The Role of Mirroring in Social Cognition

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The Challenge: What Is It Like To Be...?

- Is first person subjective experience of the other possible?
- How then do we understand the other?
- Can this subjective experience be reduced to brain activity?

Thomas Nagel, 1974

What is it like to be a bat?
Why Do Primates Have a Large Brain?

A slight increase in body size is accompanied by a much greater increase in brain volume.
Primates and humans live in complex societies, which is behaviorally and computationally very demanding → a big brain

Neocortex directly related to size of the social network or social complexity

"Dunbar’s Number" ~150
Human beings evolved big brains not to understand the world, but to understand each other.

Nick Humphrey
Profound Connections: ‘What is it like to be’ mechanisms

Neural systems for motor resonance, imitation, mimicry, emulation, coordination, empathy

“To understand the other we become the other”
Evidence supports the hypothesis that physical interaction evolved in vertebrates to help share potentially health-promoting bacteria (Tung et al., 2015)
How Do We Read Other Minds?

How do our brains perceive the mental states of others despite their inaccessibility?

How do we understand the actions, emotions, and intentions of others?

- Rationally?
- Intuitively?
Theory-Theory
(argument from analogy; disembodied knowledge; visual hypothesis)
Simulation Theory
(Direct-matching hypothesis; embodied knowledge)
- Map visual onto motor representations of the same action

Mirroring systems
- Perception-action mechanisms that allow for simulation
  - Mirror neurons
  - Mirror Neuron System

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

William James
Damage to Simulation Systems

- Autism
- Schizophrenia
- Sociopathy (antisocial personality disorder)
Mechanisms: Mirror Neurons

Discharge when the monkey performs an action and when it observes a similar action done by another agent

- **Found in:**
  - area F5 (homolog of Broca’s area)
  - inferior parietal cortex (PF/PFG/7b)

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

Di Pellegrino et al., 1992
Luppino & Rizzolatti, 2000
Simulating the How and Goal of an Action

- Congruent MNs encode *the kinematics of the action* (how an observed action is performed)
- Logically related MNs encode the goal of the action, *what it tries to achieve*, irrespective of *how it is* achieved
Simulating Personal and Extrapersonal Space

(a) visual paradigm

(b) extrapersonal stimulation

neuron 1

neuron 2

neuron 3

Rizzolatti and Fogassi, 2014
Simulating 1\textsuperscript{st} and 3\textsuperscript{rd} Person Perspectives

(a) 180°  90°  0°

(b) neuron 1

Rizzolatti and Fogassi, 2014
Network of neurons:

- Simulation
- Imitation learning
- Understanding actions
- Understanding intentions
- Empathy
- Theory of Mind

Provide the ability to understand and know ‘what it is like to be’ the other by simulating or becoming the other

Iacoboni and Dapretto, 2006
Why is the Human Homunculus Distorted?
In humans, the principal means for conveying socially relevant information involves facial expressions and hand movements.
Imitation of Hand and Facial Gestures
The Action-Perception or Mirror Neuron System

Iacoboni and Dapretto, 2006

Normal Oscillations at rest

MNS Activity --> Suppression

mu rhythm (8-13 Hz)
Mu Rhythm

- 8-13 Hz oscillation over sensorimotor cortex

- **Normal Oscillation**
  - No mirroring

- **Self Action**
  - Motor + Mirroring

- **Observed Action**
  - Mirroring only
Frequency Analysis: Suppression of Mu Rhythms

(8-13 Hz)

(15-25 Hz)
Autism Spectrum Disorders

(Leo Kanner, 1943)

Problems with:
- Social ability
- Language and communication
- Repetitive movements and restricted interests

adopted from a diagram by Daniel Rosenn, M.D. (1997)
Mindblindness Hypothesis

Social dysfunctions in high-functioning autism result from problems with ascribing mental states to others, including differentiating self from others (mindblindness)

Baron-Cohen, 1995
Common Characteristics of Mindblindness

- Impaired joint/sustained attention
- Impairment in social play and imagination
- Trouble imitating others
- Difficulty interpreting actions/intentions of others
- Inability to participate in a reciprocal conversation
- Absence or reduced empathy
- Delay in developing a theory of mind
“Autism is a cognitive and neurobiological disorder marked by under functioning integrative circuitry that results in a deficit of integration of information at the neural and cognitive levels.”

Just et al., 2004
Mindblindness results from dysfunctions in simulation systems, specifically, the mirror neuron system.

Williams et al., 2001
Atypical Connections within and between MNS and other networks

Fishman et al., 2014
Activation for Imitation of Facial Emotions

Dapretto et al., 2006
If EEG rhythms reflect mirroring/simulation and the capacity to understand actions, then children on the autism spectrum should show differences in these rhythms compared to controls.

Oberman et al., 2005
Experimental Paradigm

Measured EEG in normal children (n=12) and those with autism (n=10)

- Self-movement of hand
- Watching video of someone moving their hand
- Watching a video of a ball moving up and down

Oberman et al., 2005
Children with ASD Exhibit an Absence of Mu Suppression to Observation but not Execution of Actions
Is the Mirror Broken and Unfixable?
Creating a Temporary “Autistic” Brain

RATIONALE

Interruption of the MNS network (e.g., inhibition of neurons) should cause “autistic-like” behaviors and prevent suppression of mu rhythms.
Measured EEG in normal adults (n=8) before and after TMS

- Observation/execution of movement
- Baron-Cohen’s Eyes Task
  - Emotion and gender recognition
- 1 Hz rTMS (5 min) - left IFG
Eyes Task

playful

kind

surprised

thinking about something
Results

Reaction Time Accuracy

- Emotion Recognition
- Gender Recognition

Before IFG stimulation
After IFG stimulation
Absence of Mu Suppression

<table>
<thead>
<tr>
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<th>Mean amplitude in μV and SEM</th>
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<tbody>
<tr>
<td><strong>LIFG Pre</strong></td>
<td>![Bar chart data]</td>
</tr>
<tr>
<td><strong>LIFG Post</strong></td>
<td>![Bar chart data]</td>
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</tbody>
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* = $p < 0.05$
** = $p < 0.01$

- Non-biological
- Imitation
- Simple biological
- Complex biological
Neurofeedback Rationale

Changing the dynamics of the EEG via operant conditioning can induce brain changes to normalize connections.

This may in turn produce positive behavioral changes.
Normalizing Social Abilities in Autism

Amplitude Training at C4
- HF ASD: 7-17 yr olds
- 45 min x 2/week x 20 weeks

ASD/TD groups
- Mu activity (8-13 Hz) rewarded if above a threshold
- Theta and beta activity inhibit action if above a threshold

Pineda et al., Research in ASD, 2008
Assessments

- **Verification of diagnosis**
  - IQ, ADI, ADOS

- **Behavior Scales**
  - ATEC, Vineland, GARS, SRS

- **Cognitive Tests**
  - Test of Variable Attention (TOVA)

- **Electrophysiology Tests**
  - Quantitative EEG
  - Mu suppression index (MSI)
  - Emotion recognition

- **Neuroimaging**
  - fMRI, fcMRI, DTI
Training Produces Positive Changes in Parental Assessment

Autism Treatment Evaluation Checklist (ATEC)
Mu-Suppression to Observation in ASD Normalizes Following Training
Training Affects Functional Neuroanatomy
ASD group shows little activation before training

Bilateral premotor cortex

Inferior Frontal Gyrus

Inferior parietal lobule

TD > ASD

Alpha = .05
Post Training Activation

Training enhances activity in ASD group

Bilateral inferior parietal lobule

Bilateral Insula

Alpha = .05

Datko et al, 2012
Post Training Activation
Training does not affect TD group

No significant clusters!

Alpha = .05
Regions of Interest for Functional Analyses Within MNS

1. Right superior temporal sulcus
2. Left superior temporal sulcus
3. Right inferior parietal lobule
4. Left inferior parietal lobule
5. Right inferior frontal gyrus
6. Left inferior frontal gyrus
7. Right middle frontal gyrus
8. Left middle frontal gyrus
9. Right insula
10. Left insula
11. Supplementary motor area
Pre Training Resting State

TD

ASD

+ = overconnected
- = underconnected
Post Training Resting State

TD

ASD

R²

+ = overconnected

− = underconnected
Pre-Training Task

TD

ASD

+ = overconnected
- = underconnected

R²
Post Training Task

TD

ASD

R²

= overconnected

= underconnected

1. rMTG 2. IMTG 3. rSPL 4. ISPL 5. rIFG 6. IIFG 7. rMFG 8. IMFG 9. rINS 10. IINS 11. SMA

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Conclusions

I. Sociality and the brain
• “Humans evolved big brains not to understand the world, but to understand each other”…Nick Humphrey

II. Mechanisms for reading other minds
• Simulation systems allows us to perceive the mental states of others
• “What it’s like to be..” mechanisms to understand the other

III. Autism as mindblindness
• Neurofeedback produces positive behavioral changes
• Helps recover normal electrical activity
• Increases activation in MNS areas
• Reduces abnormal functional connections
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