Social Cognition:
Mu Rhythms and Mirror Neurons

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Research Interest

- Understanding the behavior of others
  
  The capacity to achieve internal descriptions of actions and use them to organize one’s own future behaviors

- Neural mechanisms for understanding actions and their intentions

- The effects on learning and social interactions
Motivating Questions

- How do we understand the actions of others?
  - Rationally?
  - Intuitively?

- How do we understand first- and third-person experiences?
  - Perspective-taking?
Questions

- What are mirror neurons?
- Can they help us understand actions and their intentions?
- Are they important for social interactions?
- How do we study mirror neurons noninvasively?
- What happens when mirroring systems become dysfunctional?
Classic Explanation

- Theory-Theory
  (argument from analogy; disembodied knowledge; visual hypothesis)
  - Involves striate, extrastriate, inferotemporal lobe and superior temporal sulcus, among others
A New Perspective

- Simulation Theory
  (Direct-matching hypothesis; embodied knowledge)
  - Map visual information onto motor representations of the same action

- Mirroring systems
  - bridges between perception and action that allow for simulation
    - Mirror neurons
    - Mu rhythms

“every mental representation of a movement awakens to some degree the actual movement which is its object”

William James
Mirror Neurons and Mu Rhythms

Iacoboni and Dapretto, Nature Reviews, 2006, 7:942-951
An Observation/Execution Matching System?

- A dysfunctional “mirror system” produces problems in understanding actions

“every mental representation of a movement awakens to some degree the actual movement which is its object”

William James
Biological Motion

- Visual system's ability to recover object information from sparse input
- Gender
- Activity engaged in
- Emotional state
Perret and colleagues (1989; 1990; 1994) found that cells in superior temporal polysensory area (STPa) of the macaque temporal cortex appear sensitive to biological motion. 

Biological Motion Perception: Humans

- An area in the superior temporal sulcus (STS) in humans responds to biological motion.

- Other areas do as well, including frontal cortex, SMA, insula, thalamus, amygdala.

Brain Circuit for Social Perception (SP)

- SP is processing of information that results in the accurate analysis of the intentions of others

- STS involved in the processing of a variety of social signals

Mirror Neurons

- Found in:
  - area F5 of monkey (homolog of Broca’s area)
  - STSa
  - inferior parietal cortex (7b)

- Activated by:
  - Goal directed actions (reaching, grasping, holding)
  - Observation of similar actions performed by “biological” agents

- Do not respond to target alone or intransitive gestures (i.e., nonobject directed)
- Do not respond to mechanical movements

Mirror Neuron Activity

Perception-to-Action Mapping

**Perception**

**Action**

**Congruent**

**Logically-Related**
Understanding Intentions

Grasping

Mimicking


Functional Significance

- Response facilitation
- Mimicry
- Simulation
- Imitation learning
- Understanding actions
- Understanding intentions
- Empathy
- Theory of Mind
- Language
Characterizing the System

motivational significance?  generalizability?
intentionality?  biological realism?
transitive/intransitive actions?  anthropomorphism?  social relevance?
learning?

MNS Activity  No MNS Activity
Characterizing the System

motivational significance?  generalizability?
intentionality?  biological realism?
throughive/intransitive actions?  anthropomorphism?
social relevance?

Mu Suppression  No Mu Suppression

learning?
Rolandic “en arceau” rhythm
(7-11 Hz)

“...blocked when the subject performs a movement or simply when he changes his postural tone.”

“...disappears when the subject identifies himself with an active person represented on the screen.”
Mu Rhythm Characteristics

- Analog of the feline SMR (12-16 Hz)
- Maximal over sensorimotor areas
- Attenuated or blocked by movement
- Not affected by opening/closing the eyes
- Not affected by auditory/visual stimulation in the absence of movement

Frequency Analysis of Mu Rhythm

- (8-13 Hz)
- (10-14 Hz)
Does Mu Suppression Reflect Mirror Activity?

Baseline

Move

Observe

Imagine

Action Observation and Social Interaction

To what degree do mu rhythms, like mirror neurons, reflect social interaction?

Experimental Paradigm

- Measured mu power (2 min of EEG) in normals (n=20) ages 18-34 (mean=21.1, SD=3.40) under different observation conditions:
  - Non-interacting
  - Social Action - Spectator
  - Social Action - Interactive
  - Visual white noise

- Engaged in continuous performance task during observation
Non-interacting

Social Action - Spectator

Social Action - Interactive
Results

![Bar chart showing the degree of social interaction for different categories: Non-Interacting, Social Action, Spectator, and Social Action, Interactive. The y-axis represents the degree of social interaction, ranging from 0 to 4. The x-axis lists the categories. The chart indicates that the degree of social interaction is highest for Social Action, Interactive and lower for Social Action, Spectator and Non-Interacting.]
Understanding Facial Expressions

- Are mu rhythms sensitive to processing of facial expressions?

Thurman and Pineda, in prep
Understanding Facial Expressions

Disgust    Anger    Happy

Emotion versus gender discrimination task
Results
Results (cont.)

\[ r = -0.5 \]

\[ r = -0.04 \]

\[ r = 0.73 \]
Autism: A Dysfunctional Mirror System?

- Autistic spectrum disorders are characterized by:
  - Impairments in social interaction
  - Delayed/abnormal language development
  - Impaired imagination
  - Impaired imitation
  - Repetitive and restricted patterns of behavior

- No common underlying mechanism has been identified
  - Deficits in imitation learning – Rogers and Pennington, 1991
Hypothesis

If mu rhythms reflect MNS activity and the capacity to understand actions as well as learn through imitation, then autistics should show differences in mu rhythms compared to controls.

Oberman et al., Cog. Brain Res. 2005, 24: 190-198
Experimental Paradigm

- Measured mu power (2 min of EEG) in normals (n=12) and autistics (n=10) under different conditions:
  - Self-movement of hand
  - Watching video of someone moving their hand
  - Watching a video of a ball moving up and down

Results
Creating a Temporary “Autistic” Brain

- Do sensorimotor mu rhythms reflect downstream modulation from cells in premotor cortex?

RATIONALE

If mirror neurons in IFG are involved in the direct modulation of mu rhythms, then temporary inhibition of these neurons should prevent suppression of mu rhythms and cause “autistic-like” behaviors.

Pineda et al., in prep
Method

- Measured EEG mu power in typically developing adults (n=8) under different conditions before and after IFG stimulation
  - Observation of movement (4 videos)
    - Simple (hand movements) and complex (social interactions)
  - Baron-Cohen’s Eyes Task
    - Emotion and gender discrimination
- 1 Hz rTMS (5 min at ~ 40-50% MEP threshold) targeted at left IFG
Results

ACCURACY

PERCENT CORRECT

ET-EMOTION

ET-GENDER

CONDITIONS

PRE

POST

0

0.2

0.4

0.6

0.8

1

1.2

0.2

0.4

0.6

0.8

1

1.2
Results

IFG STIMULATION

MU SUPPRESSION

PRE

POST

C3

C4

SIMPLE

C3

C4

COMPLEX

MOVEMENT TYPE
Reversing Autism?

- Operant conditioning of the mu rhythm (10 weeks)
  - HF ASD: 7-17 yr olds; n=20

- Rationale
  - Changes in mu rhythm dynamics produces changes in MNS activity and in behaviors mediated by this system

- Experimental/Control groups
  - Mu activity above threshold (E)
  - EMG activity below threshold (E/C)

Pineda et al., in prep
Assessments

- Verification of diagnosis (IQ, ADI, ADOS)
- Quantitative EEG (QEEG)
- Test of Variable Attention (TOVA)
- Imitation ability (De Renzi’s Apraxia imitation test)
- Mu suppression index (MSI)
- Autism Treatment Evaluation Checklist (ATEC - parental assessment)
- Neuroimaging (fMRI, DTI, fcMRI)
Sustained Attention

- Reduction trend in ADHD score for experimental group

![ADHD Scores from TOVA](chart.png)
MU SUPPRESSION INDEX

LOG [CONDITION/BASELINE]

CONTROLS
EXPERIMENTALS

HAND SOCIAL HAND SOCIAL
PRE-TRAINING POST-TRAINING
A Fundamental Organizational Feature of the Brain?

“Understanding others as intentional agents may be grounded in the relational nature of our interactions with the world”

- Beyond understanding actions
  - emotions: the root of empathy?
  - sounds and other senses
  - language

- Other problems in “mirroring”
  - Aberrant imitation learning: addiction?
What Is It Like To Be…?

Can aspects of subjective experience be reduced to brain activity?

Collaborators and Students

- Vilayanur Ramachandran
- Lindsay Oberman
- Eric Altschuler
- Andrey Vankov
- Bill Skinner
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