Imitation, Empathy and Mirror Neurons

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Introduction

- ‘Theory and empirical data reinforce each other’
- A review of various studies, some of which you may have heard before
- Looking at the models that fit best with recent neuroscience findings

Sensory-Motor Framework

- Theory of action: Sensory-motor framework of action:
  - Actions initiated in response to stimuli
  - Action and perception have *separate* representational formats
  - Stimuli translated to motor responses via stimulus-response mapping mechanisms

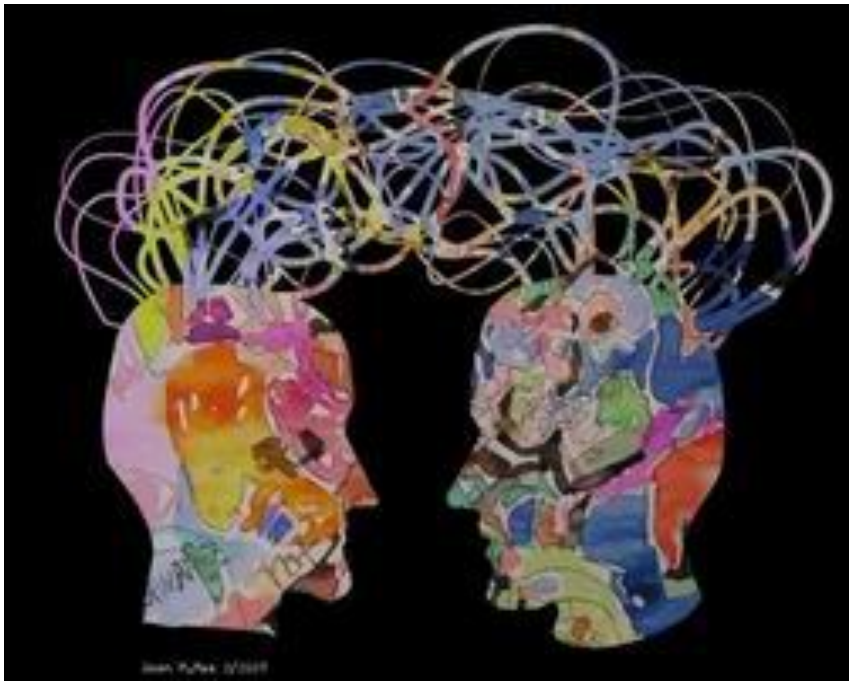
Problem: Doesn't account for similarity between observed action and the action performed by the imitator.

Problems with Sensory-Motor Framework

- The Correspondence Problem: How is sensory input from somebody else's action transformed into matching motor output by the imitator?

Ideomotor Framework

- Solves the correspondence problem:
  - Assumes common representational format for perception and action – translational processes become unnecessary



Ideomotor Framework

- Starting point of actions is a representation of the goal that the agent intends to achieve.
    - In contrast to being a response to sensory stimulation
- There is co-activation of the intended goal and the motor plan required to achieve it.
    - The co-activation is a result of **experience**: we have learned effects of our own actions and expect certain effects when we perform certain acts

Ideomotor Framework and Imitation

- Brass et al. : Subjects shown upward and downward movements of fingers and asked to respond as fast as they could with a motor response (finger movement):
  - Results demonstrated faster reaction times for responses identical to stimuli
  - In line with ideomotor framework

Ideomotor Framework and Goals

- Framework predicts goals having a higher priority than movements in imitation.
- Bekkering et al. Children asked to 'Do what I do' in two different conditions:

  - One condition the experimenter moved their arms across the table in a certain way

  - The other condition the experimenter covered up a red dot on the table with their hands

Associative Sequence Learning

- Imitative abilities are based on associations between sensory and motor representations of actions
  - Associations shaped by experience
  - Imitation is not based on a dedicated functional/ neural mechanisms

- Shares with the Ideomotor Framework the assumption that our perceptual and motor experience is important in shaping the functional aspects of imitation.

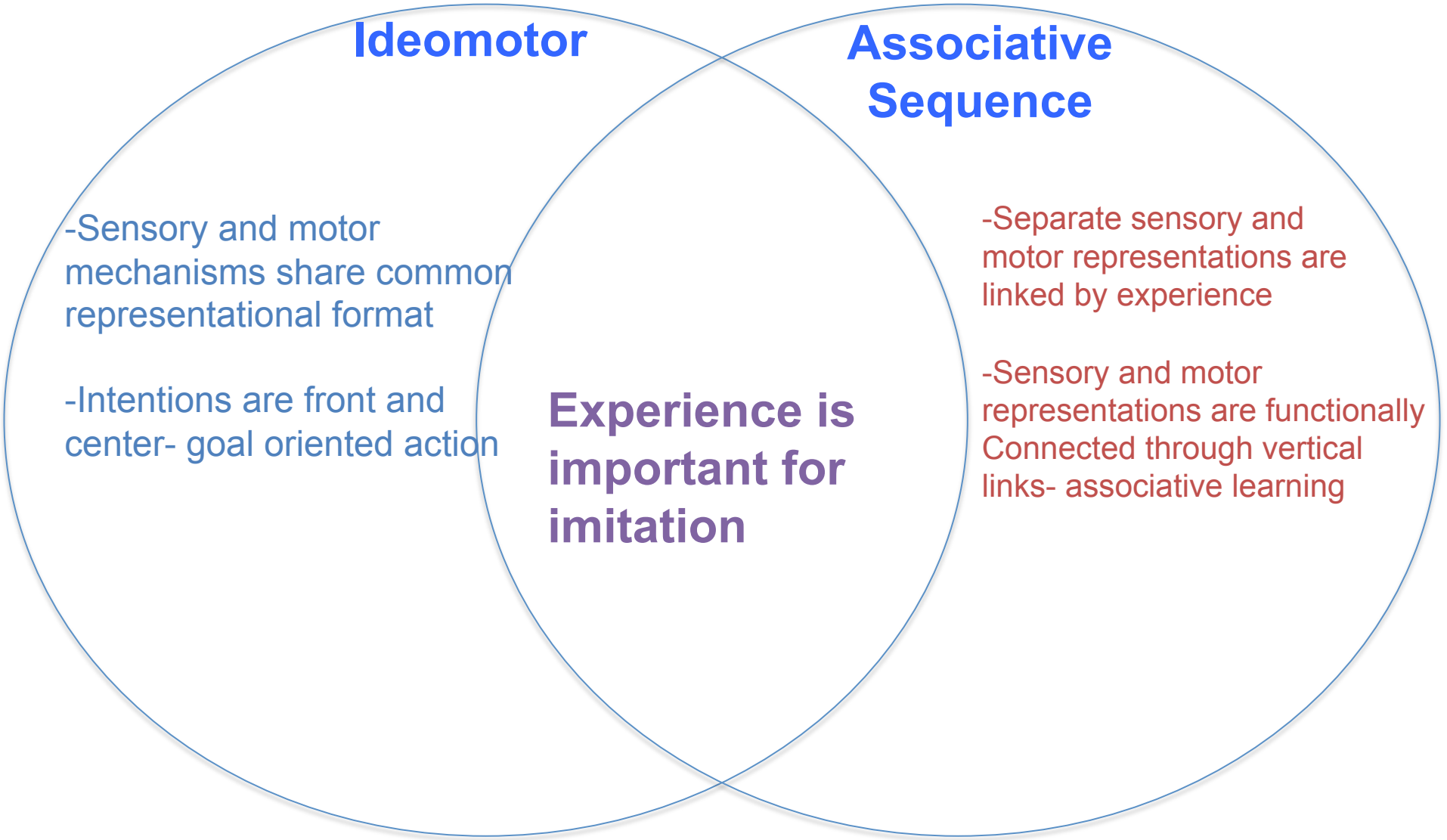
Associative Sequence Learning and Imitation

- Imitation abilities are developed by sensory and motor systems through *Hebbian Learning*
    - "Fire together, wire together"
- Imitation is (mostly) shaped by experience
    - Various species show the ability to imitate
    - The ability to imitate is shaped by environments, different environments account for differences in imitative abilities seen across species

Associative Sequence Learning and Experience

- Heyes et al: Subjects can be trained to open hand while observing a hand closing and vice versa
- Press et al: Subjects can be trained to respond to robot movements just as fast as they respond to human movements

Ideomotor Framework vs Associative Sequence Learning



Imitation and Empathy in Social Behavior

- Imitation is pervasive, automatic, and operates on a complex level

- Dijksterhuis proposes two roads to imitation:
  - Low road: imitation in direct fashion
  - High road: complex, subtle forms of imitation

High Road of Imitation

- Bargh et al. 1996
- Ppts performed scrambled sentence language task
- Some exposed to words associated with the elderly
- Results: ppts primed with elderly stereotype walked slower to the elevator than control group
  - i.e. primed ppts imitated the slowness of elderly people

High Road (Cont'd)

- Dijksterhuis et al., 2000
- Ppts sat in front of desk full of objects
- Primed with elderly or college student stereotype
- Results: when asked to recall objects on desk, ppts primed with elderly stereotype remembered far less

High Road (Cont'd)

- Dijksterhuis & van Knippenberg, 1998
- Ppts thought and wrote about college professors or soccer hooligans
- Results: college professor group performed better on a general knowledge task

Why Pervasive and Automatic?

- Facilitates social interaction
- Increases connectedness and liking
- Gets people closer to each other & fosters mutual care

Therefore…

Good imitators → Recognizing emotions → Greater empathy

Imitation and Empathy

(Chartrand & Bargh, 1999)

- Experiment 1: Imitation and Automaticity
  - Choose pic in set of photographs
  - Confederate in room performs same task as subject
  - Confederates tapped their nose or shook their foot
  - Results: subjects unintentionally mimicked motor behavior of confederate
  - Supports idea that imitation is automatic

Imitation and Empathy

(Chartrand & Bargh, 1999)

- Experiment 2: Imitation and Likability
  - Subject and confederate choose pic
  - Take turns describing
  - Confederate imitated subject or remained neutral
  - Subjects complete questionnaire
  - Results: subjects liked confederates that mimicked behavior more and rated smoothness of interaction higher
  - Imitation and liking go together

Imitation and Empathy

(Chartrand & Bargh, 1999)

- Experiment 3: Imitation and Empathy
  - Same as experiment 1
  - Subjects completed questionnaire on empathic tendencies
  - The more the subject imitated confederate the more that subject was an empathic individual

  - Imitation → Recognizing emotion → Respond compassionately

Neural Mechanisms of Imitation

- Macaque
  - Premotor cortex (PMC)
    - Planning, preparation, and selection of movements & coordinated actions
  - F4 & F5
    - Mouth and hand movements, especially grasping
    - F5 neurons discharge when performing & observing action
    - Called Mirror Neurons

Occluded Actions

(Umilta` et al., 2001)

- Observes grasping → MNs discharge!
- Observes pantomime → MNs don't discharge!
- Screen occludes grasping →MNs discharge!
- Screen occludes pantomime → MNs don't discharge!

- Same visual input coded differently based upon prior knowledge

MNs are multimodal & shaped by experience

- Kohler et al , 2002
- Discharge at sound of action alone
- Perhaps MNs facilitated emergence of language

- Early experiments showed MNs didn't fire when observing tool use
- Recent study shows otherwise
  - Due to observation of tool use by human experimenters?

Macaque Mirror Neurons and Imitation in Monkeys

Monkey see, monkey do?

•Experiment 1: Marmosets watched a demonstrator remove lids from various plastic containers to obtain a meal worm. Those that observed the demonstrator remove lids using only his hands used only their hands whereas those that watched a demonstrator use his mouth, also used their mouths (Voelkl & Huber 2000).

•Experiment 2: Marmosets observed a model marmoset who was trained to open a box in a particular way. Motion analysis revealed that the "highly unusual movement pattern of the model was faithfully replicated by observers" (Voelkl & Huber 2007).

*This is contradictory to other studies that show monkeys imitate the goal rather than individual movements.

•Experiment 3: Recent study shows that rhesus macaques display neonate imitation abilities similar to those of human neonates (Ferrari et al 2006).

We know imitative learning is not as developed in monkeys as in humans so what is the main function of MNs in the monkey brain?

- Facilitate ability to recognize actions of others
- Recognize when they are being imitated
  - Monkeys observed two experimenters manipulating a wooden cube with a hole in each side→ displayed no preferential looking
  - Monkeys manipulated the cube while one experimenter imitated the monkeys actions and the other did random actions → monkey preferentially looked at the experimenter imitating her own actions (Paukner et al 2005)
- Important social function
- Early precursor of imitative behavior of humans?
  - May be related to studies that show humans tend to prefer those that imitate them.

Human Brain Mechanisms of Mirroring

- Mirror neurons in humans are studied at the systems level using lesion studies, brain imaging and transcranial magnetic stimulation (TMS)
- Early findings: Ventral premotor and inferior frontal cortex display mirroring properties (Two positron emission tomography and a TMS study- Grafton et al 1996, Rizzolatti et al 1996, Fadiga et al 1995)

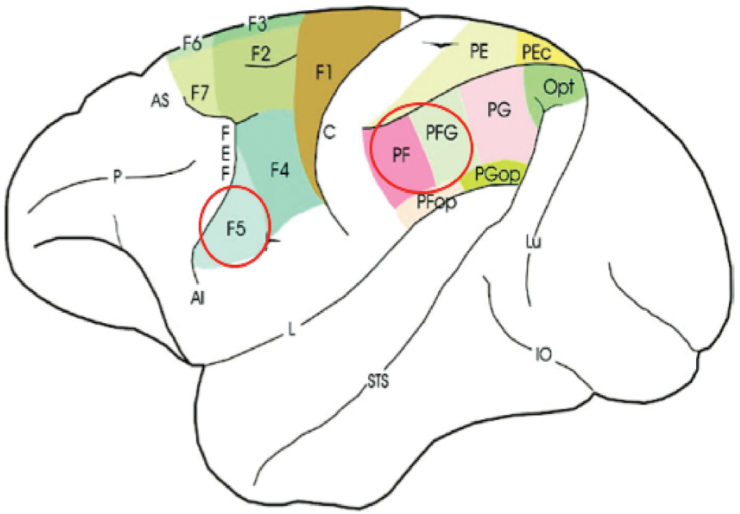
So what about imitation?....

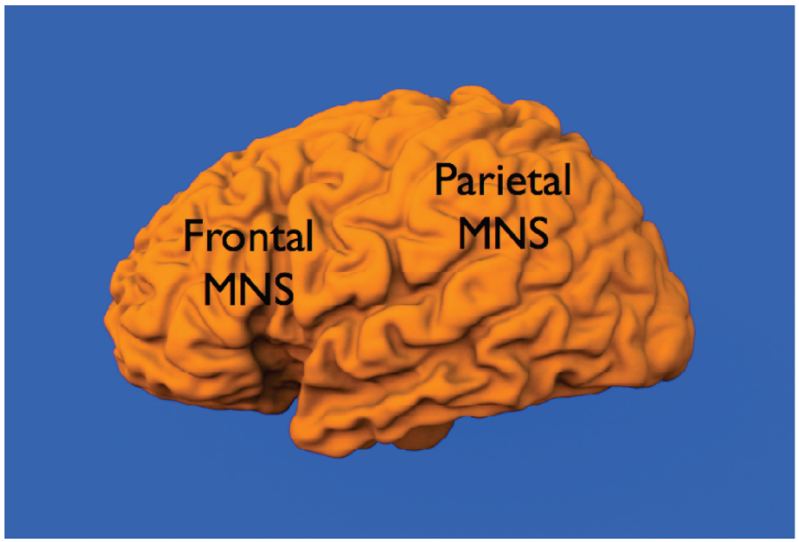
Human Mirror Neurons and Imitation

- Experiment: fMRI study required subjects to imitate simple finger movements and perform visual and motor control tasks (Iacoboni et al 1999)
  - Prediction: Brain areas with mirror neurons should have an increased BOLD signal during action observation that is approximately 50% that measured during action execution.
    - BOLD signal (action observation) = ½ BOLD signal (action execution)
    - Based on depth electrode recordings in macaques with similar results
- During imitation, subjects simultaneously watched the finger movement while copying it
  - Prediction: Mirror neuron areas may have a BOLD signal increase during imitation that is approximately equal to the sum of the BOLD signal increase observed during action observation and during action execution.
    - BOLD signal (imitation) = [BOLD signal (action observation) + BOLD signal (action execution)]

Human Mirror Neurons and Imitation

- Results: Two cortical areas displayed this pattern of activity:
  - Posterior part of the inferior frontal gyrus
  - Rostral part of the posterior parietal cortex
    - Homologues to macaque brain areas F5, in the ventral premotor cortex, and area PF/PFG in the rostral sector of the inferior parietal lobule





Additionally…

- The inferior frontal area with mirroring properties overlapped with the posterior part of Broca's area
  - Supports the evolutionary hypothesis of mirror neurons in language (Rizzolatti & Arbib 1998)
  - Or, activation in a language area during a nonlanguage task may be due to covert verbalization during the activation task.
  - TMS study showed that activity in the pars opercularis, the posterior part of the inferior frontal gyrus, is essential to imitation (Heiser et al 2003)

Core Cortical Circuitry for Imitation

- Posterior part of superior temporal sulcus
  - Responds to watching biological motion and intentional actions (Allison et al 2000)
  - STS provides a higher order visual description of actions of others and feeds this info to the fronto-parietal mirror neuron areas
- Parietal mirror neuron area
  - Code motor aspects of action
- Frontal mirror neuron area
  - More concerned with goal of the action

Interactions With the Core Circuitry and Other Neural Systems

- CC and dorsolateral prefrontal cortex critical for imitative learning (Buccino et al 2004)
- CC and limbic system support social mirroring and the ability to empathize
  - fMRI study of imitation and observation of facial emotional expressions found that empathy is enabled by a neural network composed of the mirror neuron system, the limbic system, and the insula (Carr et el 2003)
    - Mirror neurons support the simulation of other people's expressions in the observer →triggering the limbic system→ producing the emotion in the observer that other people are feeling
  - Increased activity in mirror neuron areas during imitation also spread to insula and limbic areas (Carr et al 2003)
  - fMRI study of imitation of facial expressions in children with autism vs typically developing children show a deficit in mirror neurons in children with autism as well as a direct correlation between the severity of the disease and activity in these areas (Dapretto et al 2006)

Theories & Neuroscience Evidence

→ **IDEOMOTOR MODEL:** single format for both perception and action

≠

→ **ASSOCIATION SEQUENCE LEARNING MODEL:** the format of perceptual representations are not the same as that of action's representations.

Which model is supported better from the neuroscience findings?

Evidence Supporting Ideomotor Model

- Similar discharges of mirror neurons during both observation task and execution task (same action)

- Similar firing-rates also in humans:

  -Frontal lobe

  - Medial Temporal lobe

Evidence Supporting Associative Learning Model

Clinical evidence:

-Frontal lobe → motor deficit
-Medial temporal lobe → perceptual deficit

⇒Similar discharges of neurons in the frontal lobe and in the medial temporal lobe might be due to the

VERTICAL LINKS

↓

ASSOCIATIVE LEARNING

What is the adaptive advantage of having mirror neurons?

→ How to solve the PROBLEM OF OTHER MIND?

1. Classica explanation: ARGUMENT FROM ANALOGY, that is to find a relation between: - our mental state/body state
   - our body state/other people body state

If there's a link ↓

Our body state
↕
Our mental state

↔

Other people body state
↕
Other people mental state

2. Mirror neurons:

Our pattern of MNs activity

MIRRORS

other people's pattern of MNs activity

⇒ Understanding of other people:

- through automatic imitation
- no effort

Studies concerning mirror neurons generally provides evidences about:

- IMITATION
- EMPATHY

Regarding this review, it appears that our social understanding has been built by a 'bottom-up' process:

MNs

(temporal/parietal system)

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ASSOCIATIVE LEARNING

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EMPATHY

Thanks for your attention!

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