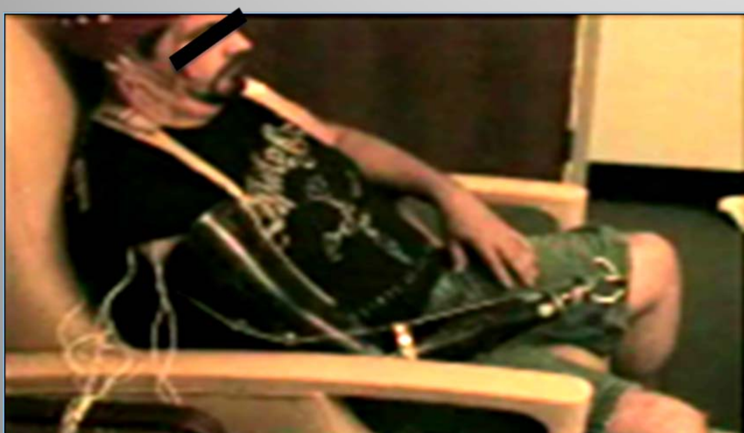
1. During **simple gestures with their prostheses**, amputees will show more activation in the posterior parietal cortex and other **neural tool network areas** than during movements of their sound side
   1. Prostheses are used as tools.
   2. Dissociation between prosthesis and anatomy
2. During **tool use pantomime** with their prostheses, amputees will exhibit **additive activation of the neural tool network** relative to their sound side.

Methods

- **Measurement**:
  - Electroencephalography (EEG)
    - Measure cortical activity
  - Electromyography (EMG)
    - Measure muscle activity to have objective recording of motion onset
    - Anterior and Posterior Deltoid were monitored
- **Tasks**:
  - 2 tasks with their sound limb and their affected limb with the prosthesis donned:

1. Reach out and rotate forearm (Rotation)
2. Watched a video of screwdriver use
3. Pantomime using a screwdriver (Tool Pantomime)
4. Each movement was performed about every 10 seconds for about 12 minutes

Methods



Rotation with Sound Side → Rotation with Prosthetic Side

Watch a video of screwdriver use

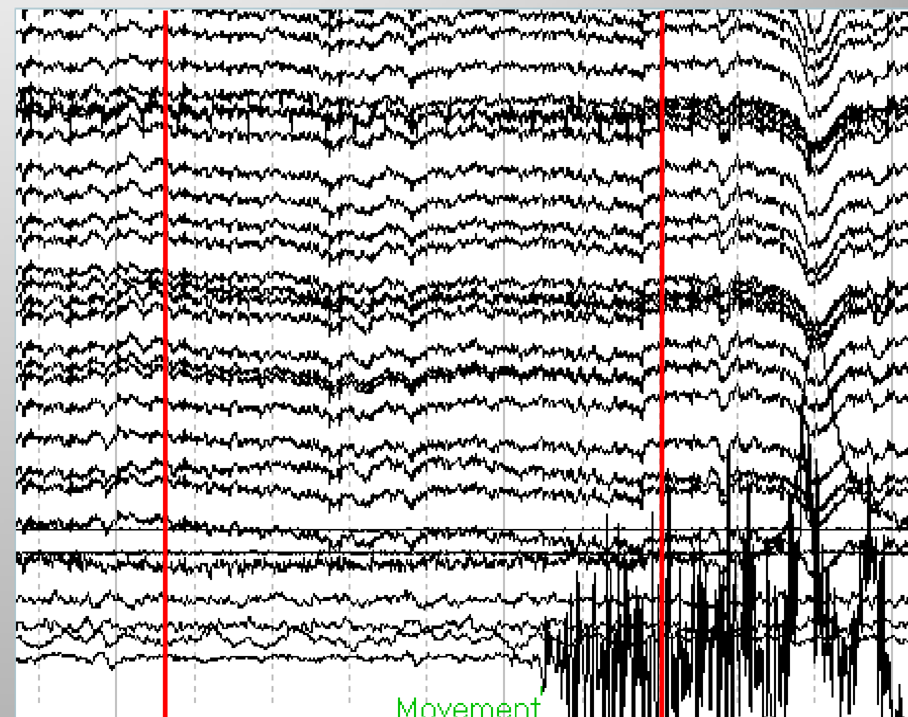
"Tool Pantomime" with Sound Side → "Tool Pantomime" with Prosthetic Side

Participants

Sex	Age	Level	Side	Time Since Amputation	Time Until 1st Prosthesis	Type of Prosthesis	Dominance
6 M, 1 F	24-68yrs. (Mean 41.7, SD 16.7)	5 TR 1TH 1PH	3L 4R	2-38 yrs (Mean 9.1, SD 12.9)	0-24 mo (Mean 10.29, SD 10.79)	4BP, 3Myo	7 Right

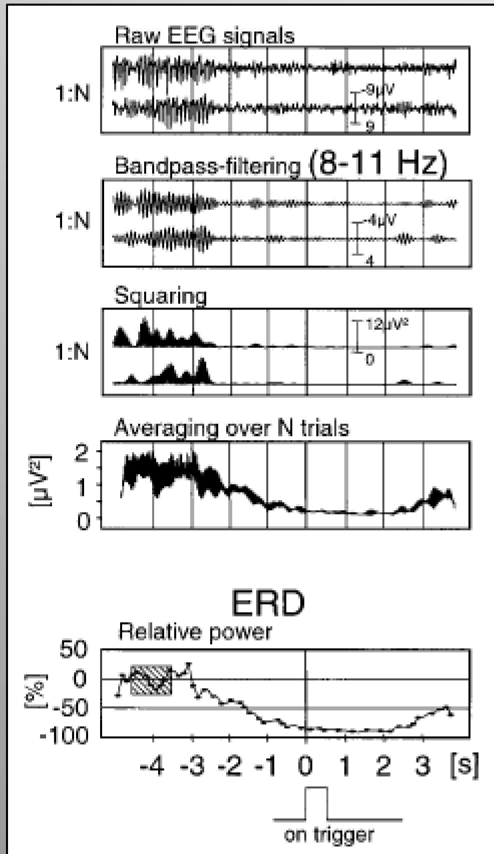
Data Analysis

- Data was marked to reflect movement onset (based on EMG)
  - Each trial started 4500ms before movement onset and ended 1500 ms after movement onset
  - We are interested in movement planning as well as execution



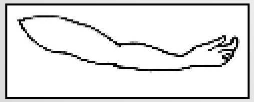
-4500ms 1500ms

Data Analysis

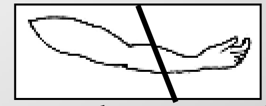


- Examined event related desynchronization (ERD)
  - Metric used to measure brain activity
  - Measure oscillations of neuronal activity within a frequency
  - Increased ERD within a frequency is correlated with increased brain activity. (Pfurtscheller, 1999)
- Data was filtered in upper beta frequency (18-22 Hz)

Average: All Participants

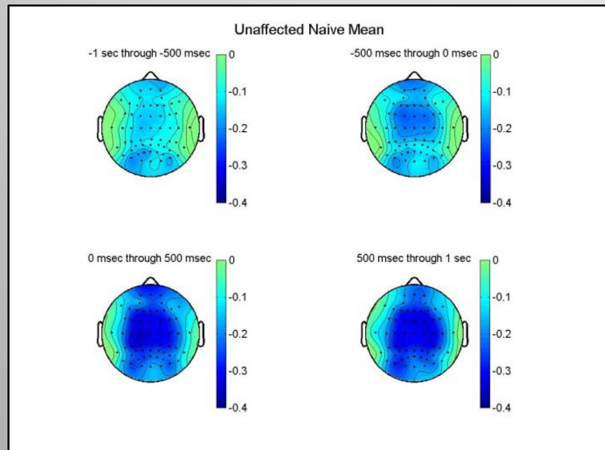


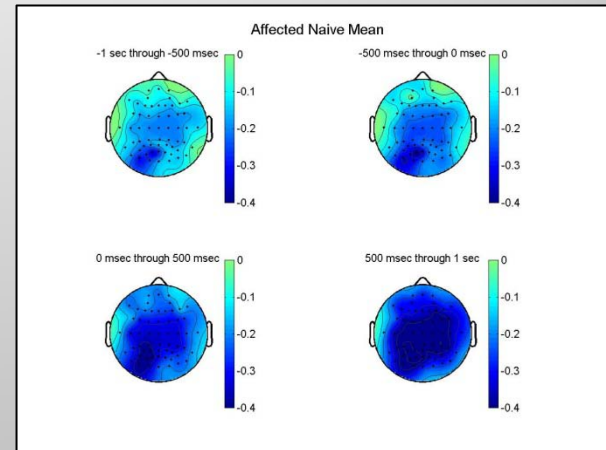
Sound Side



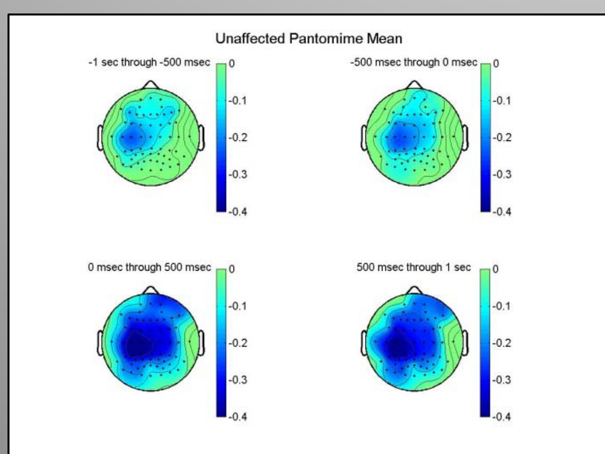
Prosthetic Side

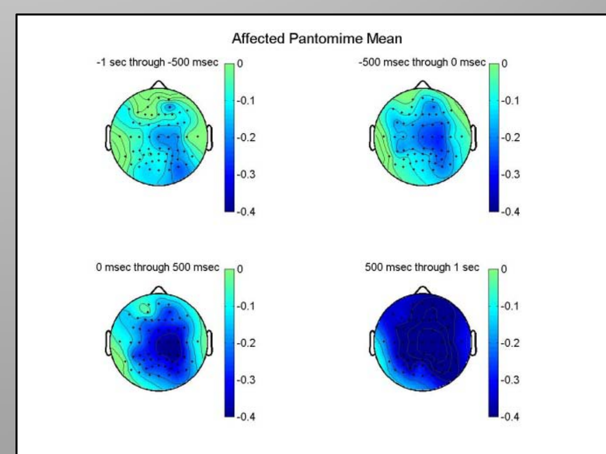
Simple Rotation



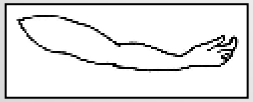


Tool Pantomime

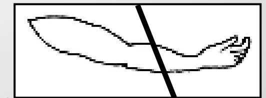




Average: Dominant Arm (Right)

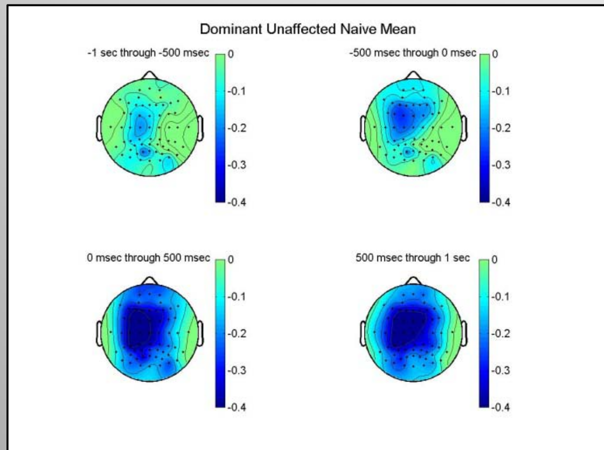


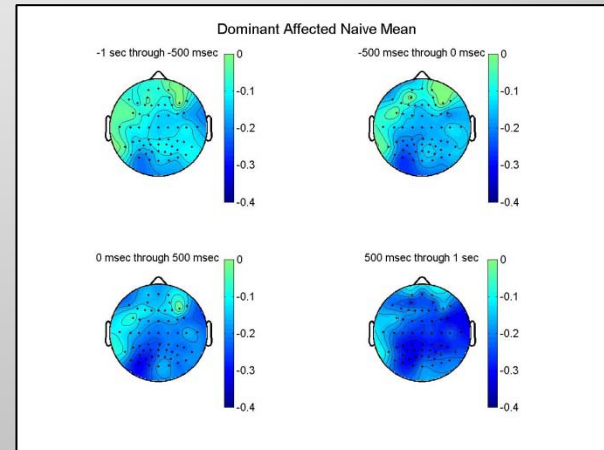
Moving Intact Right Arm



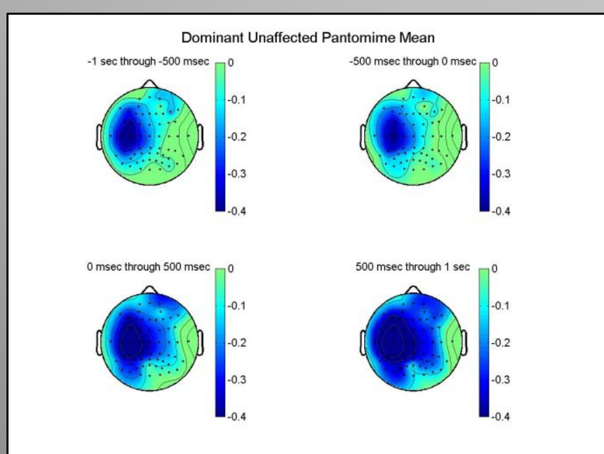
Moving Amputated Right Arm

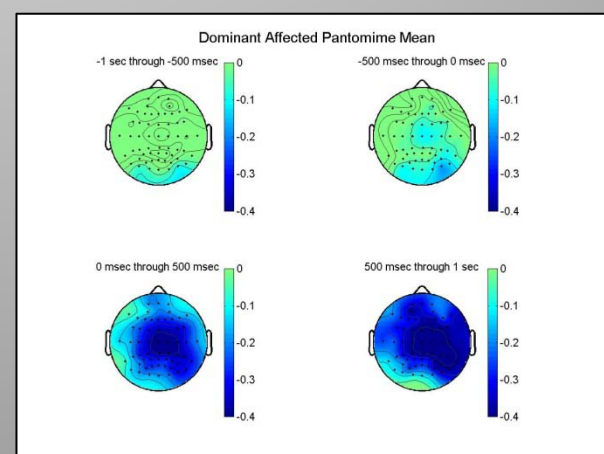
Simple Rotation



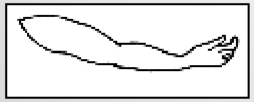


Tool Pantomime

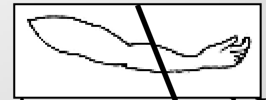




Average: Non Dominant Arm (Left)

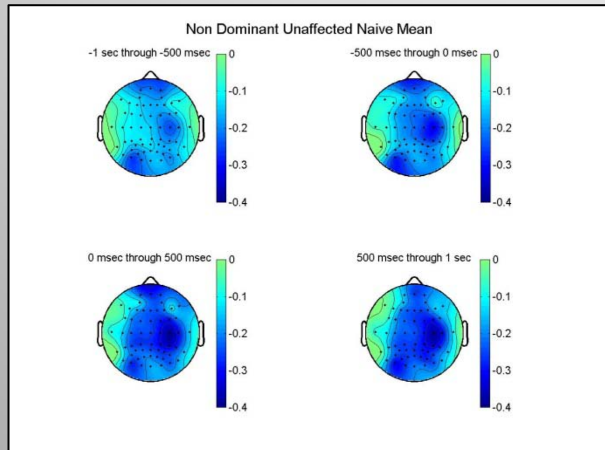


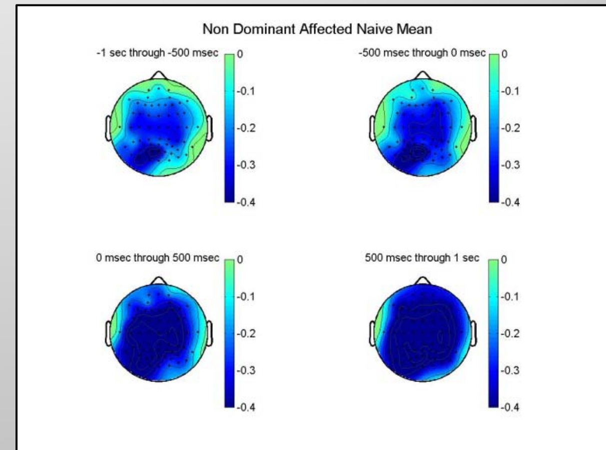
Moving Intact Left Arm



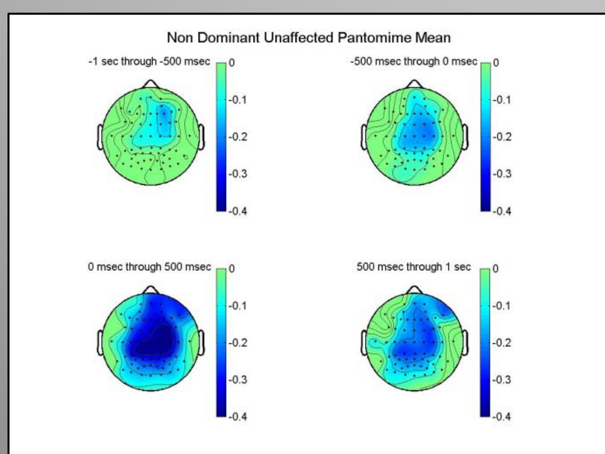
Moving Amputated Left Arm

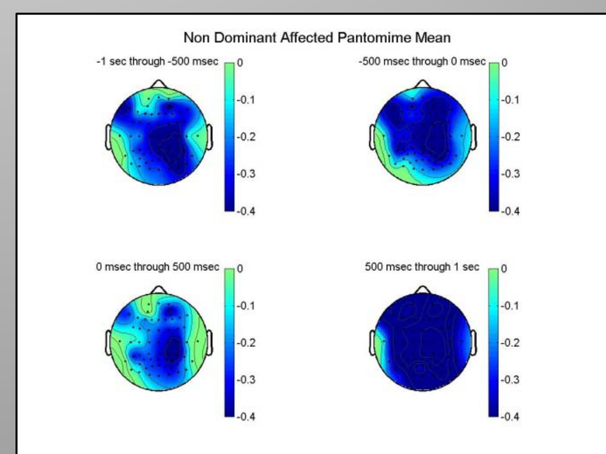
Simple Rotation





Tool Pantomime





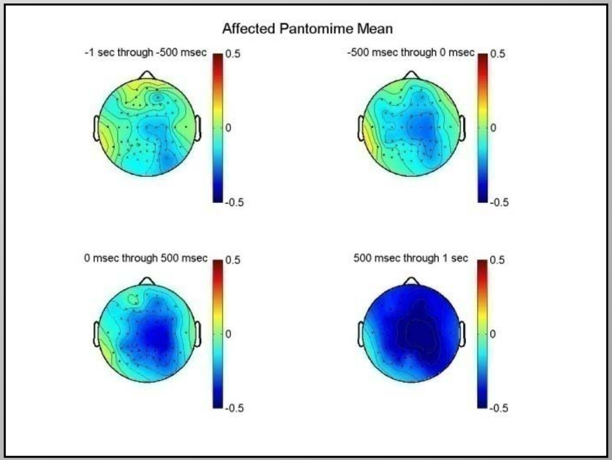
Discussion

- **Sound side rotation**
  - **Contralateral motor activation** during motor execution
  - Consistent with performing a **simple movement.**
- **Sound side Pantomime**
  - **Left lateralized parietofrontal activity** during planning and execution
  - Consistent with a **tool pantomime** task.

- **Prosthetic side rotation**
  - **Posterior parietal activation**
  - Displayed **regardless of dominance** of prosthetic side
  - Movement of the prosthesis involves **tool related processing.**
- **Prosthetic side Pantomime**
  - **Right lateralized** activation.
  - Displayed **regardless of dominance** of prosthetic side
  - Indicates **visuospatial** processing

Discussion

- Right parietal activation has been measured during tasks requiring visuospatial processing (Chaminade, 2005; Hermsdörfer, 2001)
  - Imitation of a gesture
  - Finger gestures
- Prosthetic arms offer no feedback and require visual monitoring



Discussion

Hypothesis 1: During simple gestures with their prostheses, amputees will show more activation in the posterior parietal cortex than during movements of their sound side indicating that their prostheses are used as tools.

- **Supported**, the amputated side showed more posterior parietal cortex activation during simple movements

Discussion

Hypothesis 2: During tool use pantomime with their prostheses, amputees will exhibit additive activation of the posterior parietal cortex

- **Refuted**, Amputees access a separate right lateralized visuospatial network during the prosthetic pantomime task

- Raises the question: How should the prosthesis be used?
  - Similar to gait evaluation in lower limb prosthetics

Limitations and Future studies

- Limitations
  - Variability in participants
- Future Studies
  - Limits of visuospatial effect. Do all tasks show this kind of right lateralization?
  - Effects of device type (Body powered vs. externally powered), training duration and type, amputation level, cause of amputation
  - Effects of hand transplantation on motor control

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Questions?

All Participants

Subject	Age	Sex	Reason For Amputation	Time Since Amputaion	Time Since First Px	Time Using Current Px	Side	Level	Device Used
1	38	F	Trauma	4 years	2 years	2 years	R	TR	Body powered
2	50	M	Congenital	50 years	50 years	6 years	B	TH	Myo
3	37	M	Trauma	2 years	1 year	1 year	R	TH	Body powered
4	41	M	Trauma	4 years	unknown	unknown	L	TH	Body powered
5	24	M	Trauma	2 years	1 year	1 year	L	PH	Prodigits
6	26	M	Trauma	7 years	5 years	2 years	R	TR	iLimb
7	38	M	Trauma	5 years	5 years	2 years	R	TR	Body powered
8	68	M	Trauma	6 years	6 years	1.5 years	L	TR	Myo
9	61	M	Trauma	38 years	38 years	5 years	L	TR	Body powered (VC)
10	19	F	Trauma	3 years	3 years	3 years	R	TH	Myo