Mirror neurons and beyond: Shared Circuits of Self and Other

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- The Mind-Brain Relationship, 2000 (Other Press).
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Clinical Cases

Sarah
“I deserve to be punished”

Lucy
“My baby hates me”
Self and Other…
Two sides of the same coin

We know others only in terms of our self
We represent behaviors, emotions, pain, sensation, mental states of others in the same brain regions we use for these same processes in ourselves.

Mirror neurons best studied shared circuit
We use shared circuits to process all aspects of self and other

Behavior

Emotion

Pain

Touch Sensation

Mental States
Main Point → Shared Circuits blur the boundary of Self and Other

- **Mirror Neurons** Motor Behavior
- **Insula** Emotion and Visceral-senses
- **Anterior Cingulate** Pain
- **Somatosensory Cortex** Touch
- **Mid-line default** Mental States
Shared circuits contribute to clinical issues *outside* of conscious awareness.

- Empathy, Internalization, Projection,
- Transference and Counter-transference
- Enactment
- Interpretation
Mind is a complex interaction of Brain & Body
Reality is Subjective

Beauty is in the eye of the beholder…

And so is everything else!
Background neuroscience necessary to understand shared circuits

- We don’t directly know the outside world
- We don’t perceive objective reality
- Brain actively constructs our perceptions each and every second of our experience
- This process is entirely non-conscious
Perceptual reality is constructed...

The brain constructs all perceptions.

It does this entirely outside conscious awareness!
Brain Constructs the World…Optical Illusion: Kaniza Effect

Does the white triangle really exist?...

Activity in visual cortex ‘represents’ the illusory shape!
We subjectively construct our perceptions of what is going on ‘inside’ others

1. **Somatosensory Cortex**… Touch
2. **Insula**… Emotion
3. **Anterior Cingulate**… Pain
4. **Mirror Neurons**… Motor Behavior
5. **Mid-line default**… Mental States
Touch
Somato-sensory cortex

When YOU get tickled I feel it too!
fMRI: Subject sees someone else get lightly touched

Activates somato-sensory cortex in observer

Figure F-3: Motor and Somatosensory Cortex

Motor cortex

Somatosensory Cortex

touch left > rest

touch right > rest

touch right > rest and touch left > rest
Overlap being touched vs observing touch
Pain & Emotion
Insula and Cingulate Cortex

Anterior Cingulate Cortex

Insula Cortex (under flap of Temporal lobe)

Activated with Pain & Emotion...Self & Other
Subjects in fMRI...Ant. Cingulate & Insula

ACC & INS Pain/Emotion..Self/Other

INS links internal/external sensory with limbic system

ACC= Anterior cingulate cortex  INS= Insula
Shared Circuit of Emotion >> Insula
“Your disgust is my disgust”

**Red** activated during the experience of disgust

**Green** activated during observing other’s facial expression disgust

**Yellow** zones common to disgust in self and seeing someone else's expression of disgust

[Gallese V., et al
*Trends in Cognitive Sciences, 8: 396-403, 2004.*]
Social Relationships: Mirror Neuron System

- Representing the actions of others
- Understanding intentions of others
- Imitation of others
- Empathy for others
Mirror Neuron System
Action Representation

- Seeing someone perform an action activates same pre-motor circuits that are activated when we ourselves perform that same action
- MNS “action-observation” system to represent the actions of others
Mirror neurons discovered by accident

Pre-motor neurons active when monkey observes researcher licking gelato. Activity stops when researcher stops licking.
Mirror Neurons in monkeys respond to goal-oriented action only

(a) Goal directed
(b) No observable goal

(a) Goal directed
(c) No observable goal
Mirror Neurons in humans represent both goal directed and non-goal directed action.

Mirror neurons active performing action & observing action.
Human MNS/ ventral pre-motor cortex
...Acquire and Understand Language...

X = Ventral pre-motor cortex

"Broca's Area"
Mirror Neurons Develop Early

Imitation => Observe action & perform action

Children learn more from imitation than instruction
Mirror Neurons Represent Both…

BEHAVIOR & INTENTION

When we observe a behavior we automatically infer the intention that underlies behavior.

Behavior: Shake hands and smile… Intention: to be friendly

(Frith and Frith 1999; Ruby and Decety 2001).
Mirror Neurons: Understanding actions and intentions of others…Action-Simulation system

How I know what you do & why you are doing it.

• Observe someone perform action, activates same pre-motor areas in our brain that are active when we perform that action.

• MNS linked limbic centers in brain which determine intentions

• I know your intention because I know what my intention would be if I were performing that same behavior.
MNS active with **IMITATION**

- **Imitation** core of social cognition
- **Social cognition**- empathy, mentalization
- **Chameleon effect**- humans tend to imitate each other automatically when interacting socially... via MNS
- **Empathy**- MNS activity with imitation... linked to limbic system
- **Autism**- MNS (pfc) has decreased activity during action observation. This correlates with severity
Observation vs. Imitation
Observe but NO imitation

- PFC sends inhibitory signal to motor areas
- *No* overt action is taken by observer
- Small increase of motor evoked potentials measurable in the muscles of the observer
- Matching facial expression of emotion…imperceptible muscle activity may signal non-consciously… “I got it!”
Observation vs. Imitation

Observe AND Imitate

Imitation = Observation + Action

- No inhibitory signal sent by PFC
- Pre-motor signal/ motor area activates muscles
- **Voluntary** action can occur
- Imitation: How we learn without instruction

Brain immature or damaged >> Observe + act

- Young children/people with brain damage,
- No inhibitory signal given by PFC
- **Involuntary** action occurs
Fronto-parietal mirror areas for imitation

Frontal motor aspect & goal of action

STS codes visual aspect of action

PFC codes kinesthetic aspect of action

Iacoboni and Dapretto
Nature Reviews Neuroscience, 2006
Mirror Neuron System: 3 areas, each process different aspect of observed behavior

- Prefrontal Cortex • Motor
- Superior Temporal Sulcus • Visual
- Inferior Parietal Lobule • Somato-sensory
WHO performed the action?

If my MNS becomes activated when I observe you, how do I know it was you performing the action and not me?
Mirror Neuron System
How we tell self action from other action

OBSERVE

STS (Visual)

Pre-motor cortex (Motor)

IPL (Somato-sensory Feedback)

Motor cortex & Muscles

IMITATION

Self vs. Other
We recognize the intentions of others with our mirror neurons

"Grasping the Intentions of Others with One's Own Mirror Neuron System"
Marco Iacoboni, et al (2005, PLOS journals)
Signal in inferior frontal mirror area
Intention of action: results of fMRI

Intention = action in a context

Intention activates MNS more than either context or action alone

Marco Iacoboni, et al (2005, PLOS journals)
Maurice Merleau-Ponty: Phenomenology of Perception, 1945

“It is as if the other person’s intentions inhabited my body and mine his.”

Iacoboni et al, 2005
Mirror neurons respond to sounds of action

Mirror neurons respond to sight of someone cracking nuts, but also simply to the sound alone of the nuts cracking.

[Molnar-Szackas et al. 2004]
Mirror Neurons respond to sound of action

Sounds of actions activate mirror neurons
Emotion: Mind and Body

- Emotion is a subjective feeling = motor action + body physiology
- Feelings e.g. happy, sad, angry
- Motor actions: facial expression, gesture
- Body physiology: heart, GI tract, muscles
Mirror Neurons and Emotion

• Automatic matching non-verbal cues of emotion
• Observe facial expression or body gesture of Other
• Motor activity is represented in our own MNS
• We recreate their facial expression and body gesture within our own brain
Mirror Neurons, Emotion and Empathy

- **Match** NV cues of emotion with MNS
- **MNS** connects to Limbic system via Insula
- **Insula** activates body physiology of emotion
- **Limbic System** generates emotional meaning of events
- **Empathy** occurs because we activate the other’s emotion and its meaning inside ourselves
Shared Circuit of Emotion & Empathy

1. Other’s facial expression/gesture is linked with their body physiology & emotion

2. We observe facial expression/gesture of emotion in Other

3. Recreate their motor action in our MNS

4. MNS $\rightarrow$ Insula $\rightarrow$ Limbic system

5. Activate Other’s body physiology and emotion in our Self.
Mirror Neurons, Facial Expression & Empathy
Carr, L. et al PNAS | 2003

Subjects in fMRI scanner observe or imitate facial expression of emotion. Activates similar brain areas: MNS, Insula, Amygdala

- Imitation>>> activity compared with Observation
- Empathy: Feel what others feel by representing their emotional expressions in same motor, visceral, emotional regions we use for our own feelings
Mental States: only humans capable of representing mental states of others

- Intentions, beliefs, attitudes, emotions
- Subjective, internal, intangible, *in the mind*
- Can only be *inferred* from what we observe, hear or know about a person
Mental States and Shared Circuits:

- Reflecting on mind of other uses same brain system as when we reflect on our own mind.
- We understand what is going on in the mind of the other, based on what would be in our own mind in the same situation.
- Ability to reflect on mind of other: Mentalization, TOM, Reflective Function.
Development of Theory of Mind…Where will Sally look?

- Sally puts her ball in the basket
- Sally goes away
- Anne moves the ball to her box
- Where will Sally look for her ball?
Default System: Self in World at Rest

1. Cerebral hemisphere
2. Corpus callosum
3. Thalamus
4. Midbrain
5. Pons
6. Cerebellum
7. Medulla oblongata

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8. Medial PFC
9. Posterior Cingulate
10. Precuneus

Default System: set of medial brain structures which show high tonic activity when person is at rest 8,9,10
Default System

High ‘tonic’ baseline activity at rest

- Activity: cognitive tasks & goal oriented action
- Less activity: cognitive task related to self
- Default links sensory, emotion, and meaning and serve as low level ‘background’ awareness system

*PNAS* 28: 676-82.

*PNAS* 98 4259–4264.
Default System: Self Mental State

- Cognitive task: focus on self mental state (introspection, day dreaming)
- VMPFC: ↓ activity from resting state
- DMPFC: ↑ over rest state

Default System
Mental State of Others

- Even more over baseline when reflect on relationship to Others

- Autism: high baseline activity fails to deactivate with tasks.

Medial Default System

Mirror Neuron System vs. Default System

Default...
- midline
- mental states of self and other

Mirror Neurons...
- lateral
- represent actions of self and other

MNS and Default System both contribute to different aspects of self and other
Self-Other Differentiation… MNS & Default System contribute to *different* aspects of self & other

- **Experiment:** Task is to determine if a morphed face is more like self or more like other.

- More like **self** MNS shows increased activity
- When it is more like **other** Default System shows increased activity.
- In both cases brain is matching morphed face with internal representations of self and other

[Uddin et al; self other recognition/2005]
Clinical Issues: Seeing and hearing others activates same processes in ourselves as is going on in them: behaviors, emotions, sensation, mental states

• Infants of depressed mothers exhibit same EEG pattern of depression as mother...gets better when mother’s depression is treated.
• Effects on therapists: too much empathy, projective identification
Clinical Implications: attunement, empathy, affect regulation

- Activity of shared circuits UNCONSCIOUS
- Recreate the emotion of Other in Self
- Children internalize emotional state of caretakers......positive & negative
- Children learn by imitation and instruction
- Children understand intentions from observing actions more than spoken words
- We react more to intentions than to words
“What is past is prologue”
The Tempest, Wm Shakespeare

- Early childhood experiences with caretakers shape the inferences we make about what is going on inside the Other.

- When we encounter people in our current life, these learned inferences from the past bias how our brain constructs our subjective experience of them now.
Clinical Implications What can go wrong as a result of unconscious activity of shared circuits.

- **Interpret** actions, intentions, emotion, of others using shared circuits *correctly* most of the time.

- **Can be wrong**! Mis-interpret Others
  - If we have had pathologic experience
  - Mother smiled with hostility
  - Father who loved us also beat us

- **Projective Identification**: too much empathy? Can’t differentiate self/other
Psychoanalysis reveals consciously… what was only known unconsciously

“And the end of all our exploring
Will be to arrive where we started
And know the place for the first time.”

T. S. Eliot  *Four Quarters, Little Gidding, pt. 5*
In conclusion

• Self and other are separate

• But are more intertwined than we ever before realized.

The End


