

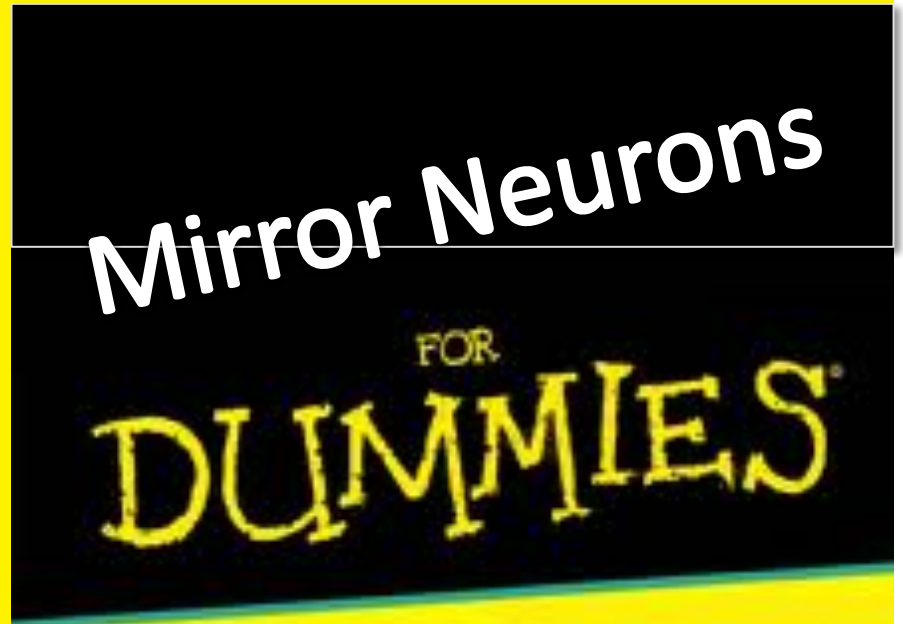
Are you stressing about finals? Don't worry-
Turella et al. has it all figured out!

Mirror neurons in humans: Consistent or confounding evidence?

By Turella et al.

Presented by:

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Disclaimer:

- “The goal of the present essay is not to cast any doubt on the importance of the discovery of mirror neurons, but to critically evaluate the substance of the speculations which have been advanced in the terms of its existence in humans.” (Turella et al., 2007)

Fact or Fiction?

- Mirror neurons are a class of visuomotor neurons activated by both the execution and the passive observation of object-related actions.

FACT!



Fact or Fiction?

- Mirror neurons exist in macaques and humans in area F5 within the premotor cortex and the PF/PFG within the inferior parietal cortex.

FICTION!

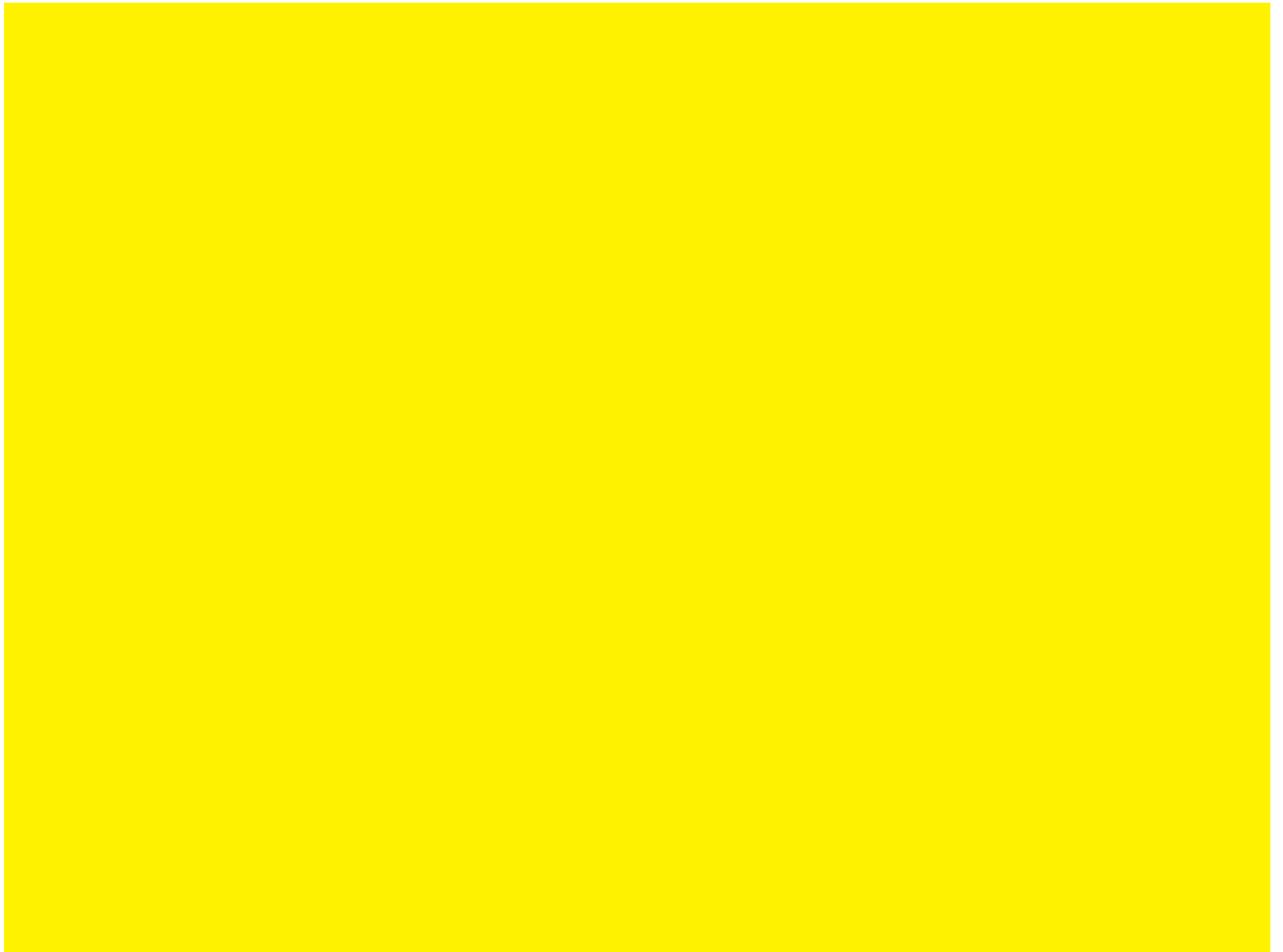


But everybody says they exist...

- Though mirror neurons have been identified in macaques in these regions, the current evidence does not warrant the existence of a homologue in humans.
- Looking at the defining characteristic of mirror neurons, fMRI and PET studies do not give strong enough evidence of the functioning of human mirror neurons to this capacity.

More fictitious literature...

- Though the proposal of a MN system in humans brings much excitement to research in its role, evidence for its involvement in these processes is weak.
- Some proposed role of human MNs:
 - Mediation of action observation and understanding
 - Mediation of imitation, understanding of intention, speech processing, music processing and perception of emotion in music, empathy, cigarette addiction, and sexual preference



PET and fMRI

- Used to Affirm that the Human Brain has...
 - Similar properties to those found in non-human primates
 - Done in order to set a platform by which comparisons between monkey and 'human' Mirror Neuron Systems may be accomplished.
 - Sets up possible discussions about how many functions the hMNS may subserve

Experiments Not Considered

- Whole body movement
- Computer graphic animated stimuli
- Johansson type stimuli
 - All these were isolated because they “not comparable with those that have been utilized to elicit mirror neurons responses in monkeys”
 - Instead consider Imitation with a focus on Frontal and Parietal brain cortices.
 - Given sufficient liberal criteria

Table 1
Action observation studies in chronological order

Studies	Object related		Premotor/IFG complex				Posterior parietal complex				
	Observation	Execution	Observation	Execution	Entire body	Overlapping	Mirror	Observation	Execution	Overlapping	Mirror
Grafton et al. (1996); PET	YES	Not tested	YES	Not tested	NO	NO	NO	YES	Not tested	NO	NO
Rizzolatti, Fadiga, Matelli et al. (1996b)*; PET	YES	YES	YES	NO	NO	NO	NO	YES	NO	NO	NO
Decety et al. (1997); PET	NO	Not tested	YES	Not tested	NO	NO	NO	YES	Not tested	NO	NO
Grezes et al. (1998); PET	NO	Not tested	YES	Not tested	NO	NO	NO	YES	Not tested	NO	NO
Grezes et al. (1999); PET	NO	Not tested	NO	Not tested	NO	NO	NO	YES	Not tested	NO	NO
Buccino et al. (2001); fMRI	YES	Not tested	YES	Not tested	NO	NO	NO	YES	Not tested	NO	NO
Perani et al. (2001); fMRI	YES	Not tested	YES	Not tested	NO	NO	NO	YES	Not tested	NO	NO
Grezes et al. (2003)*; fMRI	YES	YES	YES	YES	NO	NO	NO	YES	YES	NO	NO
Hamzei et al. (2003)*; fMRI	YES	YES	YES	Not tested	YES	NO	NO	YES	Not tested	NO	NO
Johnson-Frey et al. (2003); fMRI	YES	Not tested	YES	Not tested	NO	NO	NO	Not tested	Not tested	NO	NO
Manthey et al. (2003); fMRI	YES	Not tested	YES	Not tested	NO	NO	NO	YES	Not tested	NO	NO
Gallagher and Frith (2004); fMRI	NO	Not tested	YES	Not tested	NO	NO	NO	NO	Not tested	NO	NO
Schubotz and von Cramon (2004); fMRI	YES	Not tested	YES	Not tested	NO	NO	NO	YES	Not tested	NO	NO
Tai et al. (2004); PET	YES	Not tested	YES	Not tested	YES	NO	NO	NO	Not tested	NO	NO
Wheaton et al. (2004); fMRI	NO	Not tested	YES	Not tested	NO	NO	NO	YES	Not tested	NO	NO
Costantini et al. (2005); fMRI	NO	Not tested	YES	Not tested	NO	NO	NO	YES	Not tested	NO	NO
Iacoboni et al. (2005); fMRI	YES	Not tested	YES	Not tested	NO	NO	NO	YES	Not tested	NO	NO
Sakreida et al. (2005); fMRI	Not tested	Not tested	Not tested	Not tested	NO	NO	NO	Not tested	Not tested	NO	NO
Shmuelof and Zohary (2005); fMRI	YES	Not tested	NO	Not tested	NO	NO	NO	YES	Not tested	NO	NO
Aziz-Zadeh et al. (2006); fMRI	YES	Not tested	YES	Not tested	NO	NO	NO	YES	Not tested	NO	NO
Cunnington et al. (2006); fMRI	NO	NO	YES	YES	NO	NO	NO	YES	YES	NO	NO
Shmuelof and Zohary (2006)*; fMRI	YES	YES	YES	YES	NO	NO	NO	YES	YES	NO	NO
Molnar-Szakacs et al. (2006); fMRI	YES	Not tested	YES	Not tested	NO	NO	NO	YES	Not tested	NO	NO
Lotze et al. (2006); fMRI	YES	Not tested	YES	Not tested	YES	NO	NO	YES	Not tested	NO	NO
Hamilton and Grafton (2006); fMRI	YES	Not tested	NO	Not tested	NO	NO	NO	YES	Not tested	NO	NO
Pierno, Becchio, Wall, Smith, Turella et al. (2006b); fMRI	YES	Not tested	YES	Not tested	YES	NO	NO	YES	Not tested	NO	NO
Pierno, Becchio, Wall, Smith, Castiello (2006a); fMRI	YES	Not tested	YES	Not tested	YES	NO	NO	YES	Not tested	NO	NO
Grosbras and Paus (2006); fMRI	YES	Not tested	YES	Not tested	NO	NO	NO	YES	Not tested	NO	NO
Baumgaertner et al. (2007); fMRI	YES	Not tested	YES	Not tested	NO	NO	NO	YES	Not tested	NO	NO
Cheng et al. (2007); fMRI	YES	Not tested	YES	Not tested	YES	NO	NO	YES	Not tested	NO	NO
Dinstein et al. (2007); fMRI	NO	NO	YES	YES	NO	YES	NO	YES	YES	YES	NO
Filimon et al. (2007); fMRI	NO	NO	YES	YES	NO	YES	NO	YES	YES	YES	NO
Gazzola et al. (2007)*; fMRI	YES	YES	YES	YES	NO	YES	NO	YES	YES	YES	YES

Notes. (i) The column “Object-Related” refers to whether the observed action is object related or not. To be considered ‘mirror’, an area should be activated both when observing and when executing similar object-related actions. ‘YES’ in both the action observation and execution columns indicates that this pre-requisite has been met. (ii) The column “Premotor/IFG Complex” indicates whether activity within this potential ‘mirror’ area has been found. “Observation” indicates whether the listed study has reported (‘YES’) or has not reported (‘NO’) hand action observation type of activity. “Execution” indicates whether the listed study has reported (‘YES’) or has not reported (‘NO’) hand action execution type of activity. “Entire Body” indicates whether in the listed studies an entire person (‘YES’) or a hand detached from the body (‘NO’) was presented as a model (remember that in monkey studies F5 mirror neurons were only activated by an action demonstrated by an entire human model). “Overlapping” indicates whether overlapping activations for both observation and execution (‘YES’) were found or not (‘NO’) within the same area, as a result of conjunction analysis. The column termed “Mirror” allows for the definition of a brain area as mirror. In order for these criteria to be met, ‘YES’ should be reported within the “Object related”, “Entire body”, and “Overlapping” columns. (iii) The main column “Parietal Complex” indicates whether in the listed studies activity within this potential ‘mirror’ area has been found. This column is subdivided into four of the five categories reported above: observation, execution, overlapping, and mirror.

So What is Sufficient Liberal Criteria?

- To be considered 'mirror', an area should be activated both when observing and when executing similar object-related actions.
 - 'YES' in both the action observation and execution columns indicates that this pre-requisite has been met
 - In order for these criteria to be met, 'YES' should be reported within the "Object related", "Entire body", and "Overlapping" columns

Summary of the Faults with Respective Experiments

- Rizzolati et al.
 - Study did not reveal activation within either the frontal or parietal 'mirror' areas.
 - Activation within frontal areas was found during action observation, but not during action execution.
 - The reverse was found for parietal areas.

Hamzei et. al

- fMRI study does not allow us to draw any firm conclusion about 'mirror' type of activity, mainly because of methodological problems...
 - Used merged data from separate experiments rather than performing both action observation/execution themselves
 - Performed “fixed effect” analysis which doesn't allow for generalization

Greze's et al.

- First, the activations reported for the 'execution' conditions actually refer to activations obtained from both execution and observation conditions.
- Second, the baseline conditions might not be ideal
- Whereas for the 'execution' baseline condition subjects performed only power grip tasks.
- A final concern is that only the hand of the acting model was presented. In both single-cell recordings and fMRI studies in monkeys, 'mirror' activity within this area is only evident when the experimenter was entirely visible
 - Suggests that 'entire body' is a crucial pre-requisite for identifying 'mirror' activity.

Shmuelof and Zohary

- Again, Turella et. Al had issues with the methodological and anatomical aspects of the study.
 - First, the locus of activation was not within the rostral part of the inferior parietal lobule, but between the superior bank of the anterior intraparietal sulcus and the postcentral gyrus.
 - Secondly, the experimenters mixed results from two different experiments testing 14 participants for the action observation conditions and only 9 out of these 14 for the action execution conditions—more importantly, there was no exact match between the hand actions tested in the action execution experiment with those tested in the action observation experiment

Gazolla et. Al

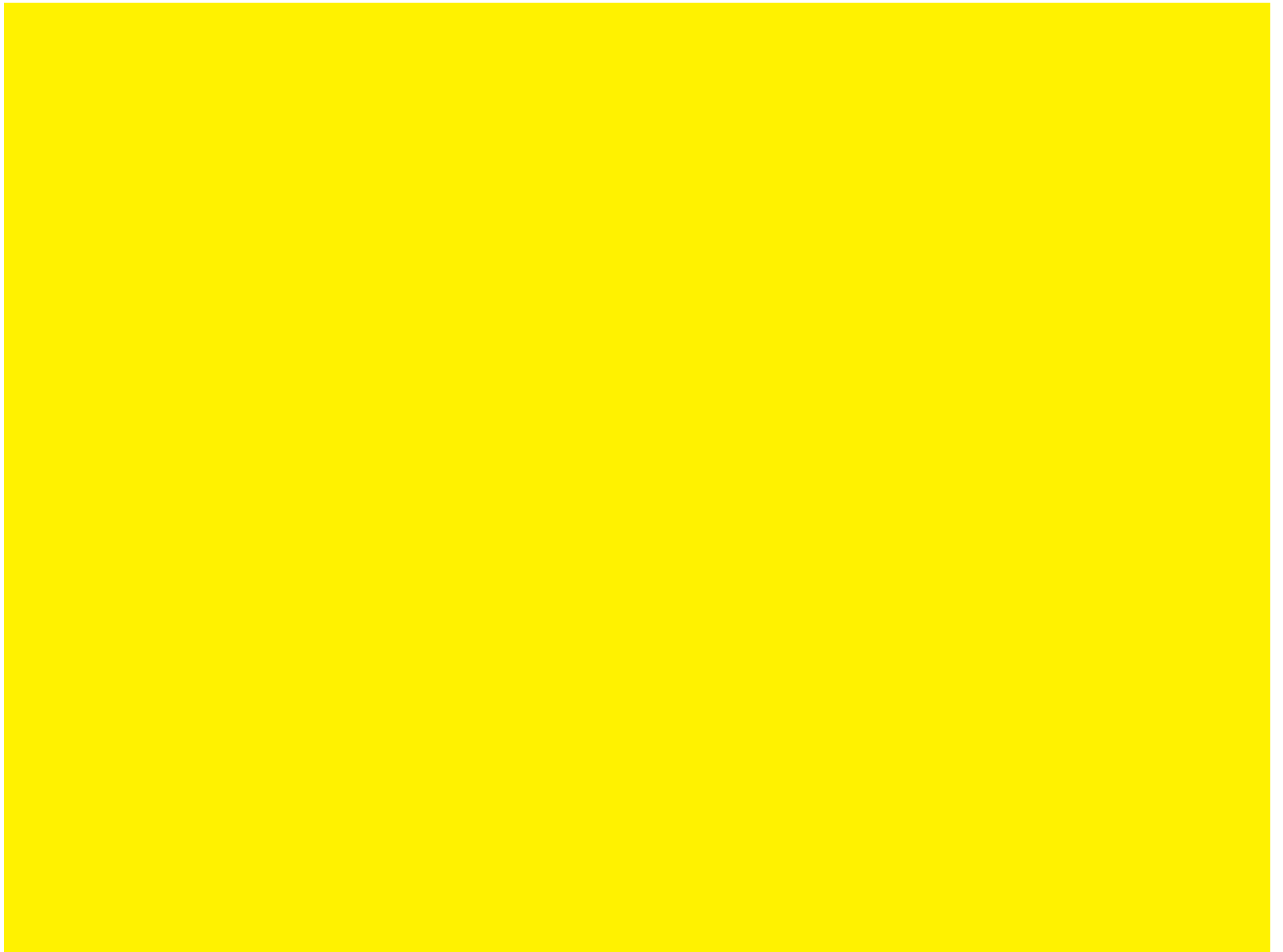
- This study, for the first time, tested both action execution and observation using the same participants
 - provides some evidence of mirror activity in humans by demonstrating that a number of areas are activated during both the execution and the observation of hand actions. HOWEVER...

- Several areas were revealed which had previously not been tested or considered, leaving no area for comparison. Most likely due to...
 - rather liberal threshold ($p < .001$; uncorrected) adopted to inclusively mask all the action observation results with the motor-execution results
 - If threshold were more conservative, then a better understanding of an anatomical 'core' MNS may have been defined

- ‘Entire body’ criteria was not explored.
- Additionally, random ordering of observation versus execution was not considered, allowing for a bias to possibly emerge.
- Lastly, ability to not be able to see “only unable to see their own action, but also unable to see the objects appears to be rather unnatural. This entails spatial search and memory components that visually guided grasping does not require”

Summary of Turella et al's. Critique

- Studies do not provide consistent evidence in favor of 'mirror' type of activity within the frontal and the parietal complex as found in monkeys.
- Ultimately, Turella suggests that Action observation alone, but not observation and execution have been found to be correlated with activation in the proposed hMNS
 - When they are, the pattern and loci of activation are more 'extended' than classic MNS expects (casts doubt on what???)



Imitation

- Brain Areas involved:
 - IFG
 - Dorsal and Ventral Premotor Cortex
 - IPC
 - Superior Parietal Lobe
 - Posterior STS
- Particular emphasis on IFG:
 - Human homologue of Area F5 in monkeys

Imitation

- According to Turella et al.,
 - Assigning imitation to specific brain region can only occur after it demonstrates classic ‘mirror’ properties
 - Only two fMRI studies using the action observation approach have the potential to show classic mirroring
 - Iacoboni et al. (1999)
 - Buccino et al. (2004)

Table 2
Imitation studies in chronological order

Studies	Object related		Premotor/IFG complex				Posterior parietal complex				
	Observation	Execution	Observation	Execution	Entire body	Overlapping	Mirror	Observation	Execution	Overlapping	Mirror
Krams et al. (1998); PET	Not tested	NO	Not tested	YES	NO	NO	NO	Not tested	YES	NO	NO
Iacoboni et al. (1999)*; fMRI	NO	Not tested	YES	Not tested	NO	NO	NO	YES	Not tested	NO	NO
Iacoboni et al. (2000); fMRI	NO	Not tested	NO	Not tested	NO	NO	NO	NO	Not tested	NO	NO
Iacoboni et al. (2001); fMRI	NO	Not tested	NO	Not tested	NO	NO	NO	NO	Not tested	NO	NO
Tanaka et al. (2001); fMRI	Not tested	Not tested	Not tested	Not tested	NO	NO	NO	Not tested	Not tested	NO	NO
Tanaka and Imai (2002); fMRI	Not tested	Not tested	Not tested	Not tested	NO	NO	NO	Not tested	Not tested	NO	NO
Decety et al. (2002); PET	Not tested	Not tested	Not tested	Not tested	NO	NO	NO	Not tested	Not tested	NO	NO
Koski et al. (2002); fMRI	NO	Not tested	NO	Not tested	NO	NO	NO	NO	Not tested	NO	NO
Koski et al. (2003); fMRI	Not tested	YES	Not tested	YES	NO	NO	NO	Not tested	YES	NO	NO
Buccino et al. (2004)*; fMRI	YES	YES	YES	YES	NO	NO	NO	YES	YES	NO	NO
Leslie et al. (2004); fMRI	Not tested	Not tested	Not tested	Not tested	NO	NO	NO	Not tested	Not tested	NO	NO
Chaminade et al. (2005); fMRI	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Makurachi (2005); fMRI	Not tested	NO	Not tested	YES	NO	NO	NO	Not tested	NO	NO	NO
Molnar-Szakacs et al. (2005); fMRI	NO	Not tested	YES	Not tested	NO	NO	NO	NO	Not tested	NO	NO
Muhlau et al. (2005); fMRI	Not tested	Not tested	Not tested	Not tested	NO	NO	NO	Not tested	Not tested	NO	NO
Rumiati et al. (2005); PET	Not tested	Not tested	Not tested	Not tested	NO	NO	NO	Not tested	Not tested	NO	NO
Aziz-Zadeh et al. (2006) fMRI	Not tested	Not tested	Not tested	Not tested	NO	NO	NO	Not tested	Not tested	NO	NO
Jackson et al. (2006); fMRI	Not tested	Not tested	Not tested	Not tested	NO	NO	NO	Not tested	Not tested	NO	NO
Williams et al. (2006); fMRI	Not tested	Not tested	Not tested	Not tested	NO	NO	NO	Not tested	Not tested	NO	NO
Jonas et al. (2007); fMRI	NO	NO	YES	YES	NO	NO	NO	YES	YES	NO	NO

Notes. Conventions are as for Table 1. Although imitation entails execution of an observed action, please note that here "Execution", as in Table 1, exclusively indicates whether the listed study has tested pure action execution conditions and not imitation.

Iacoboni et al. (1999) Study

- Three distinct conditions:
 - Imitation
 - Observe finger movements and immediately imitate
 - Execution condition
 - Perform finger movements in response to spatial or symbolic cues
 - Observation condition
 - Watch 'random' finger movements
 - Reveals activity in the IFG

Confounds with Iacoboni et al. (1999)

- Jonas et al. (2007):
 - Performed actions are not object related
 - Therefore lack pre-requisite to consider obtained activations as 'mirroring'
 - Differential activation found for object related actions vs. gestures
 - Kroliczac, Cavina-Pratesi, Goodman and Culham (2007)

More Confounds

- Nelissen et al. (2005)
 - Subjects only presented hands, not an entire body
 - Study suggests that imitation involves both observation and execution on action
 - Activation should then be the sum of both parts
 - Iacoboni et al. (2006)
- Activity is not time locked
 - In the imitation condition, it is possible that both imitation and action observation are intermixed

Issues addressed by Buccino et al. (2004)

- Guitar chord imitation task
 - Imitation of finger configurations made by model
 - Separately sample time-locked activity for action execution, observation, imitation and planning
- Results indicate ventral premotor activity for execution and observation

Confounds with Buccino et al. (2004)

- Same area responds for planning and presented object by itself
- Activity in IFG during planning, execution and observation
 - Cannot fully discriminate brain activity
 - Similar results in the IPL
- Only hand is presented to subjects

Confounds with the Buccino Study

- Guitar naïve subjects
 - Good model for imitation of novel actions but not of classical mirroring properties
 - Mirroring is primarily elicited by observation of actions already present in motor repertoire of subjects

Differential brain activation for finger and hand movement

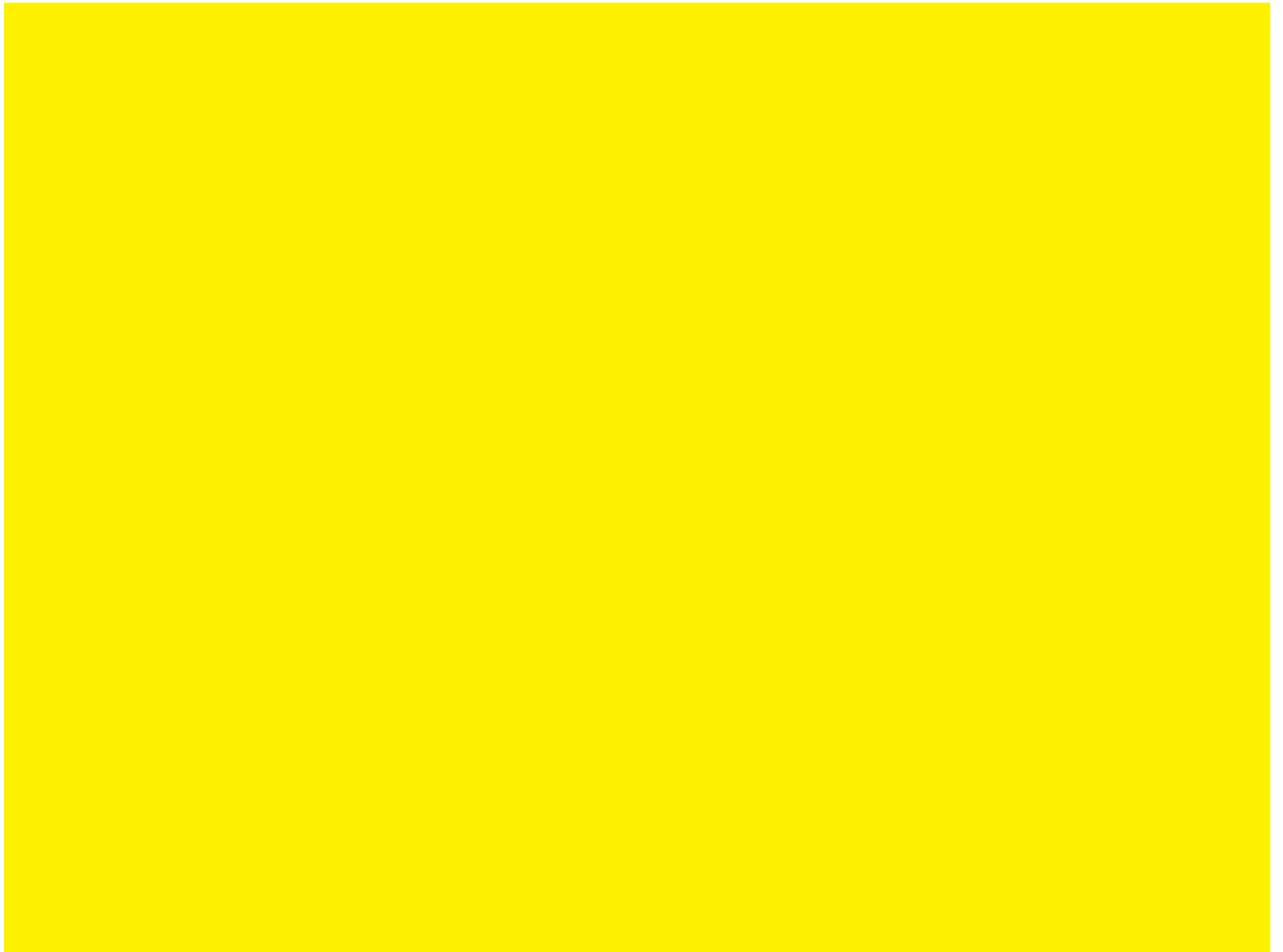
- Lesion studies show...
 - Finger imitation is found in the IFG
 - Hand imitation is found in the IPL and temporo-parietal-occipital junction
 - Goldberg and Karnath (2006)

Area F5 (monkeys)/ BA 44 (humans)

- Activated by contrast in finger-immediate imitation with static-hand observations
 - Not by contrast of hand-movement-immediate-imitation against finger-immediate-imitation
- Ventral and Dorsal sectors of BA 44 respond to immediate finger imitation
 - Ventral responds to imitation but not observation, execution or static visual control
 - Dorsal responds to immediate imitation and observation

Makuuchi (2005) Study

- BA 44 is not integral for imitation
 - Instead its necessary for delayed action execution
- Participants are continuously requested to observe and then perform an observed movement
 - No visuo-motor transformations are necessary, subjects simply reuse the same motor program repeatedly
 - Observing movement is simply a cue to activate the program



Theoretical Considerations

- The idea of a mirror system in humans is premature in relation to action observation and imitation
 - ‘mirror’ areas have also been suggested to be relevant loci for processes such as prediction and selection
- 3 Main Considerations
 1. Action Observation
 2. Overt imitation
 3. Monkey ability to imitate

1. Action Observation

- Does reproduction of a seen action require full activation of the motor representations that are primed during action observation?
 - Previous studies using fMRI and PET do not require participants to perform any action.
 - Is passive observation sufficient to generate premotor activation?
 - Many times, action observation and execution do not match up for are not active at the same time. → How is this considered 'mirror'?

2. Overt Imitation

- Studies with overt imitation do not go beyond action observation.
 - Does this mean mirror neurons do not have the ability to perform imitation? Alternatively, are they capable but imitation simply is not their function?
 - 'Generalist' theory: Areas involved in action observation (including mirror neurons) **CAN DO** imitation, but are not **FOR** imitation.
 - Mirror neurons may not have evolved for imitation, but more so evolved as a side effect in response to more general adaptive problems.

3. Monkey Ability to Imitate

- Monkeys have mirror neurons but they do not imitate (according to Lyons, Santos, & Keil, 2006; Roth & Kicke, 2005).
 - If proved, this would go against the hypothesis that MN are for imitation.
 - We need a demonstration of interplay between MN and more complex cognitive abilities.
 - Imitation is not unitary and cannot be localized to a single brain system. → Different types of imitation involve different cognitive and neural systems.

Methodological Considerations

1. Reconciling Data
2. Homologous Brain Regions?
3. fMRI Interpretations

1. Reconciling Data

- Data from single-cell recordings & imaging techniques are difficult to reconcile.
- More appropriate solution: Study similar activity within same voxel (with same stereotaxic coordinates) for both execution and observation.
 - Nelissen et al. (2005) confirmed neurophysiological evidence and revealed F5 mirror neurons respond only when model performing the action is visible in entirety (not hand acting alone).
 - Thus, view of the agent performing the action is a prerequisite to trigger a response.

2. Homologous Brain Regions?

- The possibility of establishing homologies between brain regions within different species.
 - Agreement in homologies have only been found in areas V1, V2, MT/V5
 - Must be VERY cautious in calling areas homologous
 - Is Monkey F5 = Human area 44?
 - Area 44 is not always active in both action observation and execution (F5 is)
 - Imitation only activated for fingers, but not hand movements in Area 44

3. fMRI Interpretations

- fMRI results reveal overlapping activations from independent contrasts.
 - Two different interpretations lead to no definitive answer for common neural mechanisms.
 - Common-coding interpretation: Activated cluster contains neurons engaged in a common computational process.
 - Functional-independence interpretation: Activated cluster may contain functionally independent neural populations.



TM

Okay, so that was
an exaggeration!
But seriously...

So after more than 10
years of research, why
can we not concretely
prove the existence of a
mirror neuron system in
humans?

DUH!

- Experimental paradigms have not been set up to specifically mimic the original identification of mirror neurons in monkeys and therefore studies of similar function used to assume the role of these areas in humans can not be taken as solid evidence.

What's the big idea?

- If you want to identify the homologue of macaque mirror neurons in monkeys, must use a paradigm that reflects the exact conditions designed for the relevant monkey studies.
- Until clearer evidence identifies the existence of a human mirror neuron system that closely resembles that found in monkeys in terms of brain areas and functions, PET and fMRI studies are simply speculative.

Remember:

1. Use Turella et al.'s critical analysis of the current research on mirror neurons to create your own theory and justifications.

2. Don't let these opinions
throw your COGS 171 world
upside down!



But most importantly...

**Good luck
on finals!**