Autism, Social Cognition, and "Mirror Neurons"

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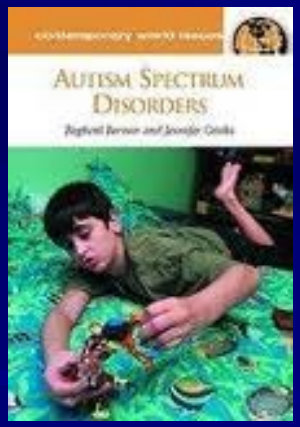
Disclosures

- No Conflicts of Interest
- Funding sources:



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AUTISM SPEAKS™

National Institutes of Health
The Nation's Medical Research Agency

Bernier, R. & Gerdts, J. (2010). Autism Spectrum Disorders, ABC-CLIO.

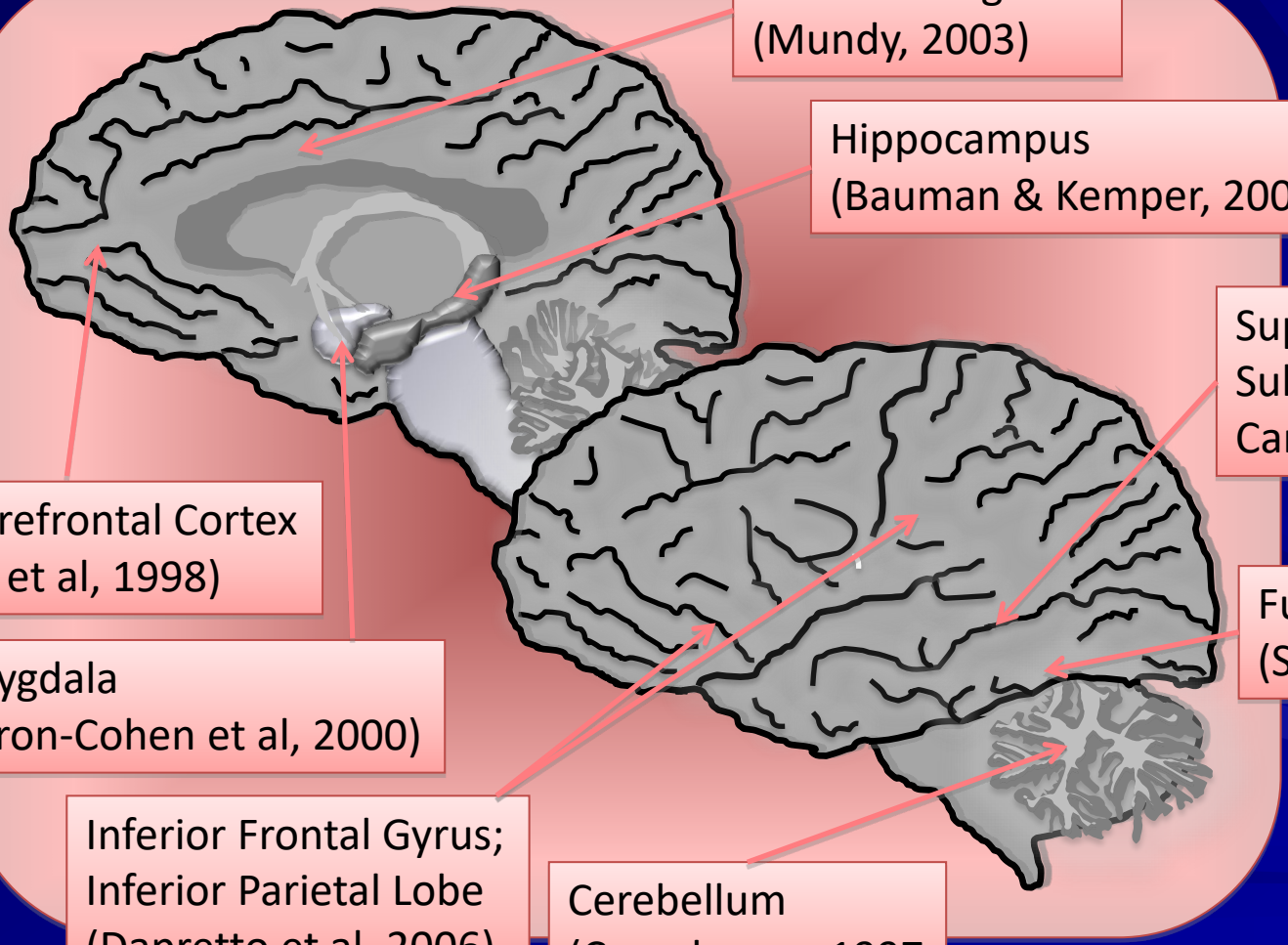
Overview

- Autism as disorder of social cognition
- Imitation and autism
- “Mirror Neuron System”
- Current work underway

Social Cognition

- The ability to detect, attend to, and process social information in the environment, and to use this information to guide behavior

Social Brain Circuitry Implicated in ASD



Anterior Cingulate (Mundy, 2003)

Hippocampus (Bauman & Kemper, 2005)

Superior Temporal Sulcus (Pelphrey & Carter, 2008)

Medial Prefrontal Cortex (Dawson et al, 1998)

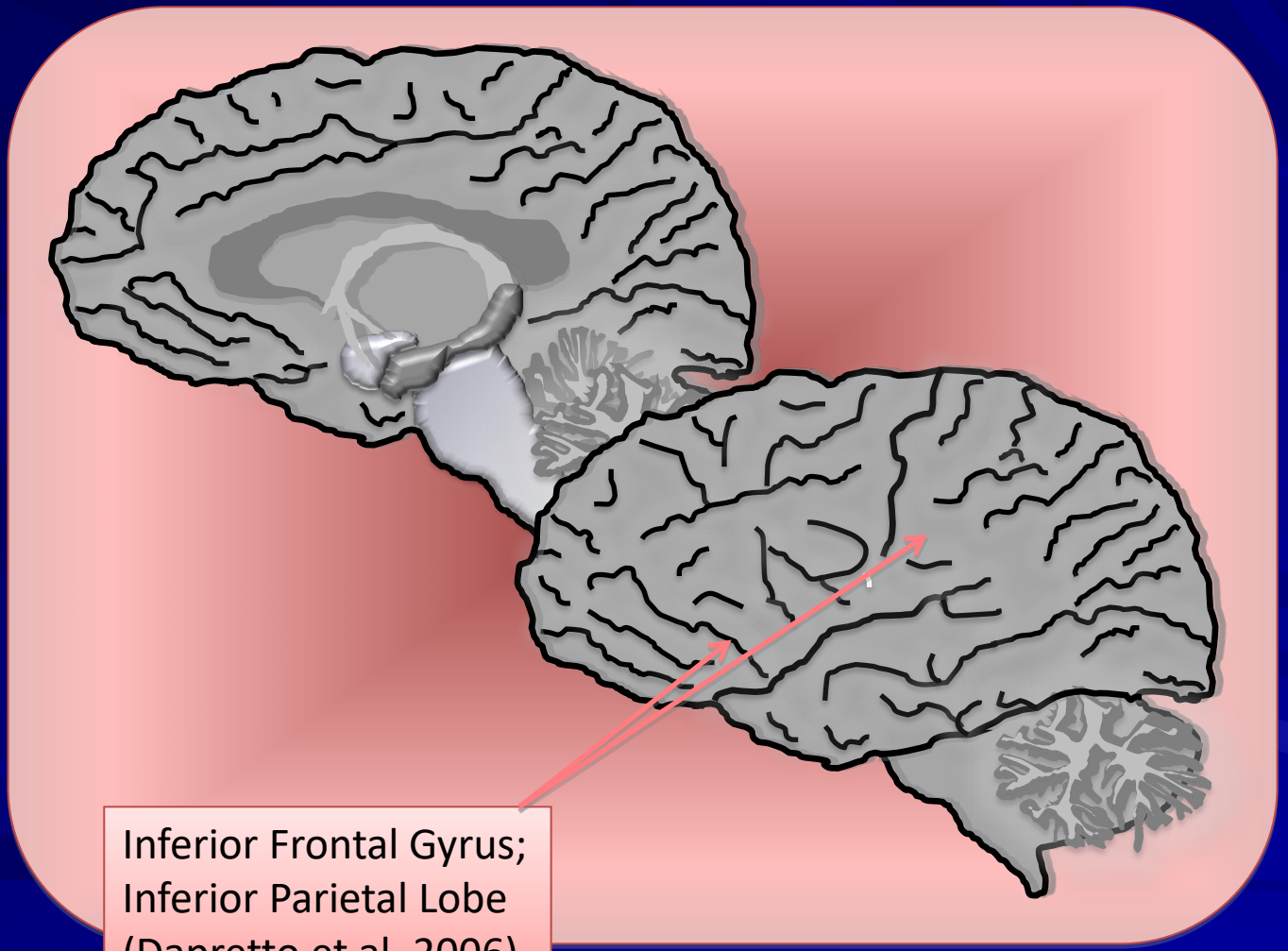
Fusiform Gyrus (Schultz et al, 2000)

Amygdala (Baron-Cohen et al, 2000)

Inferior Frontal Gyrus; Inferior Parietal Lobe (Dapretto et al, 2006)

Cerebellum (Courchesne, 1997

Social Brain Circuitry Implicated in ASD



Inferior Frontal Gyrus;
Inferior Parietal Lobe
(Dapretto et al, 2006)

Imitation Impairments in Autism

- Symbolic meaning hypothesis
  - (Baron-Cohen, 1988; Rogers et al, 1996)
- Executive functioning hypothesis
  - (Ozonoff, Pennington & Rogers, 1991; Rogers et al, 1996)
- Poor social motivation to attempt tasks
  - (Trevarthen & Aitken, 2001)
- Dyspraxia or motor dysfunction
  - (Jones & Pryor, 1985)
- Deficit in Self-Other mapping
  - (Rogers & Pennington, 1991; Williams et al, 2001)

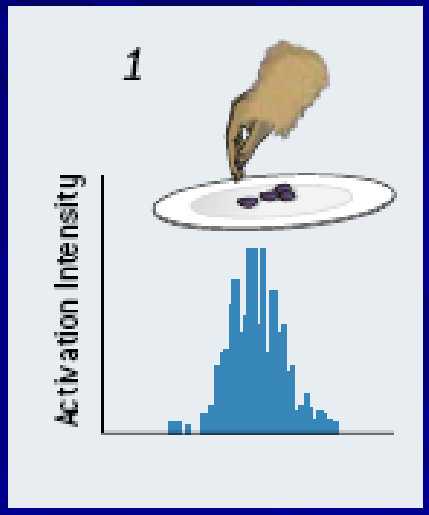
Imitation and Mirror Neurons

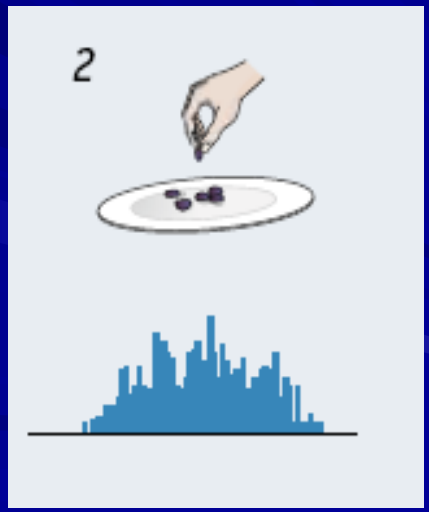
- Class of visuomotor neurons that activate when an individual is both performing an action and observing a similar action
- Potentially serve as neurological substrate for self other mapping

Mirror Neurons: non-human primates

- Mirror neurons activate during the execution AND observation of actions.
- First identified in area F5 of monkeys.
- Proposed to mediate action understanding.

(Gallese et al, 1996)





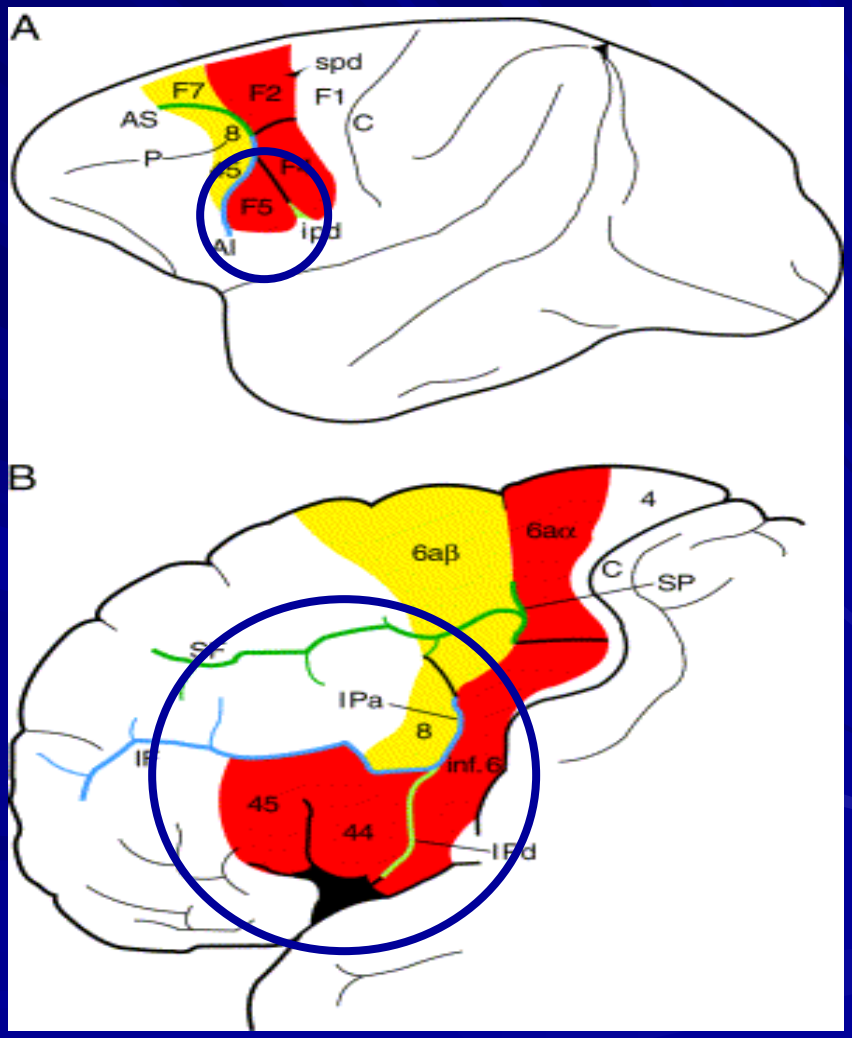
(from Ramachandran & Oberman, 2006)

Mirror Neurons: Humans

- In humans, also appears to be an execution/observation system.
- Proposed to be the mirror neuron system—limited direct evidence (e.g., fMRI and EEG).

Mirror Neuron Regions

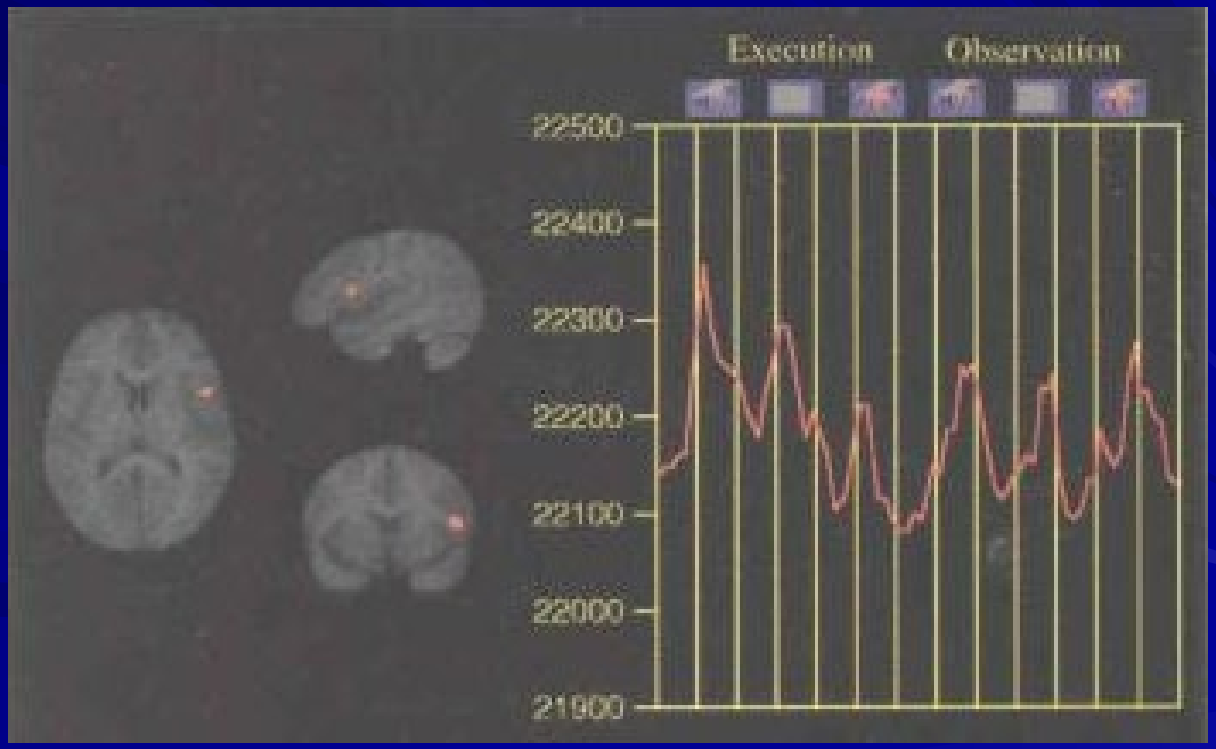
- Inferior Frontal Gyrus
- Inferior Parietal Lobe
- Related regions?
  - Superior Temporal Sulcus
  - Insula
  - Anterior Cingulate



Rizzolatti & Arbib, 1998

Mirror Neurons: Humans

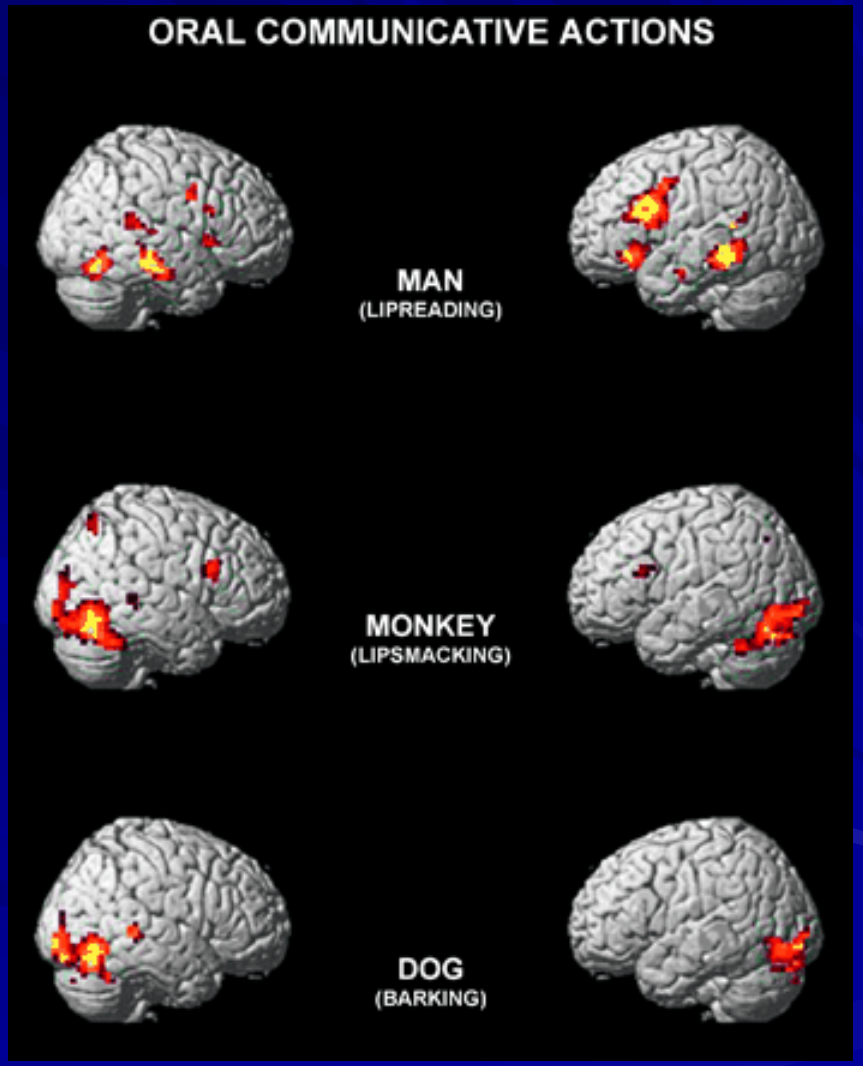
- In humans, area 44 (Inferior Frontal Gyrus) is activated when observing, executing, and imitating movement.



- Iacoboni et al, 1999

Mirror Neurons: Humans

- Only species specific actions result in MNS activation.



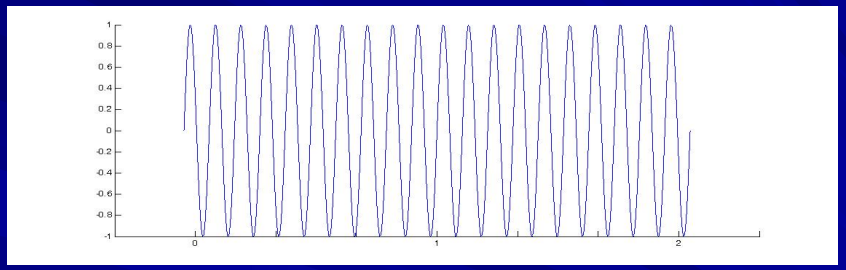
- Buccino et al, 2004

Mirror Neurons: Humans

- Activation occurs
  - With intransitive movements
  - Actions that are in behavioral repertoire (lip reading vs barking)
  - Emotional expressions
- Seems to serve a wider role.
- Provide the ability to understand others' actions and emotions through internal representation without reflection.
- Hypothesized to underlie imitation, empathy, theory of mind, metaphor, and evolution of language.
- How best to study non-invasively with individuals with autism?

Electroencephalography and Mirror Neurons

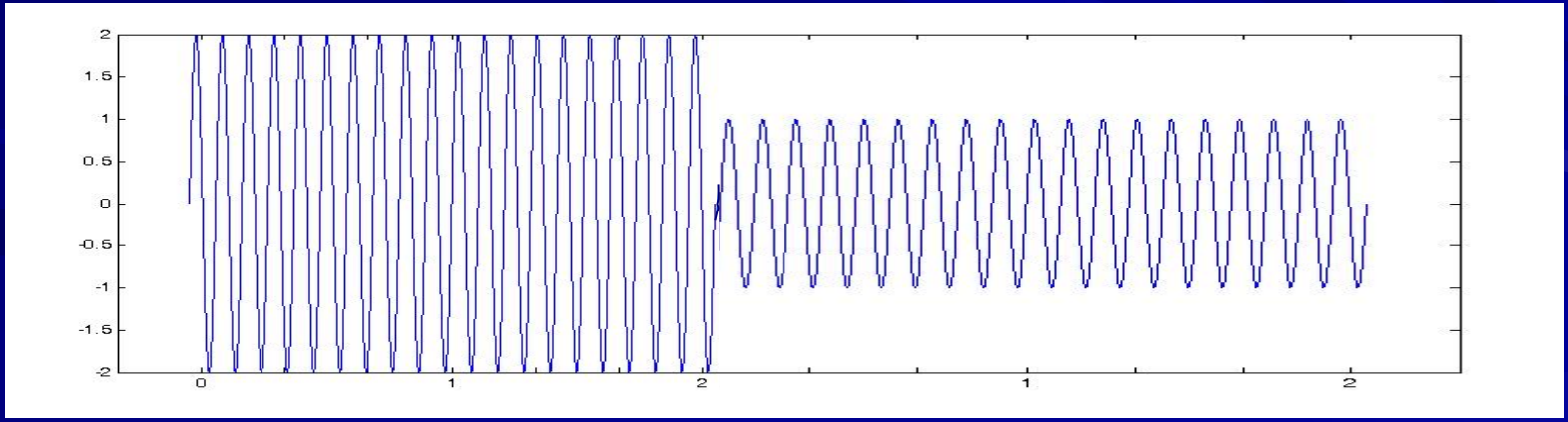
EEG Mu rhythm reflects execution/observation matching system



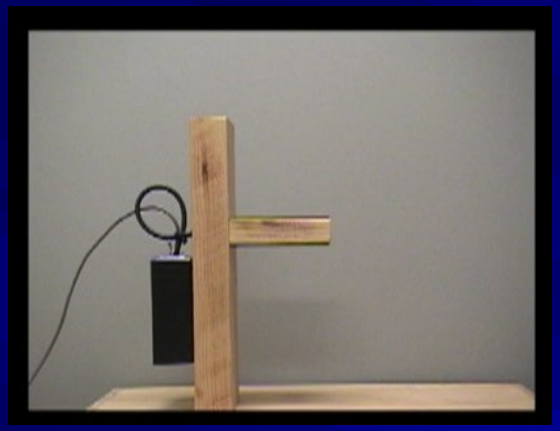
EEGs and Mirror Neurons

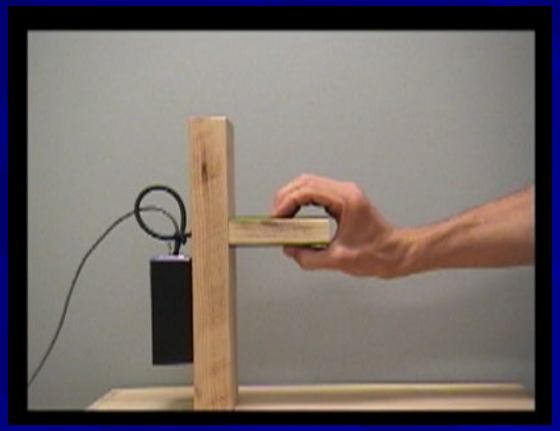
Mu rhythm is neuronal activity recorded from central channels over motor cortex in ~8-13 Hz frequency band

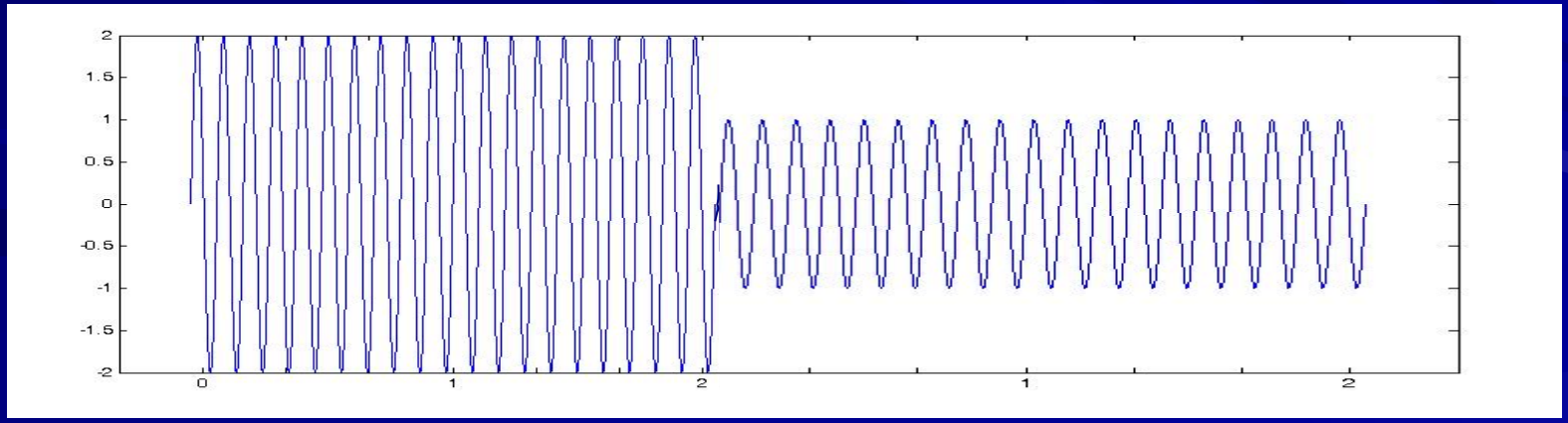
- At rest = synchronous
- Execution and observation of movement = asynchronous → reducing mu amplitude



EEGs and Mirror Neurons





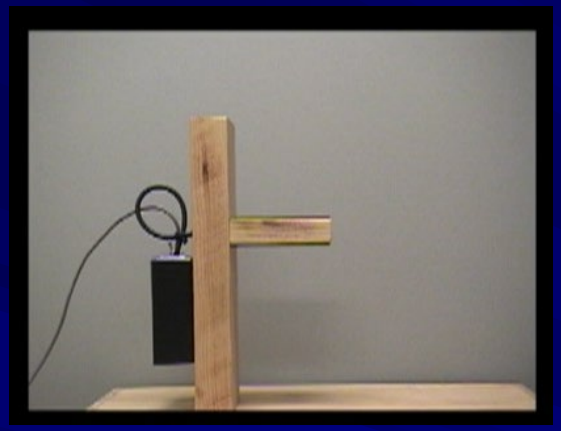


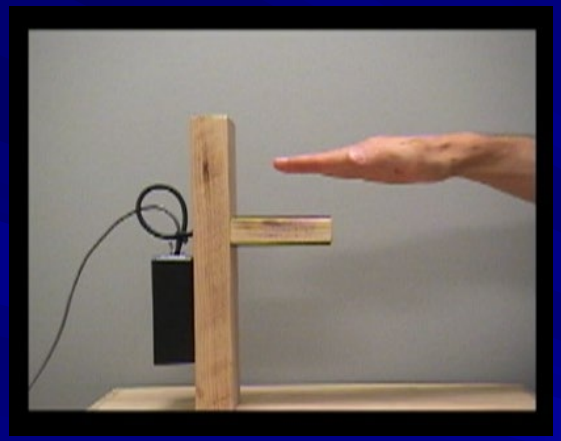
Research Questions

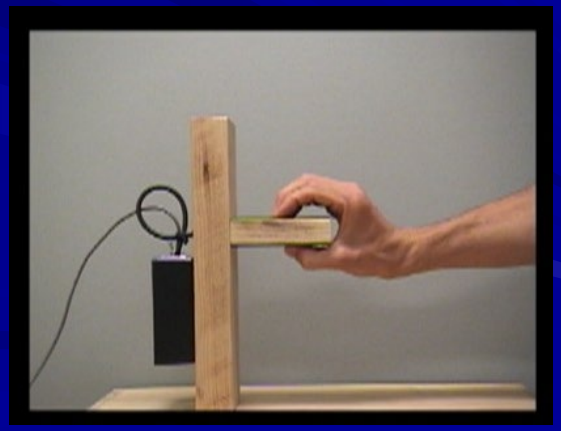
- Proposed role of MNS in social cognition.
- Proposed dysfunction of MNS in individuals with autism.

- Is there disruption of the MNS in autism?
- Is there a correlation between imitation ability and MNS functioning?

Procedure







Imitation battery

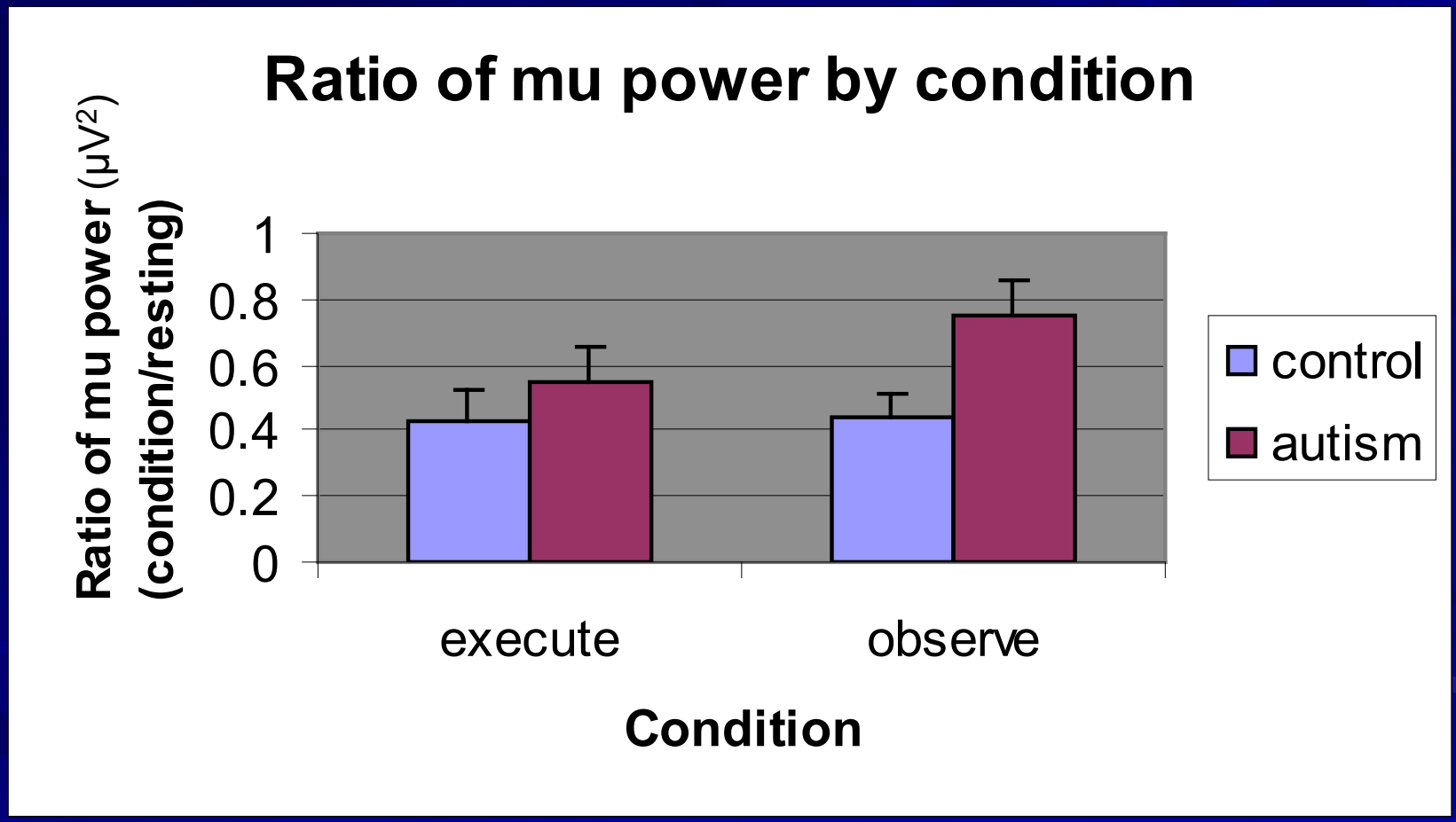
- Tasks:
  - Single step facial expressions
  - Sequenced facial expressions
  - Single step hand gestures
  - Sequenced hand gestures
  - Complex two hand gestures
  - Meaningless hand movements
  - Actions on objects (gentle or harsh style)

Imitation Task Models

Single Face Expression Example

Sequenced Hand Gesture Example

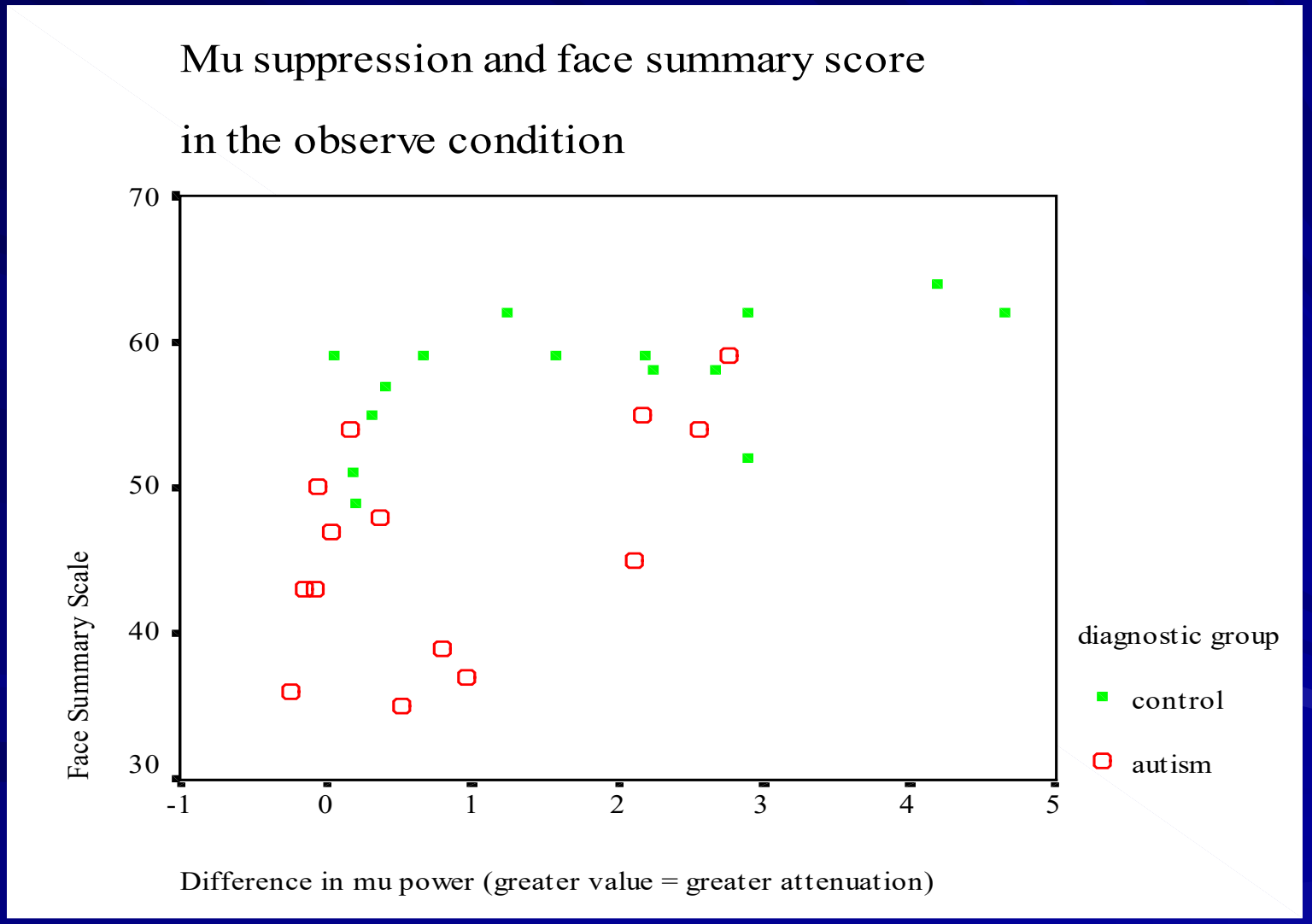
Results



Condition X Group: p<.05

Bernier et al 2007

Results



Bernier et al 2007

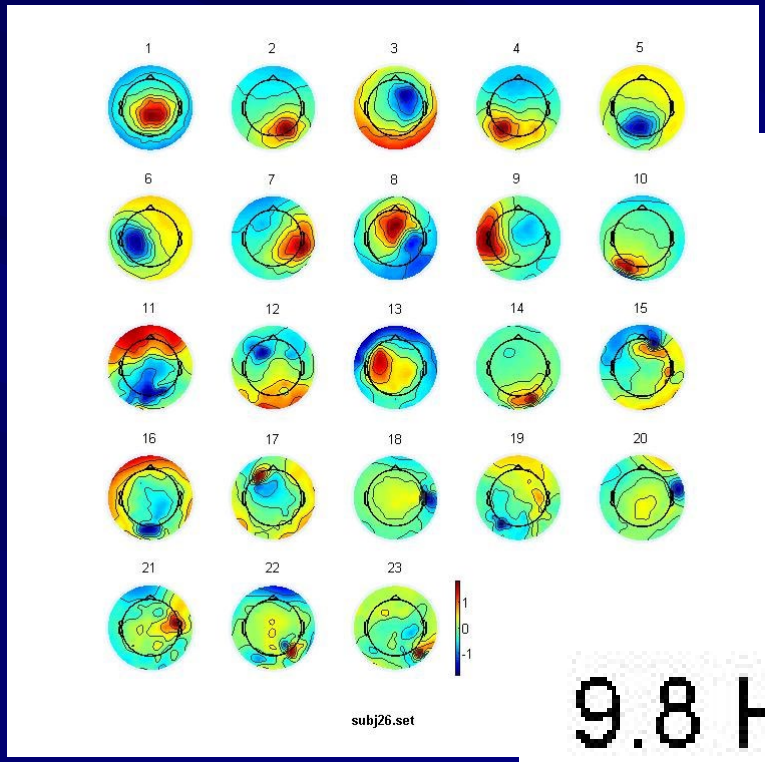
Conclusions

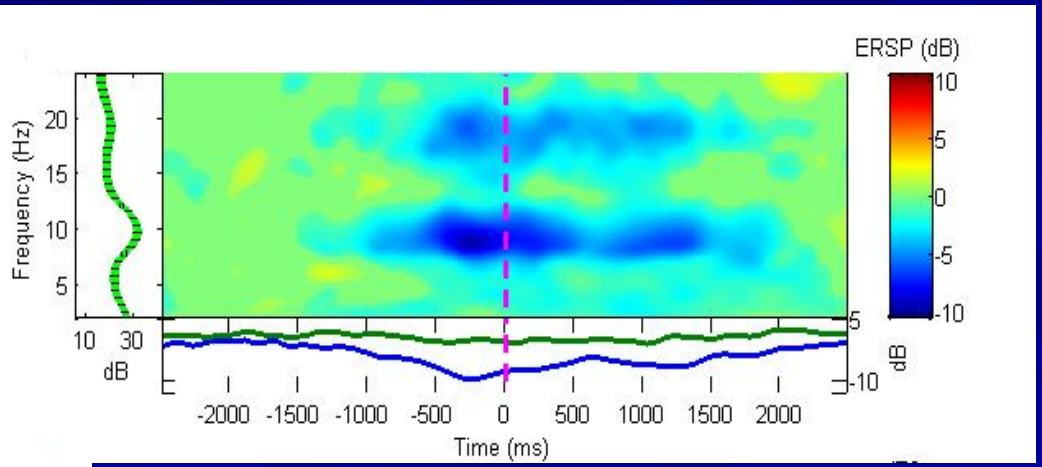
- Individuals with ASD show less attenuation of the mu rhythm in response to the observation of actions. Suggests dysfunction of the mirror neuron system.
- Continued impairments in behavioral imitation skills.
- Mu wave attenuation when observing actions correlates with facial imitation skills. Suggests the EEG mu rhythm may reflect underlying neurological activity related to imitation ability.

Question?

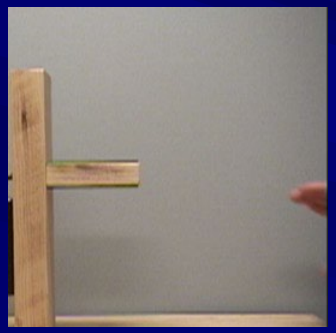
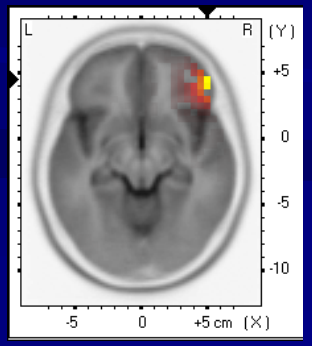
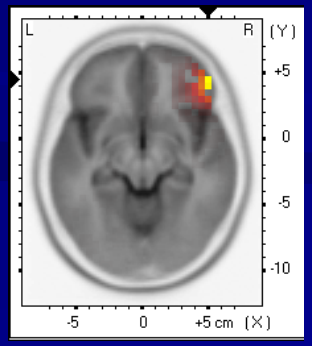
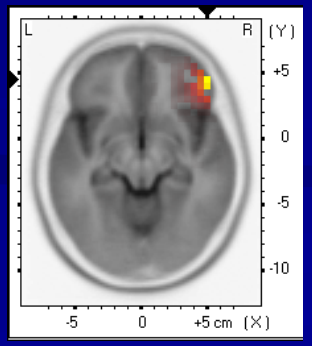
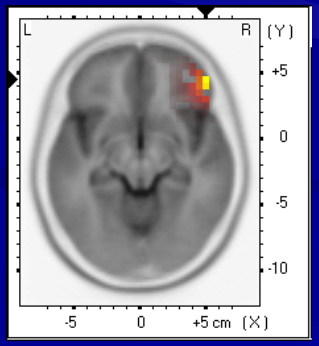
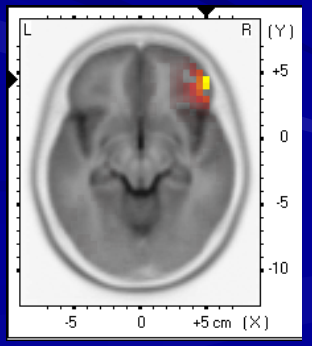
- Individuals with autism demonstrate differential mu rhythm activity.
- Do individuals with autism show differences in areas of cortical activation when observing, executing or imitating actions?

Source Localization



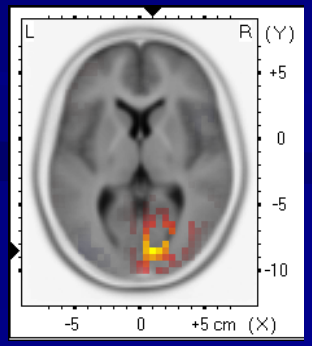


Observation and Imitation

Time 1	Time 2	Time 3	Time 4	Time 5
				
				

Observation and Imitation

Time 2



Greater amplitude in Cuneus (BA17) in typical adults compared to adults with ASD.

Bernier, Lunde & Dawson, 2007

Conclusions

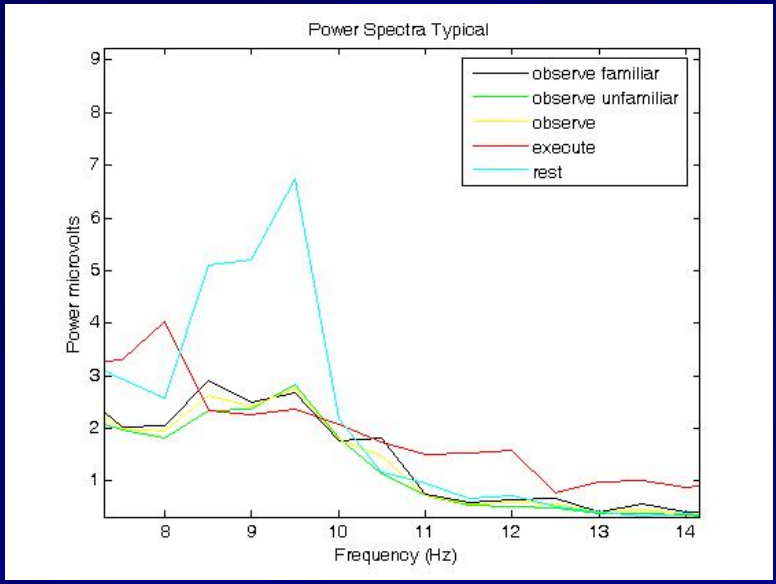
- No significant differences between peak areas of activity for execute, observe, and imitate conditions.
- Peak areas of activation are similar for both groups.
- Differences are found during distinct phases of action (ie, approach to grasp).
- Other areas (ie, Cuneus) warrant further investigation.

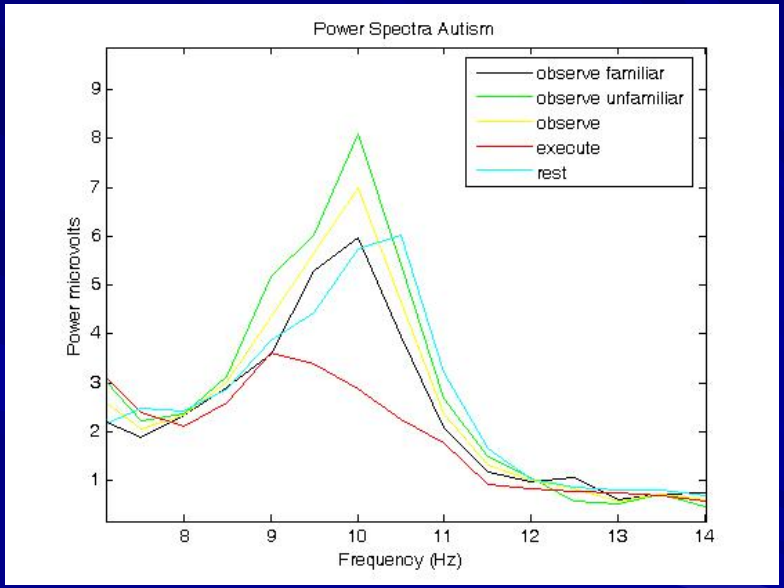
Question?

- Adults with autism demonstrate differential mu rhythm activity linked to distinct stages of action observation.

- How does this system work in children with autism?

EEG mu rhythm in children: 6-7 year olds



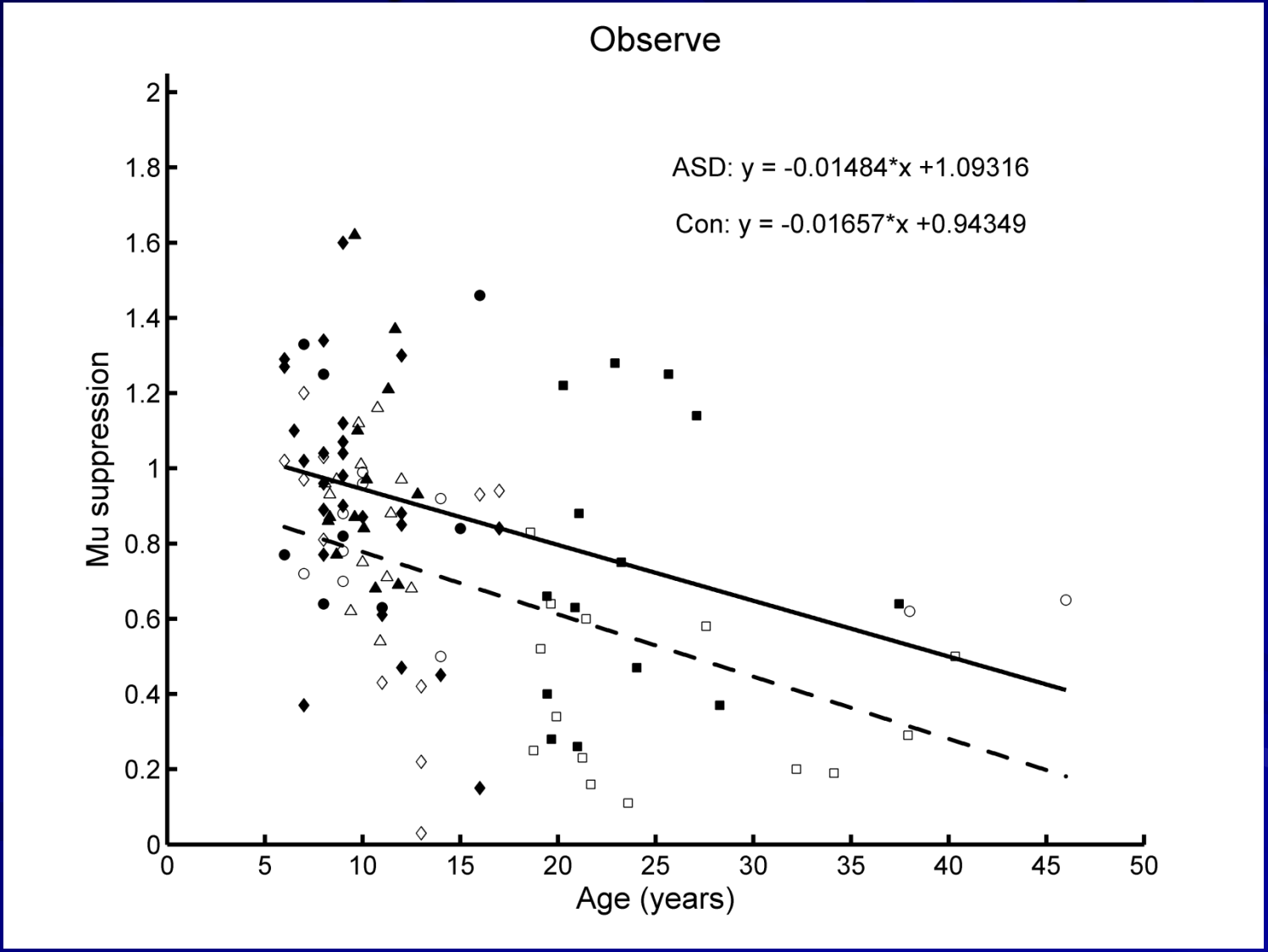


Bernier & Aaronson, in preparation

Question?

- This system is disrupted in both children and adults with autism.
- How does this system work across the lifespan?

EEG Mu rhythm over development



Oberman, McCleery, Hubbard, Bernier, Pineda, under review

Now what?

- This action execution/observation system is disrupted in both children and adults with autism.
  - How is this system impacted by intervention?
  - Is this electrophysiological signature an endophenotype?
  - Is there a way to address connectivity?

Studies underway

- Intervention Response Study
- Family Traits Research
- Twins study
- Social Connectivity

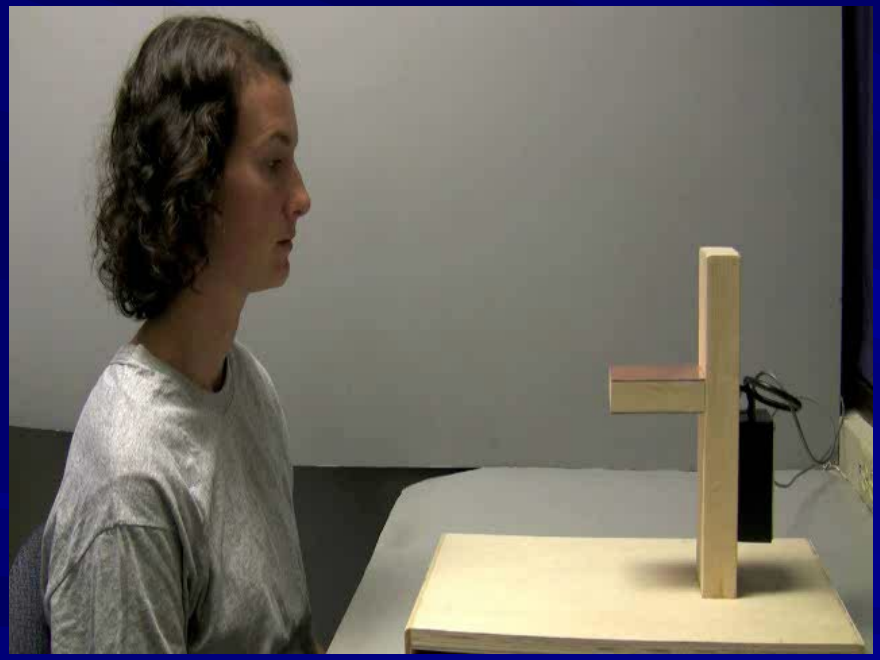
Current EEG mu rhythm study:

- Response to Early Start Denver Model (ESDM) intervention
- Diagnosed and assigned b/w 18-30 months
- Received 2 years of intervention
- Evaluated for follow-up b/w 6-7 years

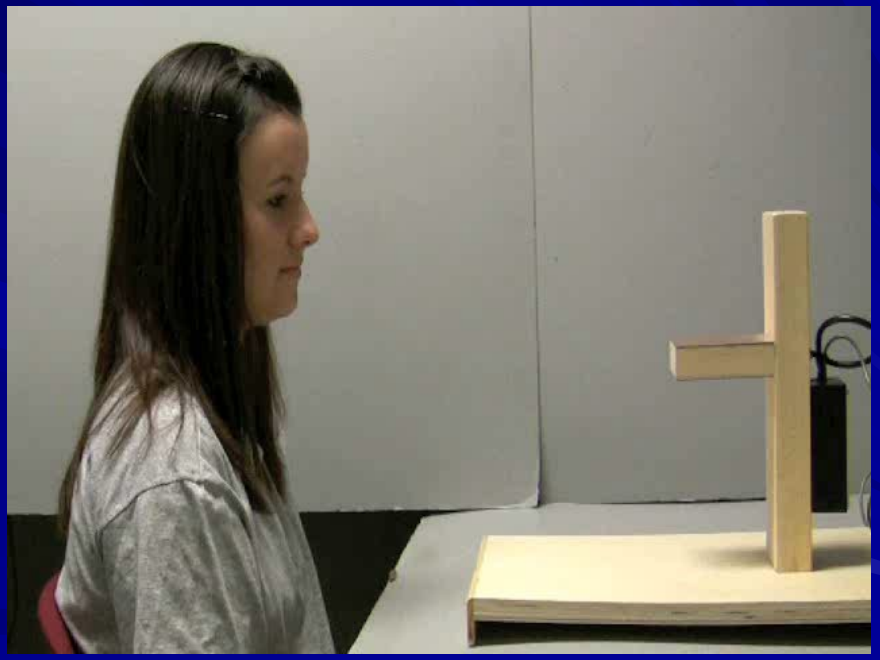
Bernier & Aaronson, in preparation

Familiarity Vs. Unfamiliarity

Unfamiliar

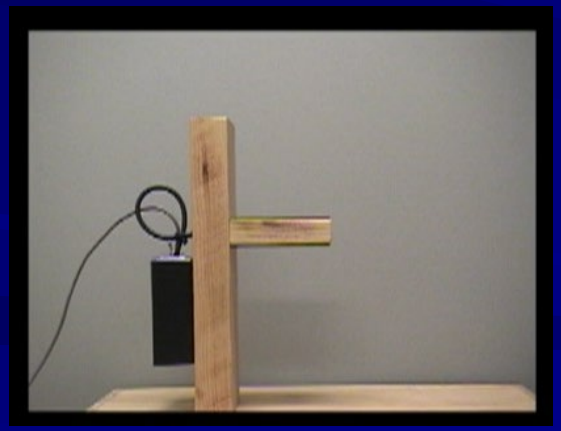


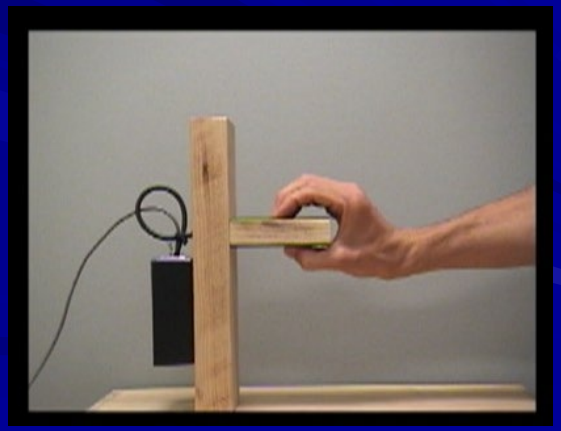
Familiar



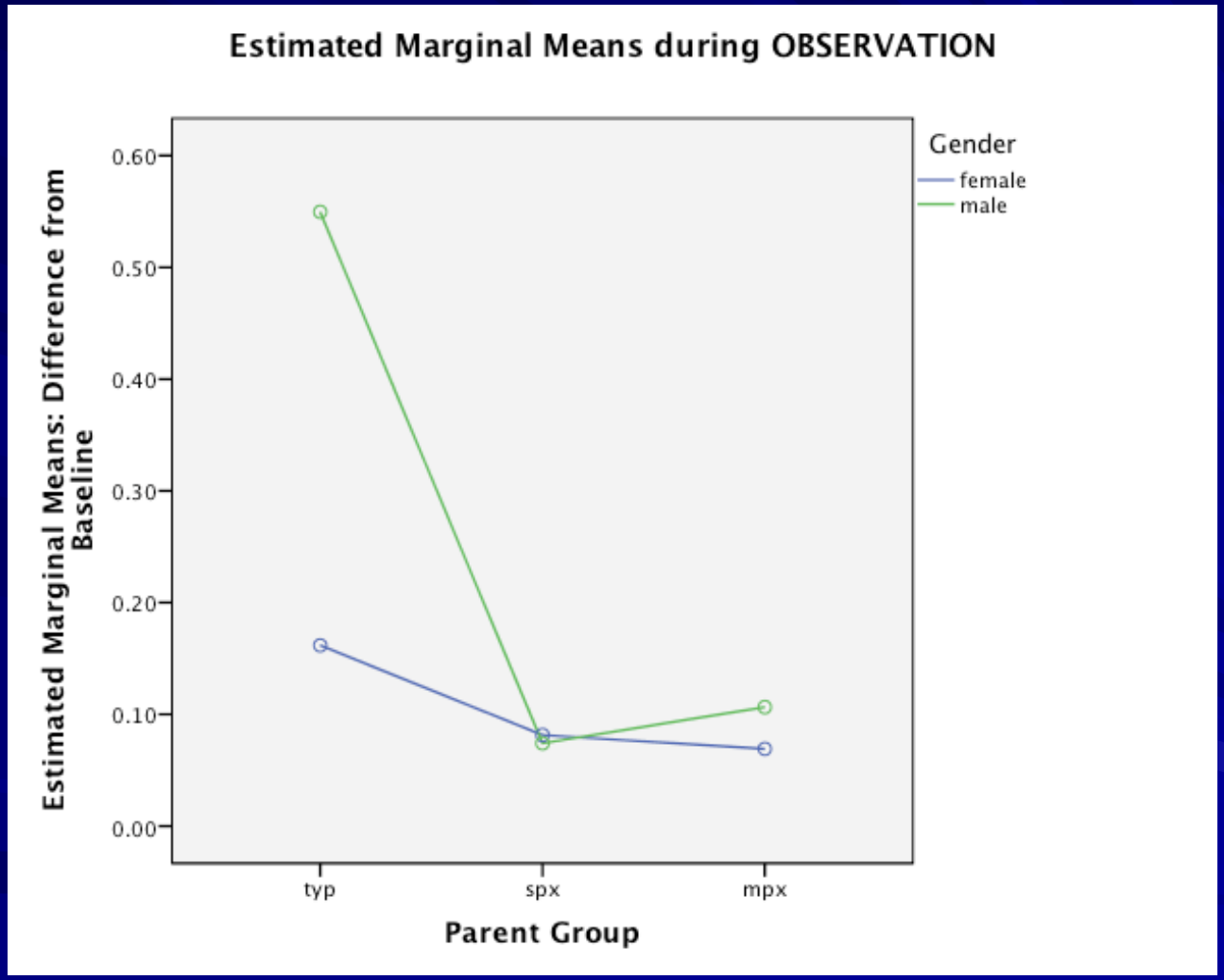
Family Traits Research (ACE Project 1)

- EEG mu rhythm in parents
  - Parents in Simplex families
  - Parents in Multiplex families
  - Parents of typically developing children





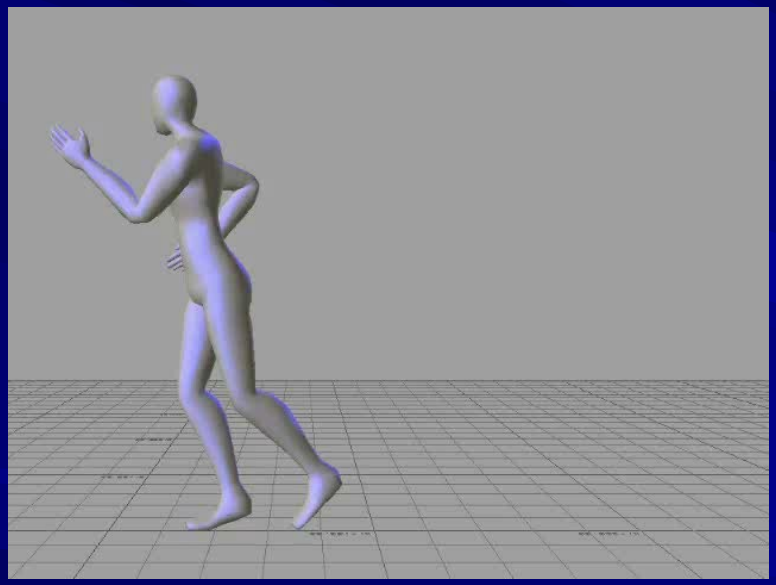
EEG Mu Rhythm



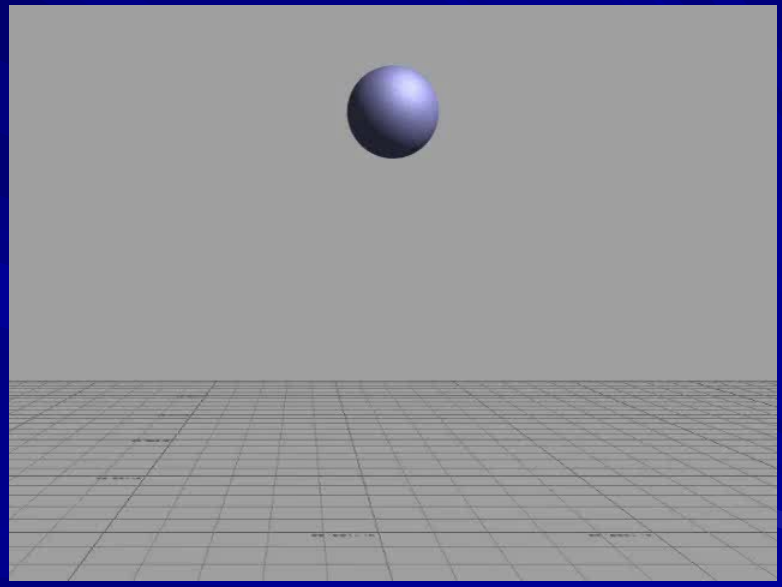
Main Effect for Group: p<.001; Main Effect for Gender: p<.01;
Interaction Effect for Group X Gender: p<.05

Twins

Biological Motion



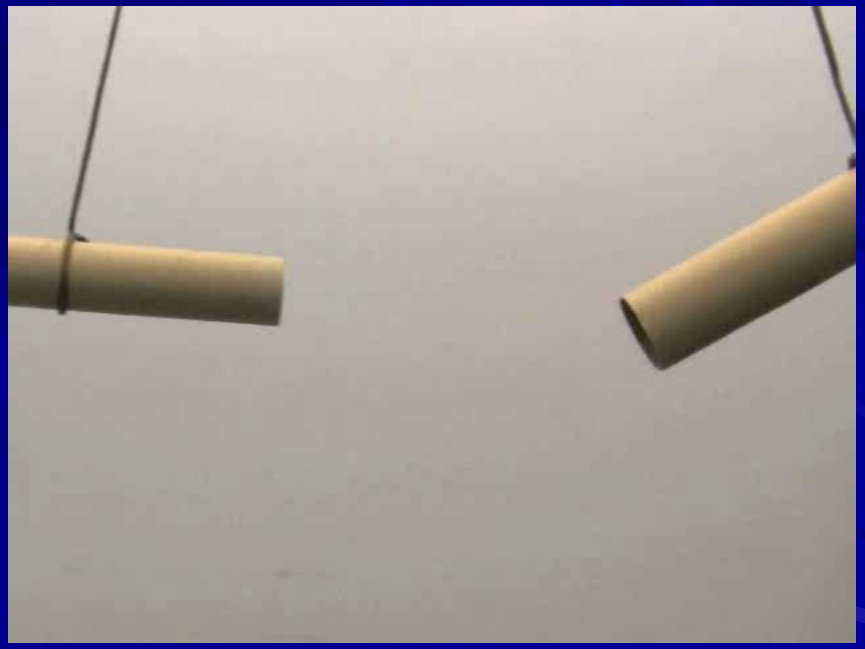
Non-biological Motion



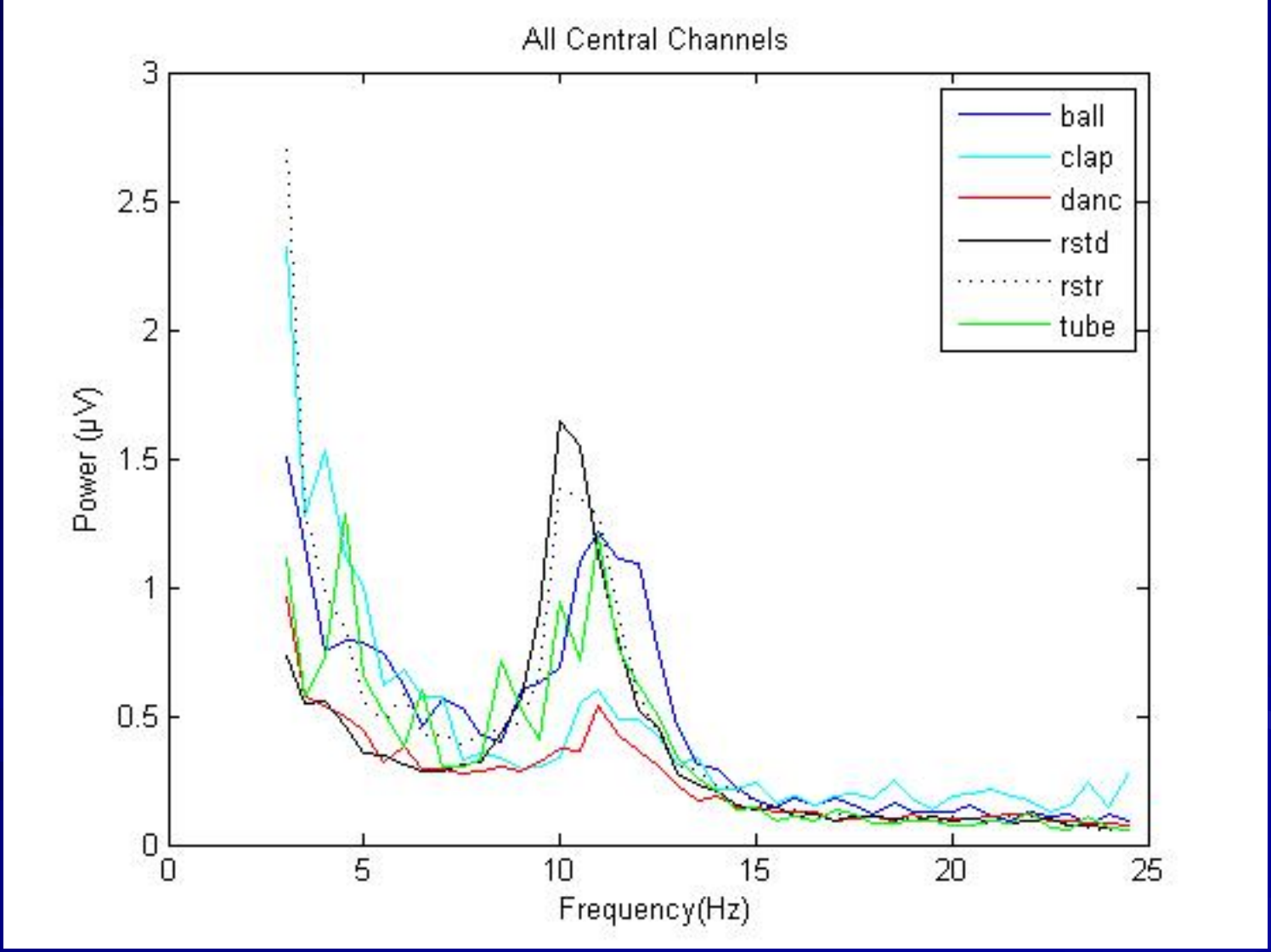
Twins

Biological Motion

Non-biological Motion

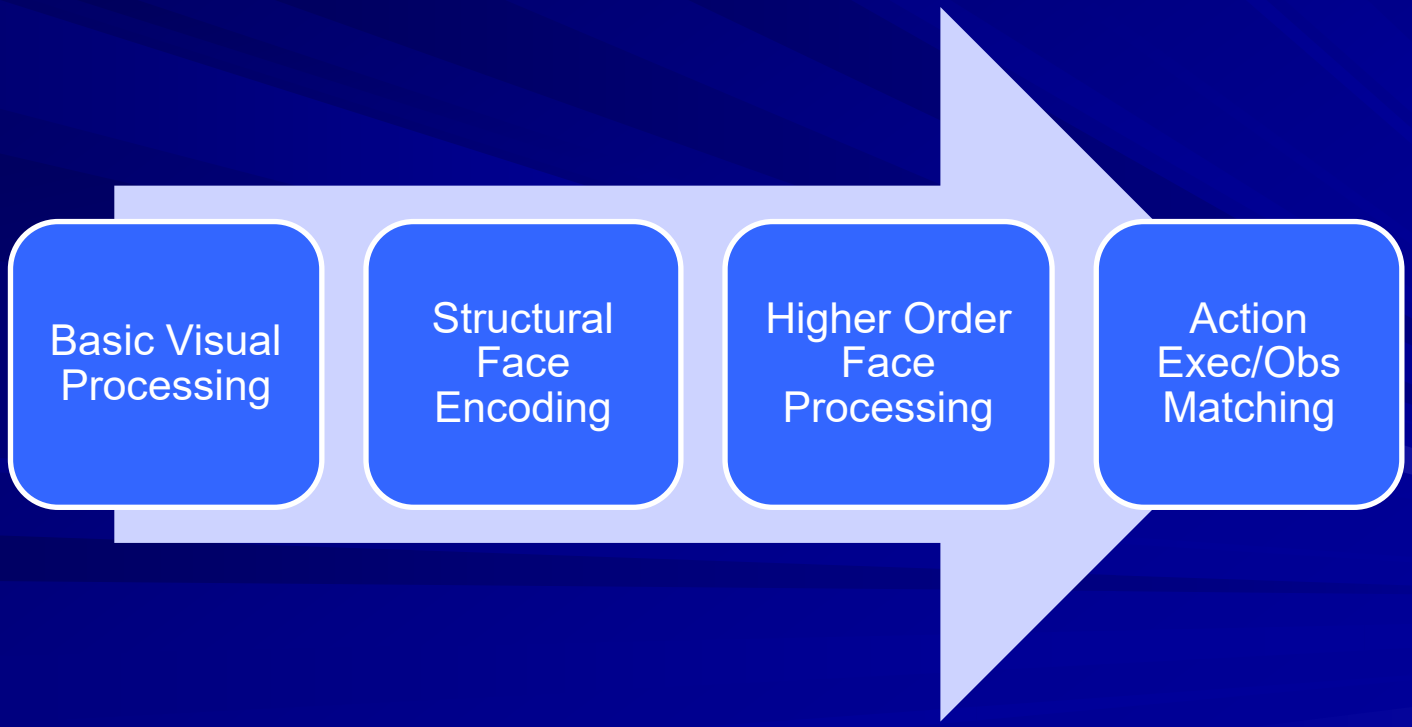


Twins


All Central Channels
Power (μV)
Frequency(Hz)
0
0.5
1
1.5
2
2.5
3
0
5
10
15
20
25
ball
clap
danc
rstd
rstr
tube

Social Connectivity

- Effective connectivity based on ERP/EEG components involved in face processing.



Social Connectivity

- Three types of face stimuli:

Non-emotional movement

Emotional movement

Impossible movement

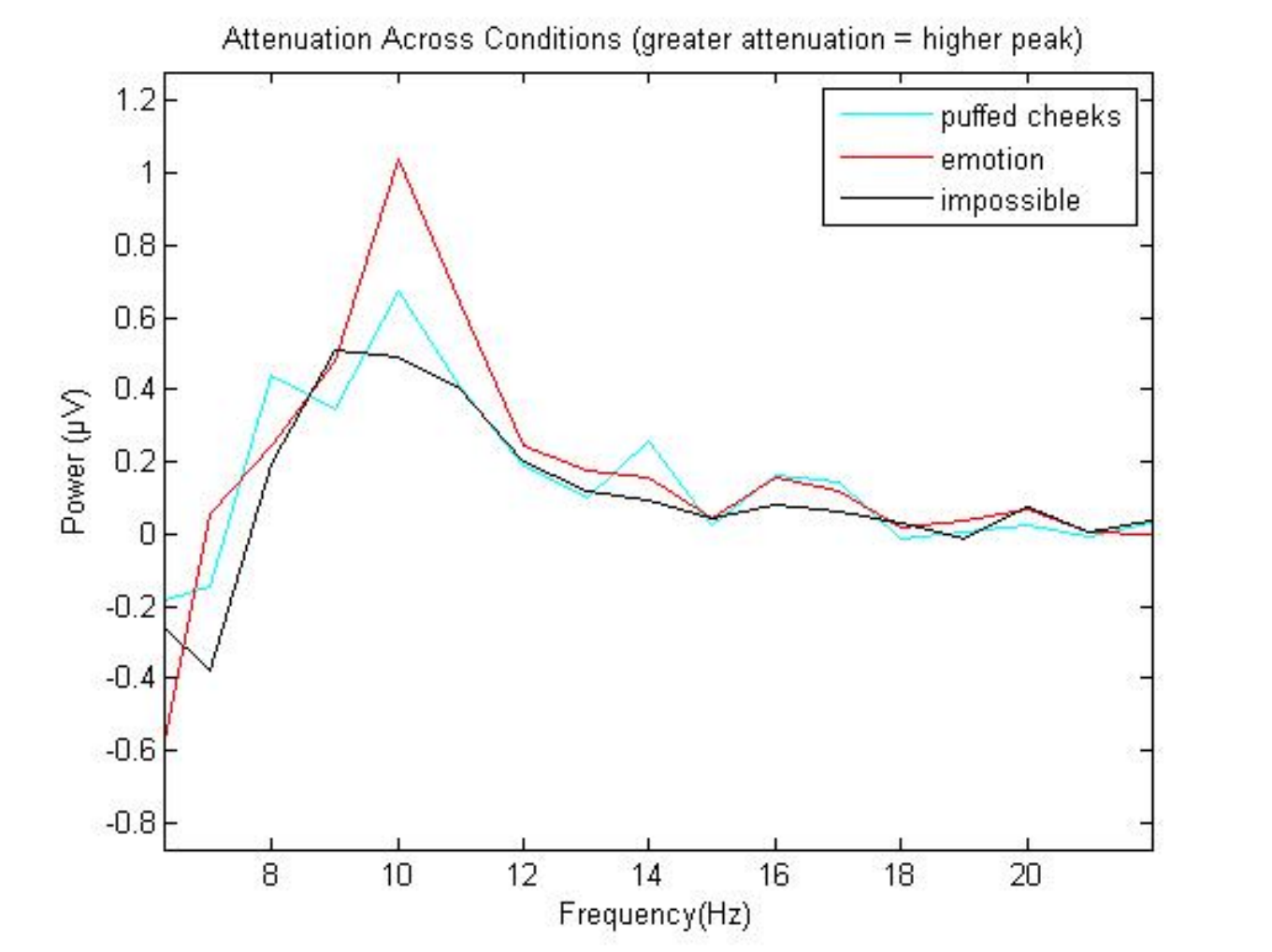
Social Connectivity

EMOTION

PUFFED CHEEKS

IMPOSSIBLE MOTION

Pilot data


Attenuation Across Conditions (greater attenuation = higher peak)
puffed cheeks
emotion
impossible
Power (μV)
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
8
10
12
14
16
18
20
Frequency(Hz)

So What????

- This system is functioning differently.
- Better understanding may help with:
  - Understanding the etiology of autism
    - Endophenotype?
  - Aid in early detection
    - Earlier is better.
  - Help focus intervention approaches
    - Physical demonstration over observation
    - Medication

Thanks to:

All the participating families

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- Evan Eichler, PhD
- Jack McClellan, MD
- Ellen Wijsman, PhD
- Wendy Raskind, MD
- Nicky Chapman, PhD

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AUTISM SPEAKS™ It's time to listen.

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Mirror Neurons and Autism

- Evidence for dysfunction:
- **Imaging:**
  - Dapretto et al, 2006
  - Hadjikhani et al, 2006
  - Williams et al, 2006
  - Martineau et al, 2010
  - Yamasaki et al, 2010
- **Electroencephalography:**
  - Oberman et al, 2005
  - Bernier et al, 2007
  - Bernier et al, 2007
  - Oberman et al, 2008
  - Martineau et al, 2008
- **Transcranial Magnetic Stimulation:**
  - Theoret et al, 2005
- **Electromyographic Activity:**
  - Cattaneo et al, 2007

- Evidence against dysfunction:
- **Imaging:**
  - Dinstein et al, 2009
- **Electroencephalography:**
  - Raymaekers et al, 2009
  - Fan et al, 2010