Hierarchically Organized Mirroring Processes in Social Cognition: The Functional Neuroanatomy of Empathy

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Motivation

- Review the complex literature on the neurobiology of empathy
- Relate it to MNS

Starting Assumptions

- Empathy is the glue that makes human society possible
- Empathy, like many social cognition processes, is mediated by mirroring processes
- Mirroring refers to functions that allow us to map domains and understand the meaning of actions and emotions by internally replicating them

Social Cognition

- Processes with mirroring-like properties occur in a continuum at all levels of information processing in the CNS
  - Stimulus enhancement, response facilitation, emotional contagion, mimicry, simulation, emulation, empathy, and theory of mind
- Most of these processes occur in other species
- The organization of this hierarchy is dynamic and modifiable
- Levels are interdependent as well as partially dissociable

- Needed an organizing principle or set of principles to place empathy in a proper context of neural system functioning
  - Phylogenetic continuity and discontinuity
  - Cognition as a hierarchy

What is Empathy?

- Blair (2005) argued that there are at least 3 major components to empathy (based on autism and psychopathy studies)
  - Cognitive
  - Motor
  - Emotional

Other Views

- Preston and de Waal (2002) come at it from a comparative ethology perspective and see empathy as:

"a super-ordinate category that includes all sub-classes of phenomena that share the same mechanism and includes emotional contagion, sympathy, cognitive empathy, helping behavior, etc"

Our View

- Empathy is a super-ordinate construct incorporating cognitive, motor, and emotive subcomponents but in a loose collection of partially dissociable systems that evolve out of a rich repertoire of more fundamental processes

BOX 1. Definition of terms

emotional contagion:	the involuntary adoption of another's posture/mannerism/emotion.
emulation:	the increased ability to reproduce an observed goal (not the kinematics of the movement).
imitation:	reproduction of the exact goal and precise kinematics of movement, based on priming, such that a significant elevation in the frequency of an observed action occurs.
mimicry:	adopting the same behavior or emotion that is observed.
mirroring:	process that allows direct understanding of the meaning of actions and emotions of others by internally replicating or simulating them without any explicit reflective mediation.
priming:	increased accessibility to a representation based on prior activation of that representation.
response facilitation:	the increased likelihood of voluntarily or involuntarily performing the same action following observation of that action.
simulation:	same as mirroring but applicable when "observed" object is not present.
stimulus enhancement:	the increased tendency to pay attention to a place or object after observing actions at that place or in conjunction with those objects.
social contagion:	an increase in the motivational homogeneity of a group increasing the tendency to perform the same behaviors at the same time.
theory of mind:	ability to represent one's thoughts, beliefs, knowledge, and internal processes, as well as those of others; often depends on empathic processes.

Empathy & ToM

- Relatively independent of each other (Singer, 2006); others argue that it's a gradient
- Emotional empathy: relies on phylogenetically older limbic & paralimbic areas
- Motor empathy: relies on MNS
- Cognitive empathy (ToM): relies on evolutionarily younger neocortical areas
- Psychopaths show impaired emotional responses but no deficits in ToM

Phylogenetic Continuity

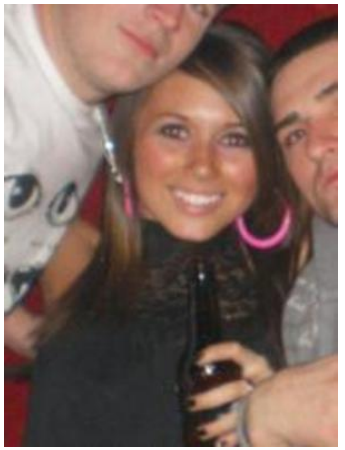
- Before language, nonverbal communication was the method of transmission of information → importance of "body language"
- Emotion and recognition of emotional signals is critical
  - Universal human emotions (Ekman, 1972; anger, disgust, fear, happiness, sadness and surprise)
  - Chimps can discriminate Ekman's basic categories
  - Chimp's heart rate changes based on emotional vocalizations of others

Emotions

- Negative
  - Fear
  - Anger
  - Grief
  - Hate
- Positive
  - Love
  - Empathy
  - Caring
  - Joy

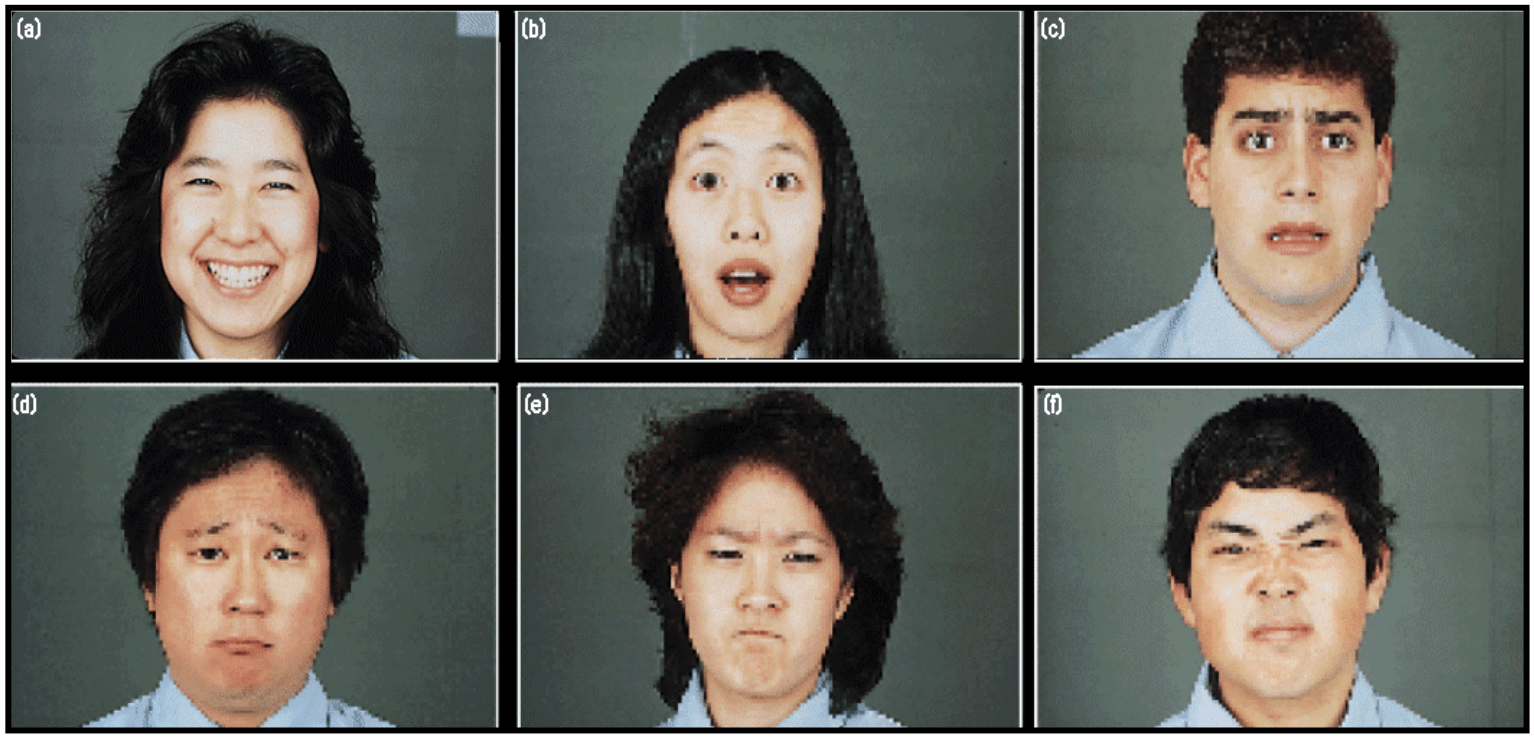
useful as motivation for moving away from what one doesn't want

useful as motivation for moving towards what one does want



Expressing Emotion

- Culturally universal expressions



Expressing Emotion

(a)

(b)

(c)

(d)

Smiles can show different emotions:

a) Mask anger

b) Overly polite

c) Soften criticism

d) Reluctant compliance

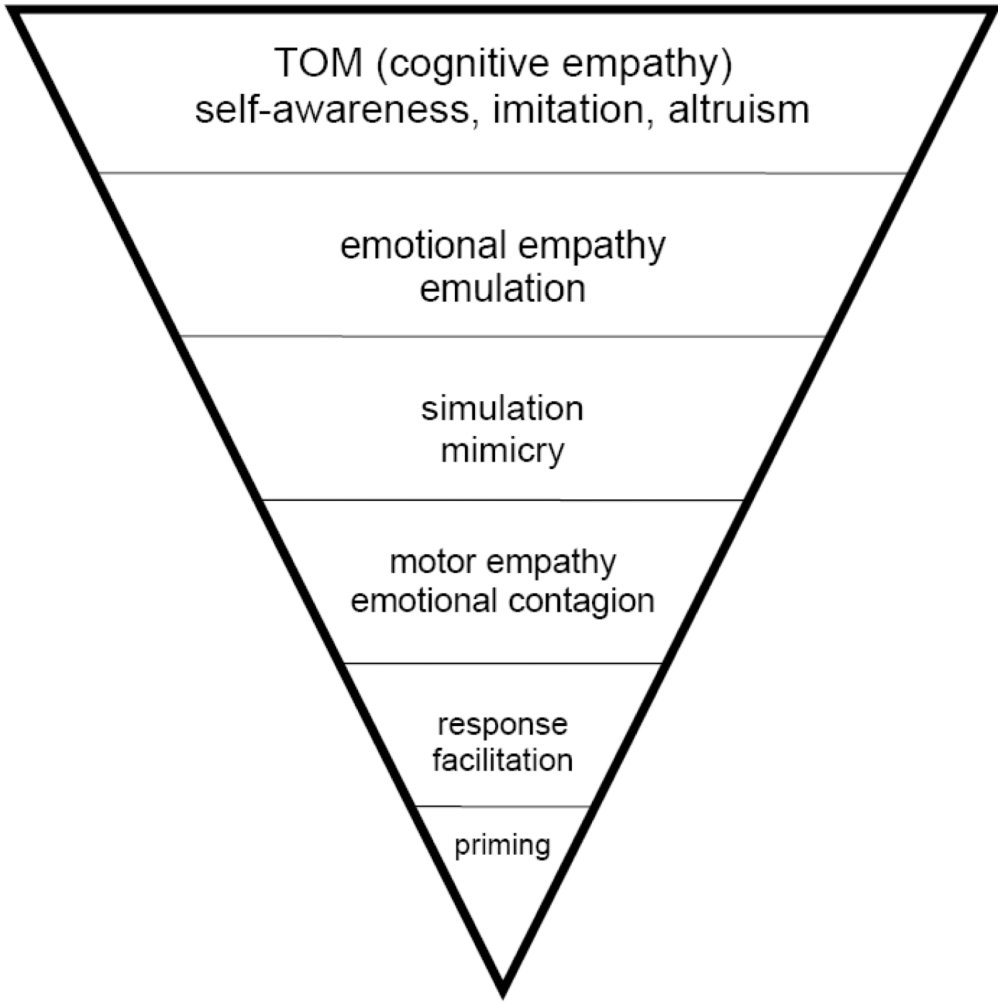
Monkeys and Apes

- Both show signs of empathy
  - Naïve rhesus monkeys can adopt the fear state of another in response to the presence of a snake
- Monkeys show no signs of ToM
- Empathy & ToM are relatively independent

Developmental Study

- Newborns show evidence of emotional contagion in the form of contagious crying
- 3-4 year old humans master false-belief theory of mind tasks
- Empathy and ToM rely on similar underlying structures (e.g., learning through mirroring) but also on different structures that may be present in humans but not non-human primates

Foundational Mechanisms



- We associate ‘priming’ with the simplest form of ‘mirroring’ and these are built up in progressively more complex forms to produce motor empathy, emotional empathy, and cognitive empathy
- Mirroring processes reflect a range of mechanisms for ‘representing the hierarchical mapping of information at different levels of organization’

Implications of this view

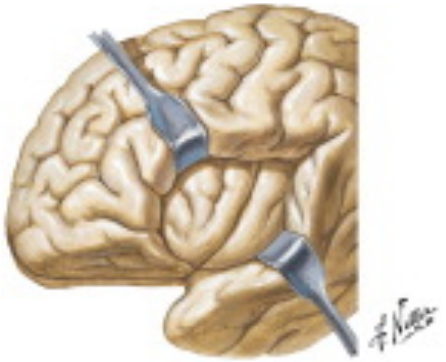
- Mirroring occurs in other species and provides evidence for phylogenetic continuity
- Mirroring at each level is the outcome of more primitive functions that can be reorganized to produce different functionalities
- There are gradations in terms of voluntary control of processing
- Organization is more functional than anatomical
- Increased interconnectivity and complexity of the human brain may produce unique processes such as “perspective taking, self awareness, and emotion reappraisal”

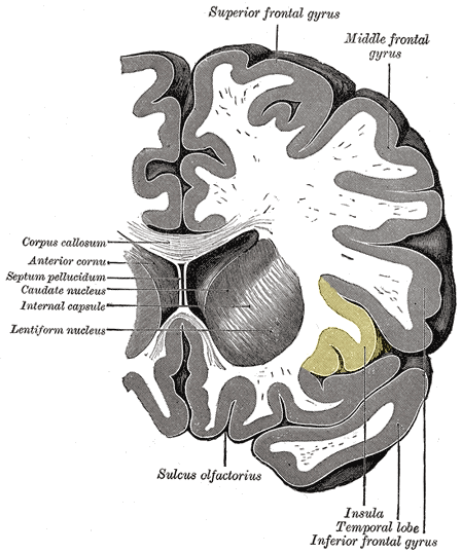
Functional Neuroanatomy of Empathy

- Empathy allows us to infer and simulate the feelings, beliefs, and intentions of others
  - Exteroception: sensitivity to stimuli originating outside of the body; cognitive/motor empathy
  - Interoception: sensitivity to stimuli originating inside of the body; emotional empathy
    - Fibers that carry info regarding temperature, pain, hunger, anxiety (A-delta and C fibers)
    - Serve to maintain homeostasis (homeostatic emotions)
    - Somatic information is relayed to the insula (insular cortices)

Emotion & Anterior Insula

- Tasks that involve emotion activate the anterior insula
  - Recall-generated sadness, anger, pain, disgust, sexual arousal, affiliative touch, response to music
  - Sense that the self is constant (Damasio's mental self)





Empathy & Insular Cortices

- Insular cortices likely to subserve the simulation of feeling states (feeling a feeling – as opposed to having a feeling)
- Studies show that insular cortices are involved in re-representing feeling states during empathy

Empathy & Insular Cortices

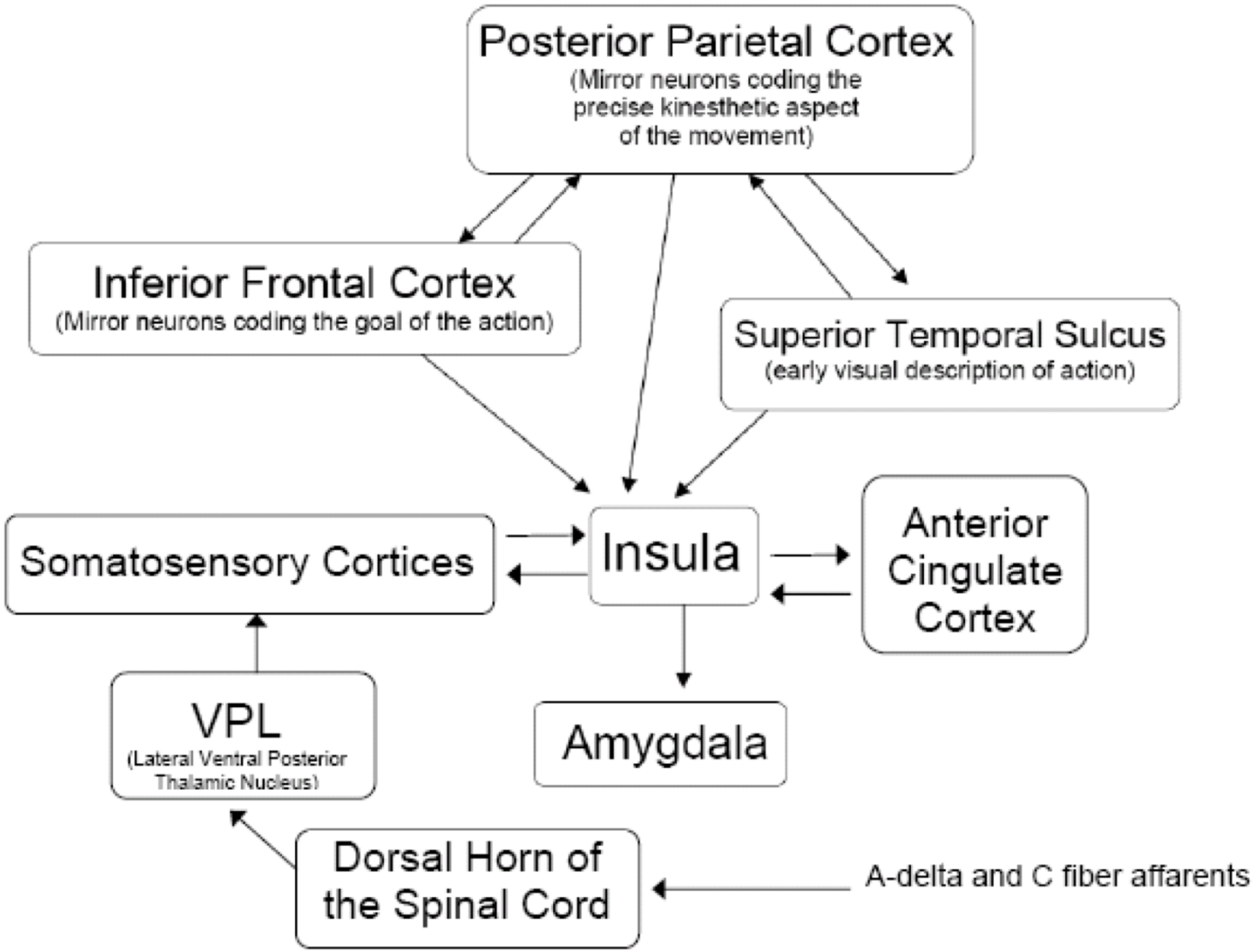
- Disgust
  - Passively viewed movies of individuals smelling a substance & then exhibiting a smile, disgusted grimace, or neutral expression
  - Later, subjects actually inhaled pleasant or unpleasant odors
  - Pleasant and unpleasant odors activated amygdala and insular cortices
  - Overlap of activation during viewing of disgusted faces and during experience of disgust
    - Left anterior insula & right anterior cingulate cortex
    - Amygdala not activated during the viewing condition

Empathy & Insular Cortices

- Pain
  - Observing another in pain activates the insula and ACC
  - The degree of perceived intensity of pain is directly correlated with degree of activation
  - No amygdala activation found

Amygdala

- Implicated in emotional processing
- Two routes
  - Cortical route: conscious ID of stimulus
  - Sub-cortical route: automatic and reflexive processing
    - Activates autonomic & hormonal systems that lead to the emotional response
- Not involved in simulation of feeling states
  - Only activated when feeling pain yourself
  - Provides a distinction between the self & other

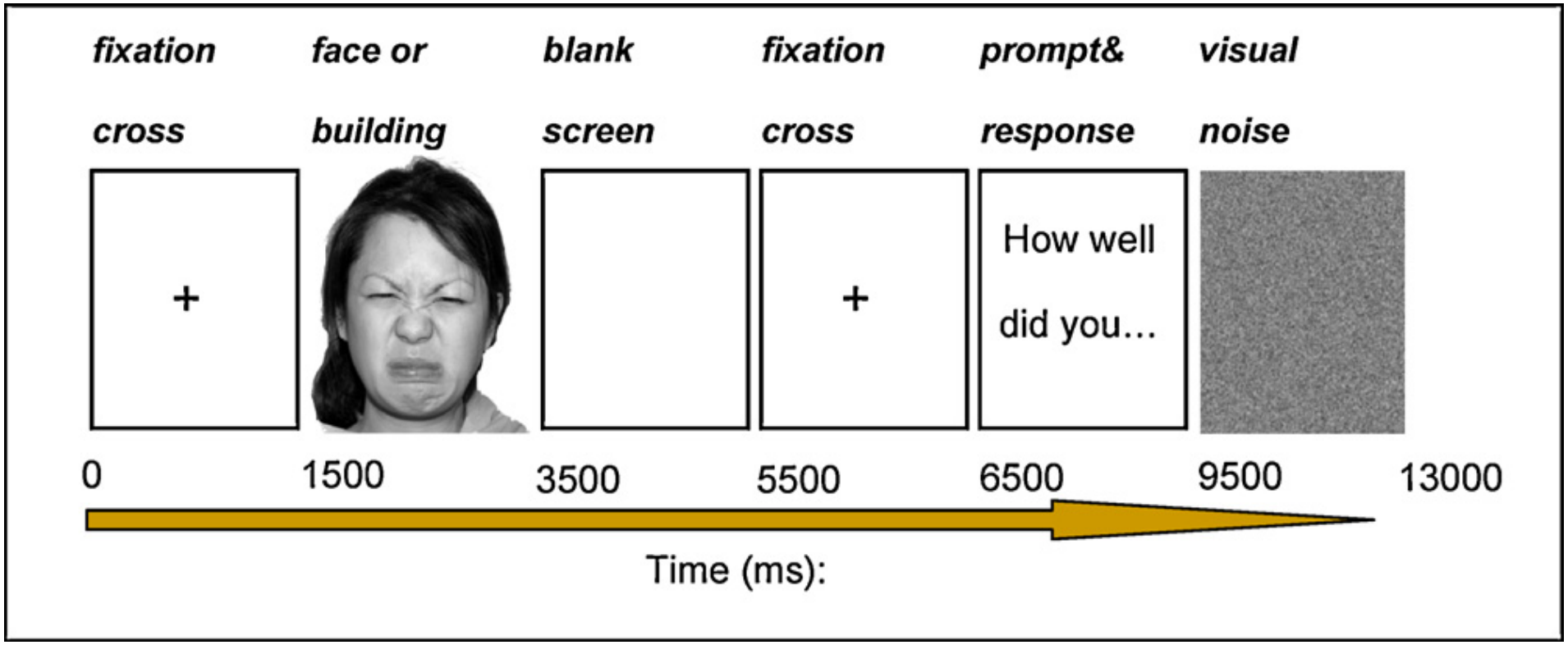

Posterior Parietal Cortex
(Mirror neurons coding the precise kinesthetic aspect of the movement)
Inferior Frontal Cortex
(Mirror neurons coding the goal of the action)
Superior Temporal Sulcus
(early visual description of action)
Somatosensory Cortices
Insula
Anterior Cingulate Cortex
VPL
(Lateral Ventral Posterior Thalamic Nucleus)
Amygdala
Dorsal Horn of the Spinal Cord
A-delta and C fiber affarents

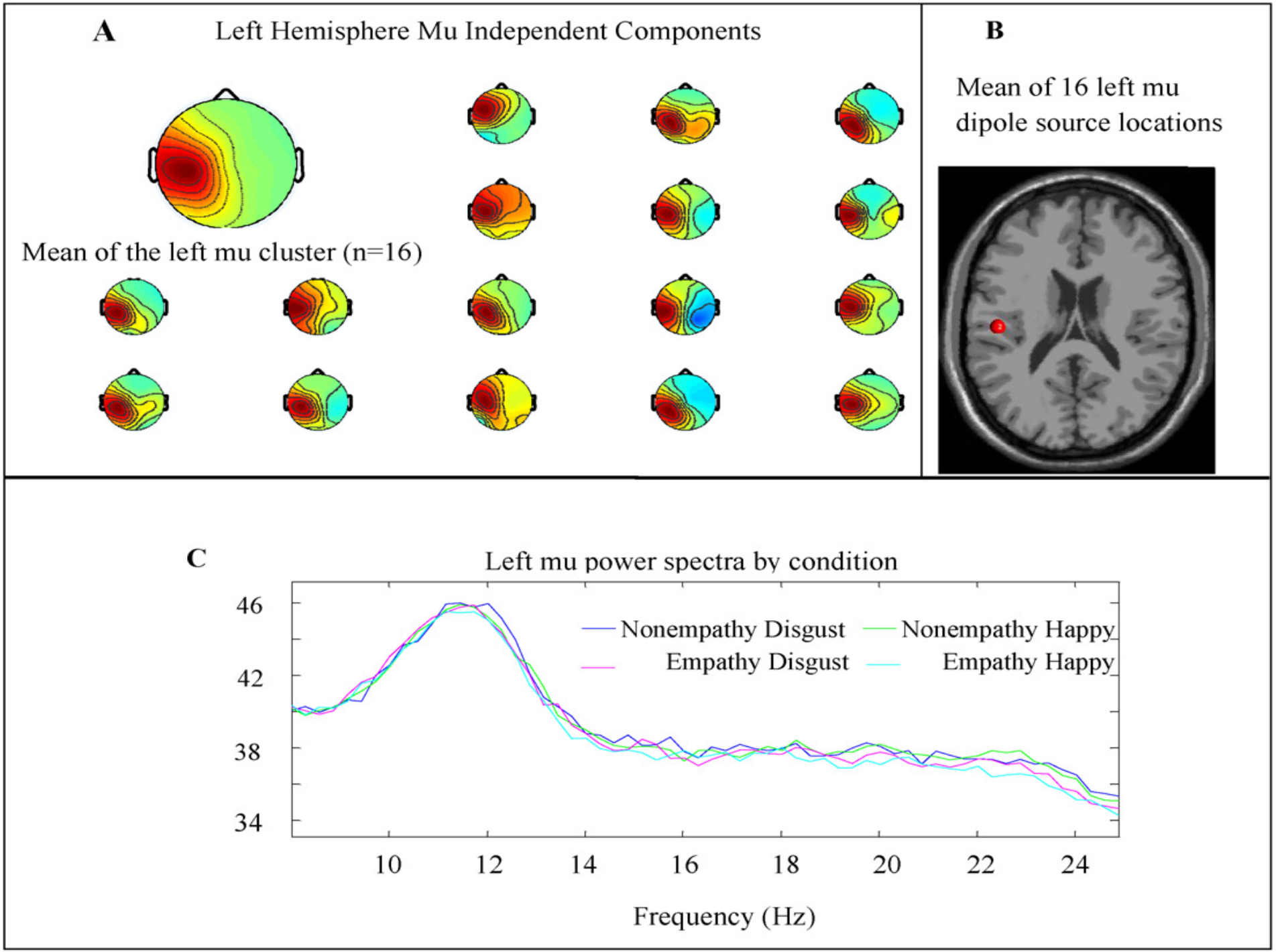
Motor Mirroring: MNS

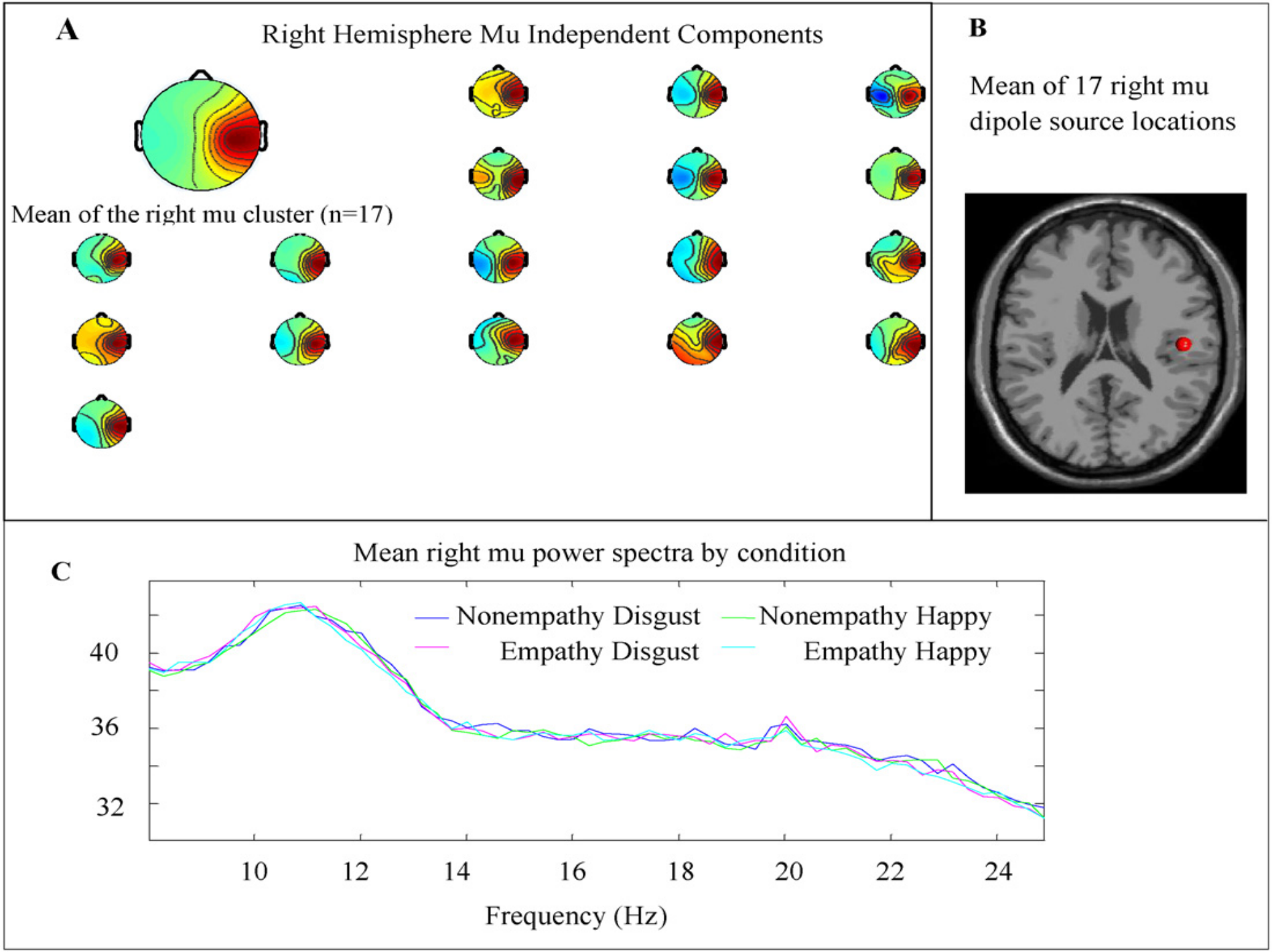
- Rostral inferior parietal lobe, pars opercularis of the inferior frontal gyrus, & premotor areas
- Mediates action understanding
- Activation of the MNS by observing an action automatically engages one's own motor representations
- Infer the actions & goals of others based upon their behavior

Motor Mirroring: Mirror Neuron System

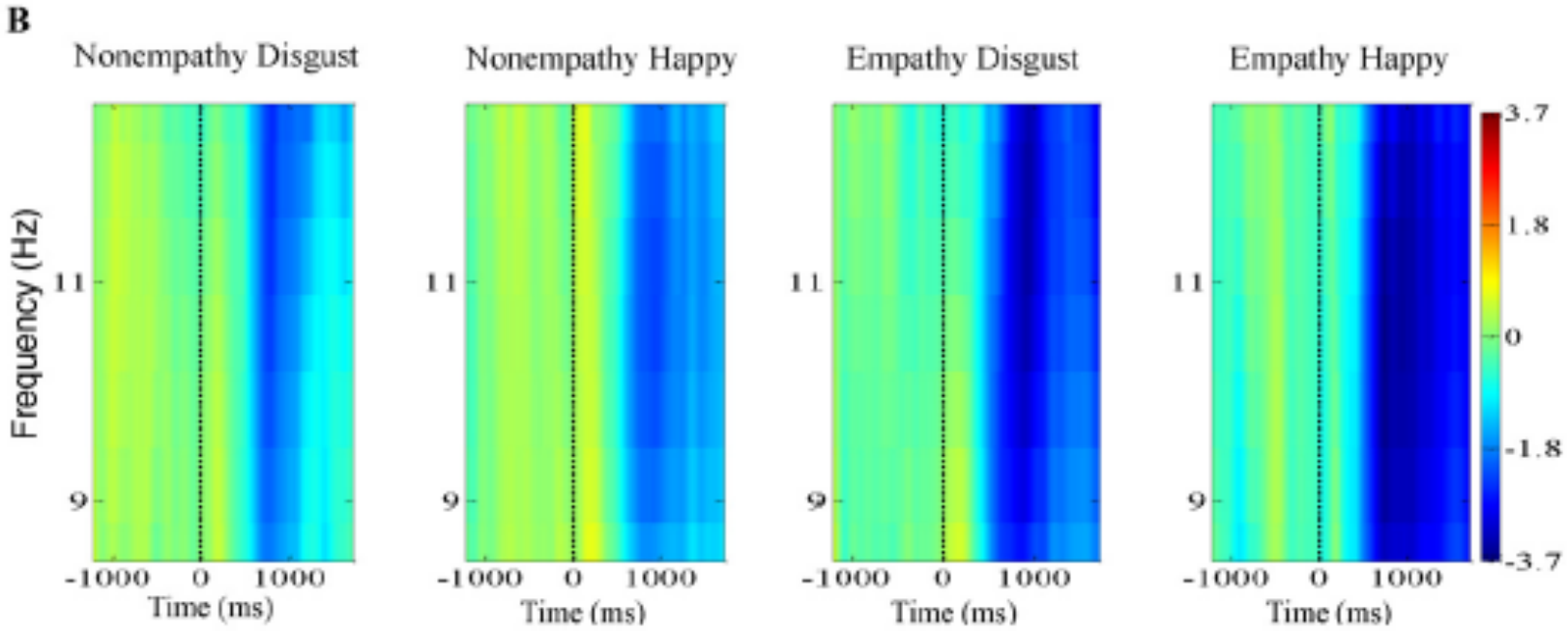
- Carr et al (2003)
  - View emotional faces (pain, anger, fear, etc)
  - Imitate the emotion
  - Overlap of activation of pars opercularis, premotor face area, anterior insula
- Simulating the actions of others


fixation cross
face or building
blank screen
fixation cross
prompt& response
visual noise
+
+
How well did you…
0
1500
3500
5500
6500
9500
13000
Time (ms):


A
Left Hemisphere Mu Independent Components
Mean of the left mu cluster (n=16)
B
Mean of 16 left mu dipole source locations
C
Left mu power spectra by condition
46
42
38
34
10
12
14
16
18
20
22
24
Frequency (Hz)
Nonempathy Disgust
Nonempathy Happy
Empathy Disgust
Empathy Happy


A
Right Hemisphere Mu Independent Components
Mean of the right mu cluster (n=17)
B
Mean of 17 right mu dipole source locations
C
Mean right mu power spectra by condition
Nonempathy Disgust
Nonempathy Happy
Empathy Disgust
Empathy Happy
40
36
32
10
12
14
16
18
20
22
24
Frequency (Hz)

Event related spectral perturbations



Self-Other

- When empathizing, we do not normally hold the other's feelings for our own
- Inferior parietal lobe, medial frontal cortex, & medial parietal areas
  - Keeping self and other separate

Conclusions

- Mirror mechanisms provide the foundational basis for social cognition
- Mirroring is necessary for all levels of information processing relevant to social cognition