Gaze but not arrows: A dissociative impairment after right superior temporal gyrus damage

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Human Social Interaction
perspectives from neuroscience

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Room B47

Drop-in sessions: Tuesdays 10-12

www.psychology.nottingham.ac.uk/staff/rwn

Understanding Action: Mirror neurons, simulation, imagination and the sense of agency

Last week: How we detect and process eye movements and (human) motion/actions

This week:
How do we recognise and understand those actions?

The discovery of Mirror neurons in monkeys

Do MNs exist in humans, and if so, where?

MNs and simulation
Imagined actions
Shared representations

Distinguishing self from other in shared representations

Current research

Understanding actions

Understanding actions

How do we recognise and understand the ~~emotions~~, actions and ~~minds~~ of other people so quickly and easily?

Understanding actions

How do we understand others' actions?

A fundamental question in Psychology for many years

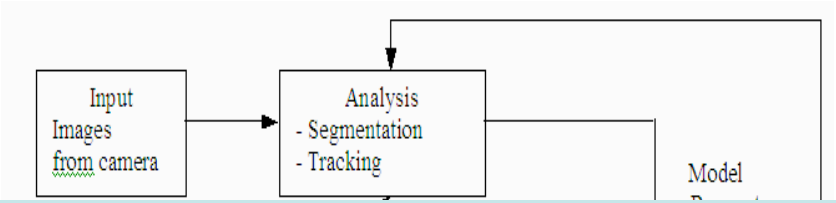
Understanding actions

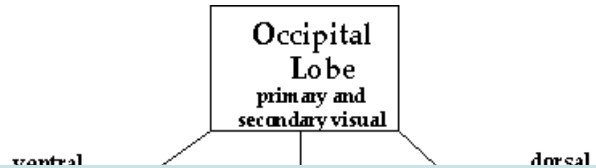
How do we understand others' actions?

A fundamental question in Psychology for many years

Understanding actions

There are theories / models like these…



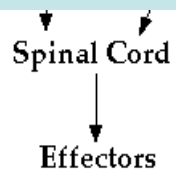


But, these are slow and require learning/memory processes

(sometimes referred to as visual hypothesis or visual analysis of action)

Understanding a simple reach to grasp action would require, at minimum, the activity of the extrastriate visual areas (objects), the inferotemporal lobe (body parts) and the superior temporal sulcus (biological motion)

What we really want is a system that is fast and automatic



Or there's this..

Fast and automatic

(sometimes referred to as direct matching hypothesis or unmediated resonance)

Understanding simple reach to grasp actions require nothing more than for that action to be in the observers own motor repertoire.

Involves a direct matching between observation and execution of the same action

Observation of an action causes the observers motor system to 'resonate'.

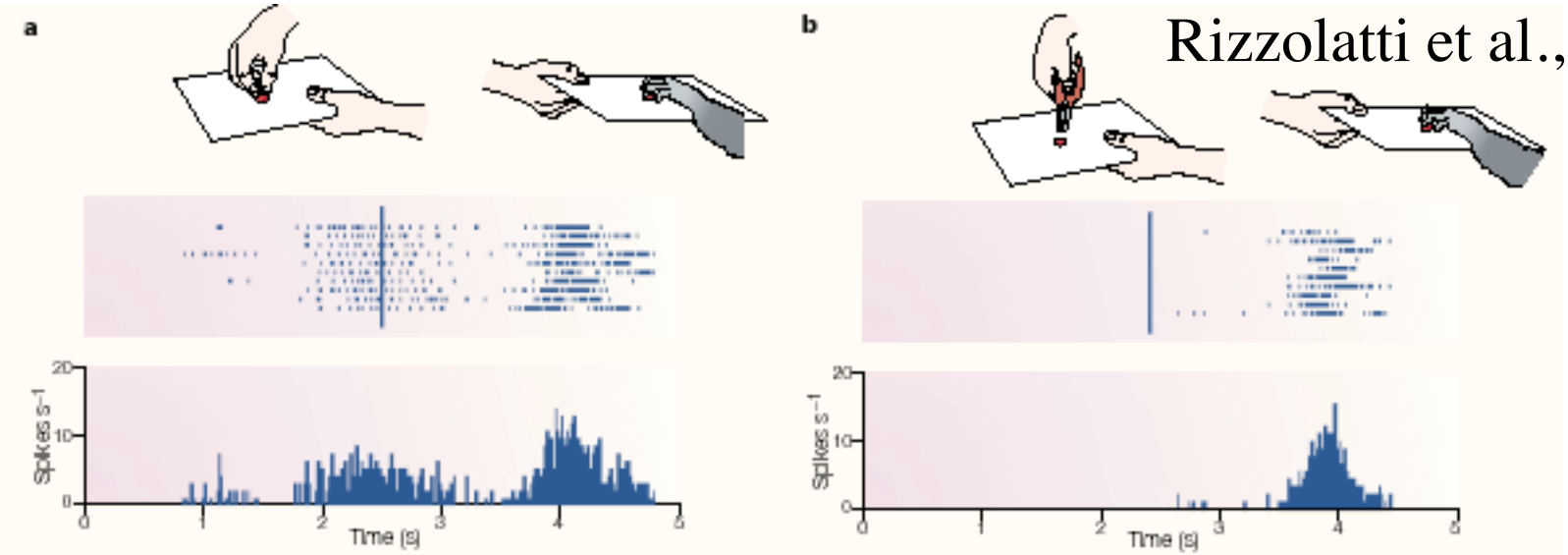
The mirror system seems to fulfill this role.

observing the same action

The mirror system in monkeys

Mirror neurons: visuomotor neurons discovered in monkey vPMC (F5)

Area F5 characterized by neurons that code goal-directed motor acts (e.g. hand and mouth grasping). Some are motor neurons, others respond to visual stimuli. Others (mirror neurons) also respond to action observation

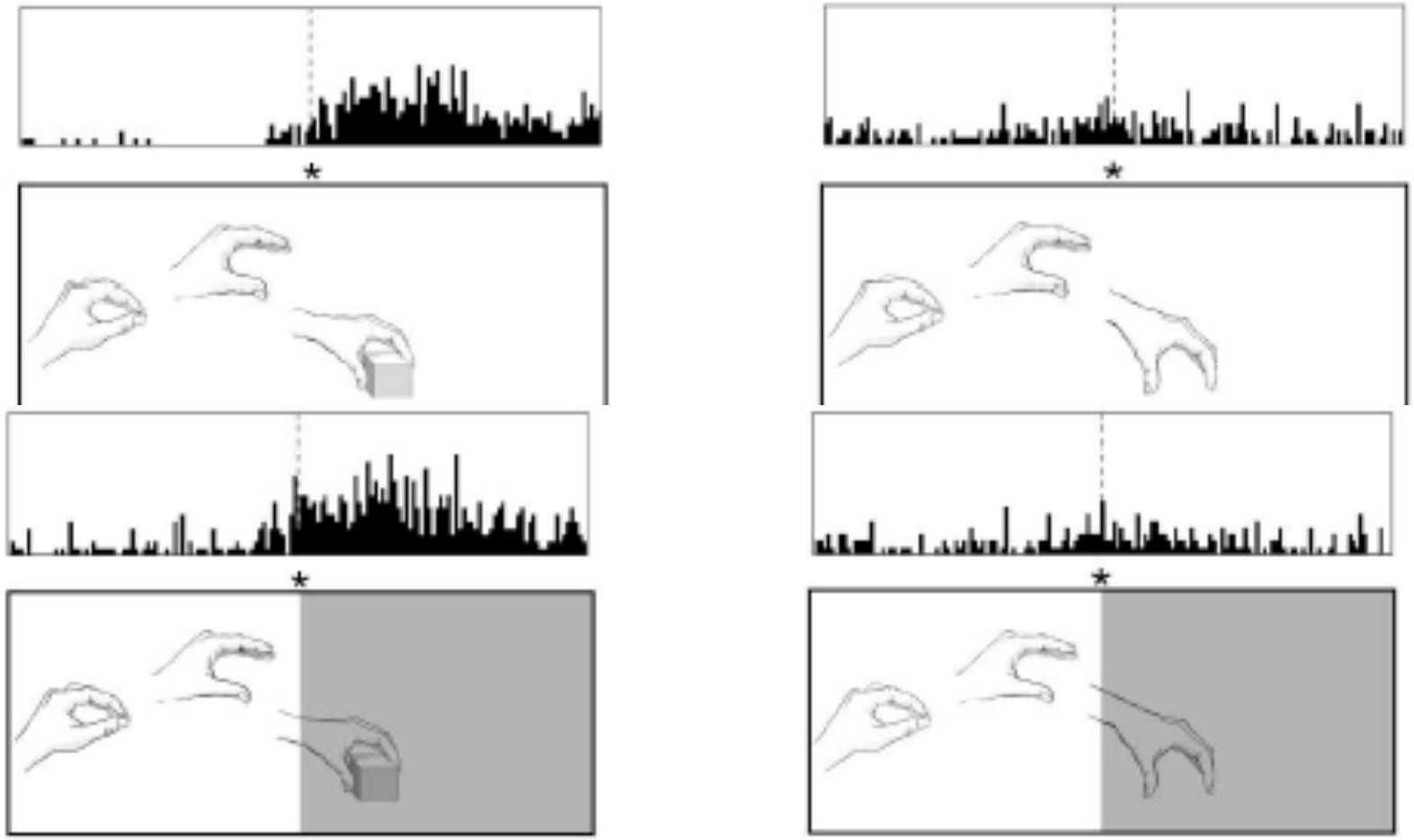


Rizzolatti et al., 1996

allows direct matching between visual description of action and its execution without attaching any meaning to that action, but in a way that the observer is able to understand.

Inferring the actions of others (action understanding)

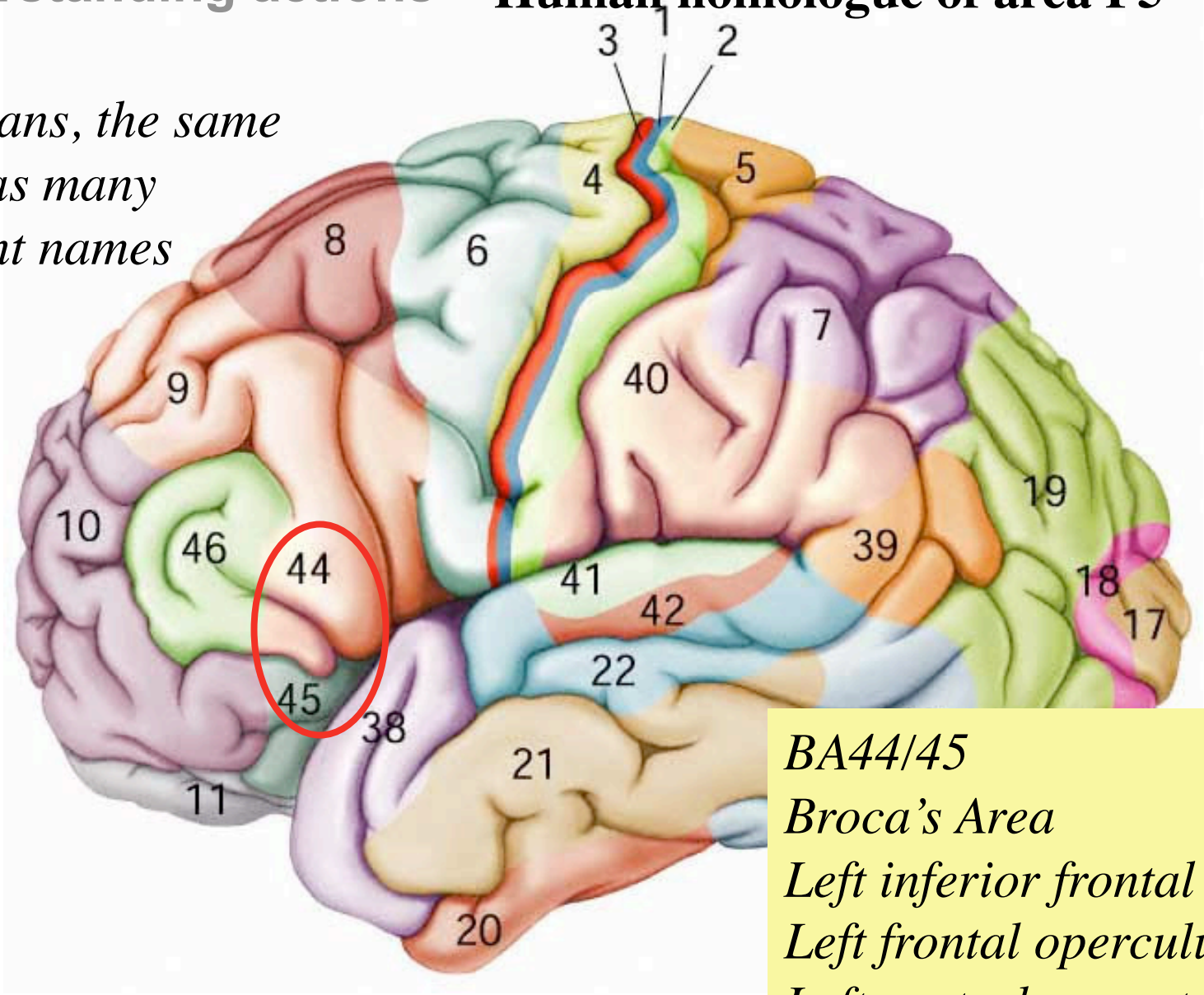
Ulmita et al., 2001



Despite monkey not seeing action, it knew the meaning

Human homologue of area F5

In humans, the same area has many different names



BA44/45
Broca's Area
Left inferior frontal gyrus
Left frontal operculum
Left ventral premotor area
Monkey F5 homologue

Do Mirror Neurons exist in humans? -EEG and MEG evidence

Traditional EEG studies distinguish between alpha and mu rhythms

alpha rhythm present when sensory systems are inactivate, and disappears on presentation of sensory stimuli.

mu rhythm present during motor rest, disappears during active movement

Gastaut and Bert, and Cohen-Seat et al. showed that observing the actions of another human (i.e. not active movement) blocks the mu rhythm of the observer.

Mirror system in humans -MEG evidence e.g. Hari, 2004

Data suggests human motor cortex is activate both during the execution of a motor task and during action observation.

findings strongly supports the existence of an action observation/ execution matching system in humans.

Do Mirror Neurons exist in humans? -Evidence from TMS

Fadiga et al. 1998 & 2005
stimulation of left motor cortex (involved in action production) while subjects observed grasping movements performed by an experimenter.

Motor-evoked potentials (MEPs) were recorded from various arm and hand muscles.

results showed a selective increase in MEPs (compared to control conditions) in the regions that the subjects normally use for producing the observed movements

Later double-pulse studies by Paus et al. also suggest analogy at cortical level of action observation and action execution mechanisms

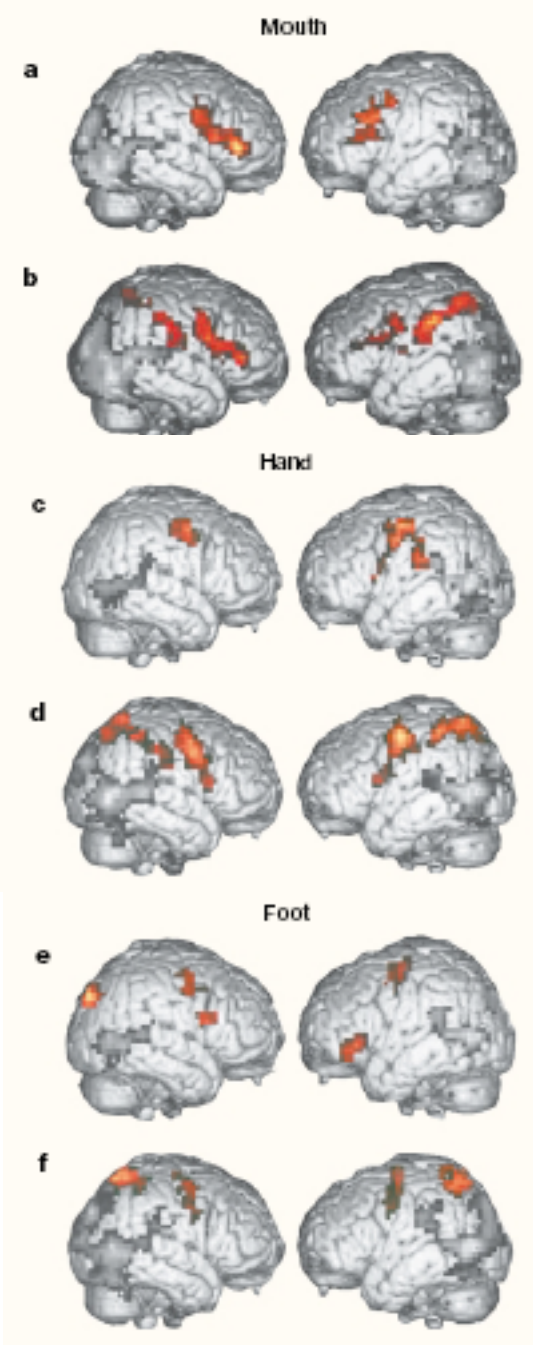
But EEG, MEG and TMS studies do not localise human mirror system

Do Mirror Neurons exist in humans? - Evidence from fMRI

Buccino et al. 2004
participants observed mouth, hand and foot actions (biting an apple, grasping a ball, kicking a ball) and non-object actions (chewing,mimicking reaching and kicking)

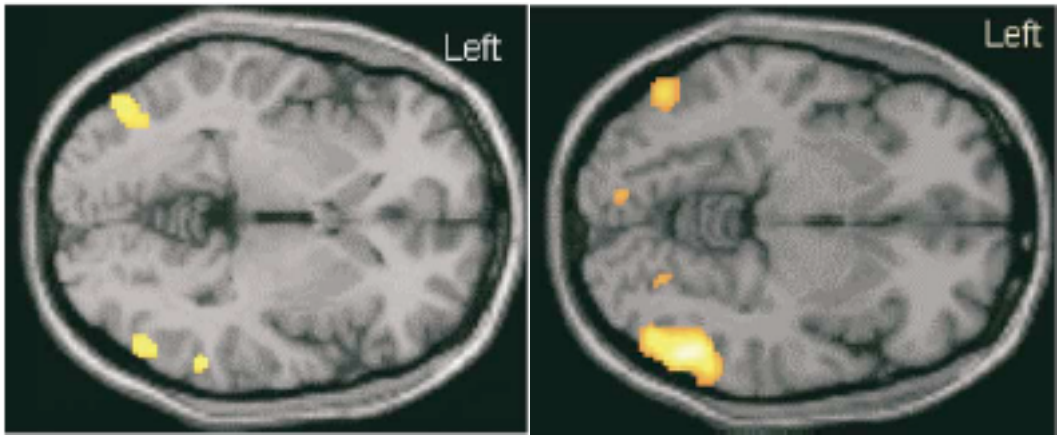
observing both action types led to somatotopic activation of the premotor cortex and activation in Brocas area.

During the observation of object-related action, a roughly somatotopic activation was also found in the posterior parietal lobe.

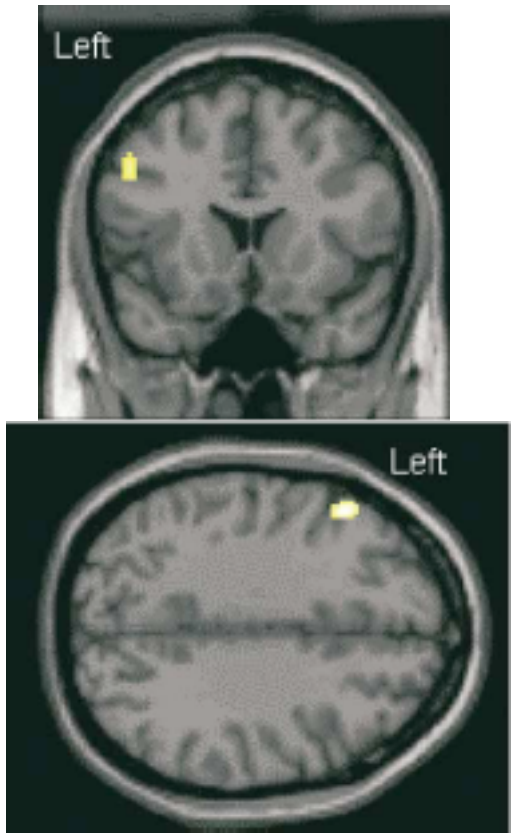


Mirror neurons are only mirror for biological actions

Tai et al. 2004 man v robot reaching and grasping



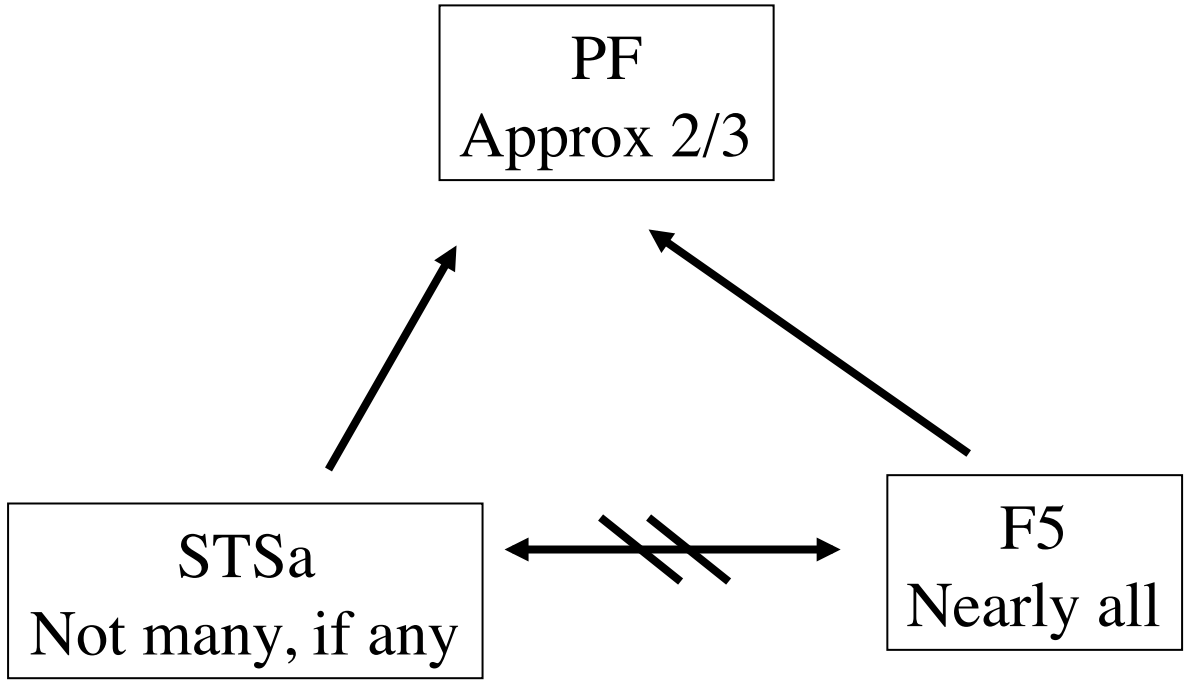
V5 activation for man v robot
(robot action interpreted as meaningful?
Maybe, but could be due to static control
subtraction.



Left PMC activation for man, not robot.
Mirror response for bio actions only.

How are mirror neurons related to STS biological motion processing?

number of biological motion responsive cells with mirror properties



STS codes for observed actions, but is not active during motor execution and therefore does not have mirror properties

Interim Conclusions:

Activation of Broca's area during observation of hand actions reflects a genuine mirror phenomenon.

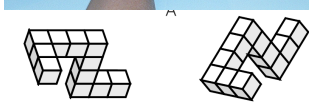
This area is the human homologue of monkey area F5 where MNs have been found

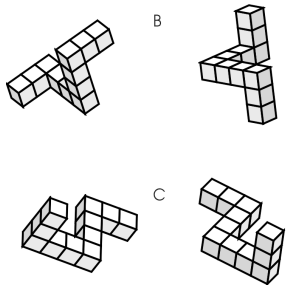
The mirror system is not limited to hand movements

But it is limited to meaningful biological movements

The parietal lobe is also part of the human mirror system and is strongly involved when a subject observes object-directed actions

Hesslow's account of simulation, 2002





Simulation has 3 core attributes

(1) simulation of actions: we can activate motor structures of the brain in a way that resembles activity during a normal action but does not cause any overt movement;

(2) simulation of perception: imagining perceiving something is essentially the same as actually perceiving it, only the perceptual activity is generated by the brain itself rather than by external stimuli;

(3) anticipation: a simulated action can elicit perceptual activity that **resembles the activity that would have occurred if the action had actually been performed**.

Understanding actions

Jeannerod's account of motor cognition (1999)

An action involves a covert stage, corresponding to its pragmatic representation (practical results), which includes its goal, the means to achieve it, and its consequences.

Such pragmatic representation may be activated under a variety of conditions in relation to action, either self-intended or perceived from other individuals.

Even though this process may have a conscious counterpart (one can consciously generate a mental image), most of its generation occurs at the covert level

Action representations are subconsciously activated by observation of another's action

Goldman's account of full-on simulation , 2002, 2005.

In order to understand the mental state of another when observing the other acting, the individual imagines themselves performing the same action.

This is a covert simulation that does not lead to any overt behaviour.

Note: In trying to attribute mental states to others, an attributor has to set aside her own current mental states and substitute those of the target (Goldman, 2005).

They must put themselves in the 'mental shoes' of the other person.

Relates more to ToM than action understanding, but principles similar

3 theories of simulation

These 3 theories are broadly similar and only vary by degrees in 2 aspects:

1. *The amount to which the mental simulation is automatic or deliberate*

2. *The scope of the simulation (covering action understanding only or extending to intentions and theory of mind).*

They all employ some kind of covert rehearsal of actions in order to understand the actions (and as a consequence the intentions) of another being.

Evidence for similarities between overt and covert actions: Imagined actions

Imagined actions retain the same temporal execution characteristics as the real action e.g. :

1. Reciprocal tapping (Fitts law)
2. Graspability: determining the feasibility of grasping objects at different orientations is similar to the time taken to actually grasp it: suggests mental movement of the arm before a response can be given.
3. Mental motor imagery in the old slows to match actual movements.

Patients with corticospinal hemiplegia behave normally on above tasks

Overlapping brain areas are activate during both imagined and actual grasping movements

Evidence for similarities between overt and covert actions: Imagined actions

The man who executed imagined actions (but was unaware of doing so) (Schwoebel et al., 2002). Patient CW: Bilateral parietal damage

When told to (e.g.) imagine touching finger and thumb he would actually perform the movement (top), but was not aware that he had done so

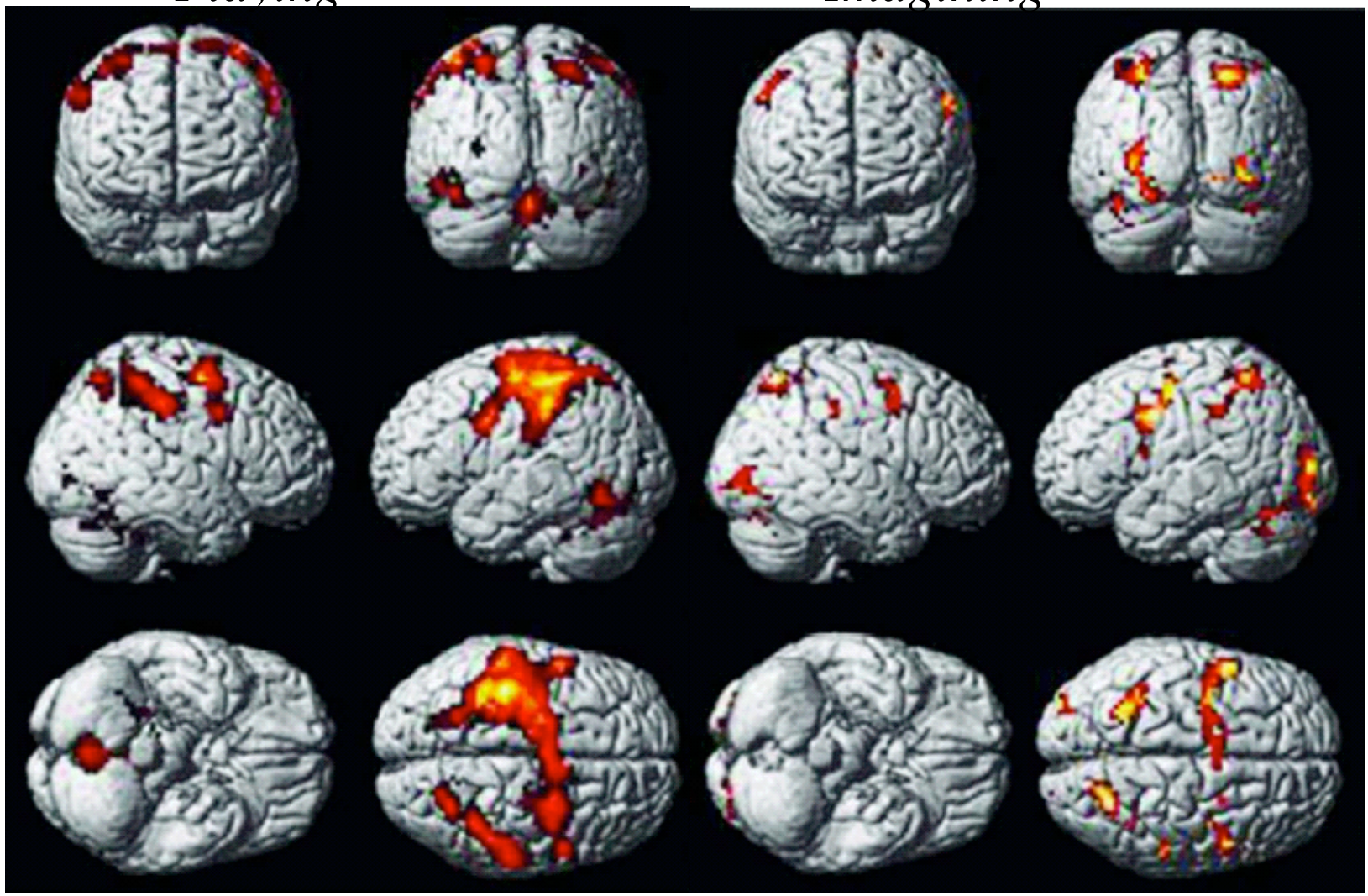
Suggests imagined movements may involve inhibition of actual movements

Covert simulation - the evidence

Similarities between overt and covert actions: imagined actions

Playing the piano in the mind. Meister et al., 2004

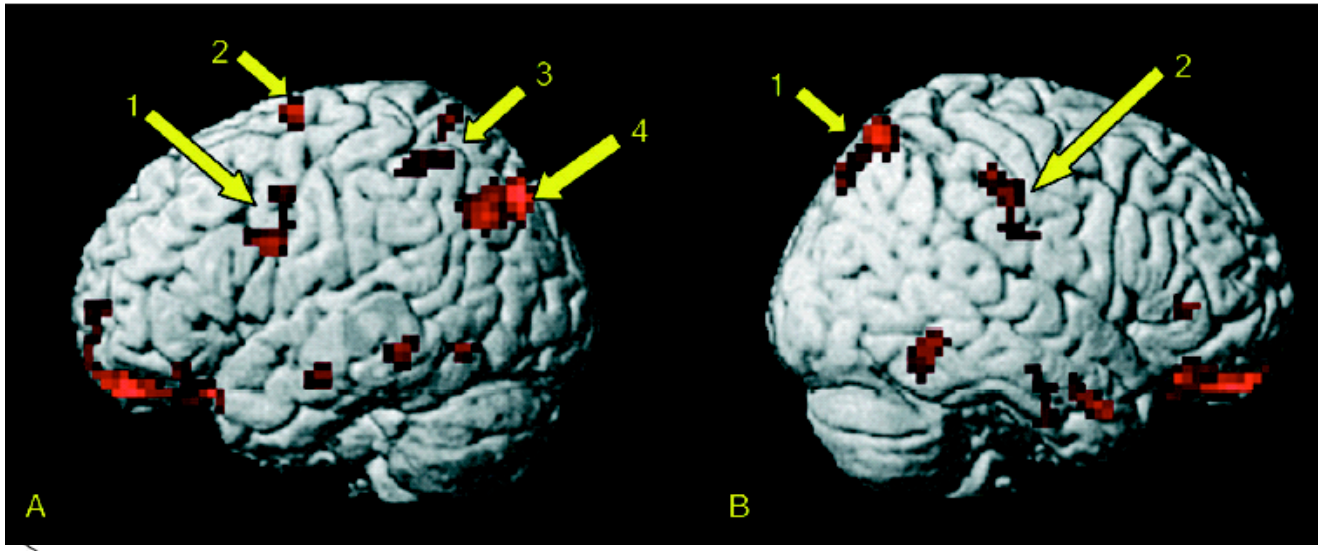
Playing *Imagining*

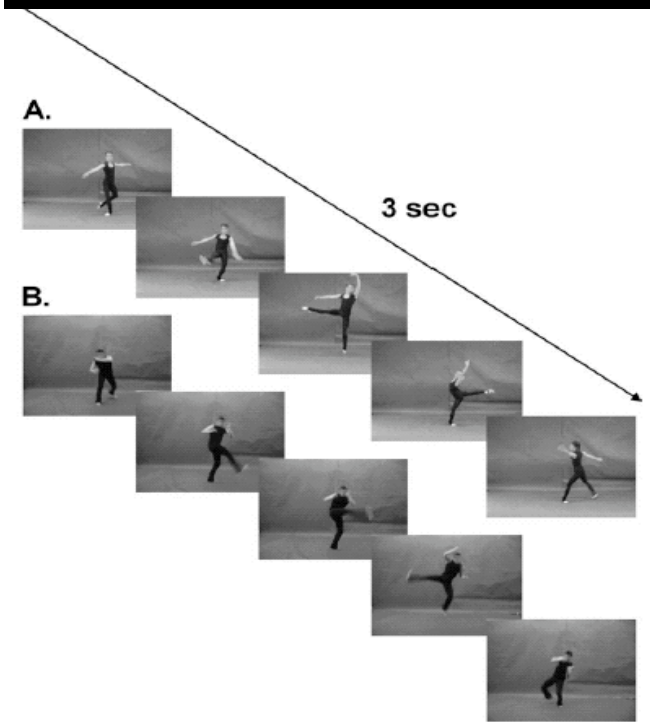


Understanding actions

Our own motor repertoire

Similarities between overt and covert actions: observed actions



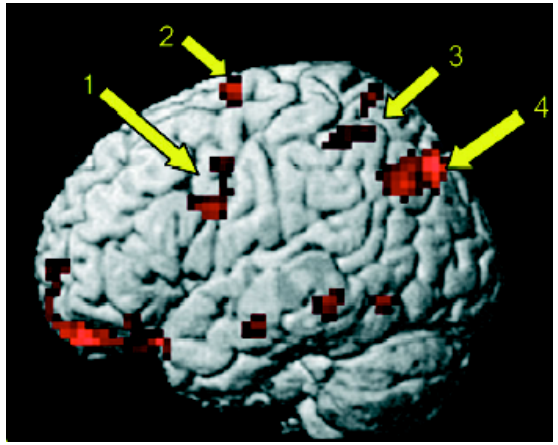


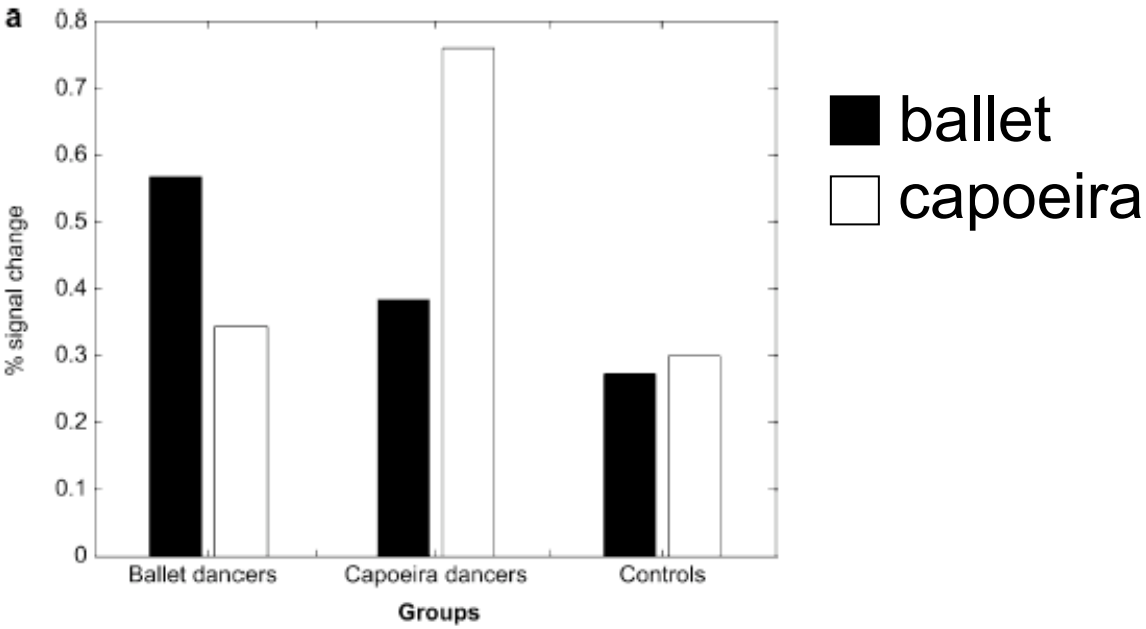
Action observation and acquired motor skills. Calvo-Merino et al, 2004

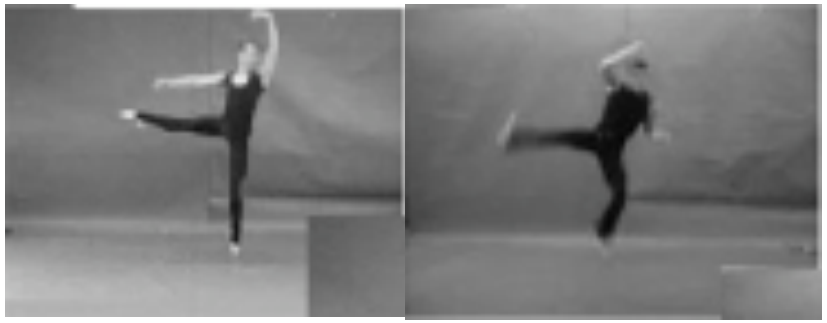
Left	*Right*
1. PMv	*1. SPL*
2. PMd	*2. IPS*
3. IPS	
4. pSTS	

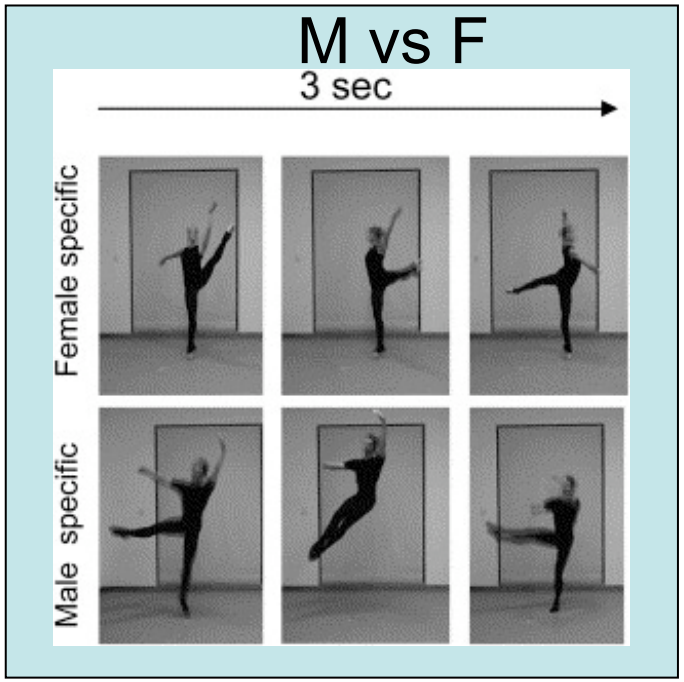
Understanding actions

Our own motor repertoire









[Note that this is not simply the same as recognising another's action]

$E=MC^2$

Understanding actions

How do we understand others' actions?

Our own motor repertoire

Understanding actions


NISSAN

What does all this mean?

We do not have to go through cumbersome and laborious thought processes in order to understand what someone else is doing.

We have a FAST and AUTOMATIC understanding of what someone else is doing - has huge evolutionary and social benefits

We can put ourselves in the ‘mental shoes’ of the other person

We know what someone else is doing/about to do without thinking about it

A parsimonious (simple) explanation of everything. Quite simply, the best thing since sliced bread.

After the break - the problem with Mirror Neurons

Self/other representations

Telling our own actions from the actions of others

Shared Representations

Mirror neurons: A parsimonious explanation of everything

Many psychologists think that mirror neurons provide the mechanism by which we can perform:

Imitation
Empathy
Language
Theory of mind
Imagination
Mental simulation
Etc etc

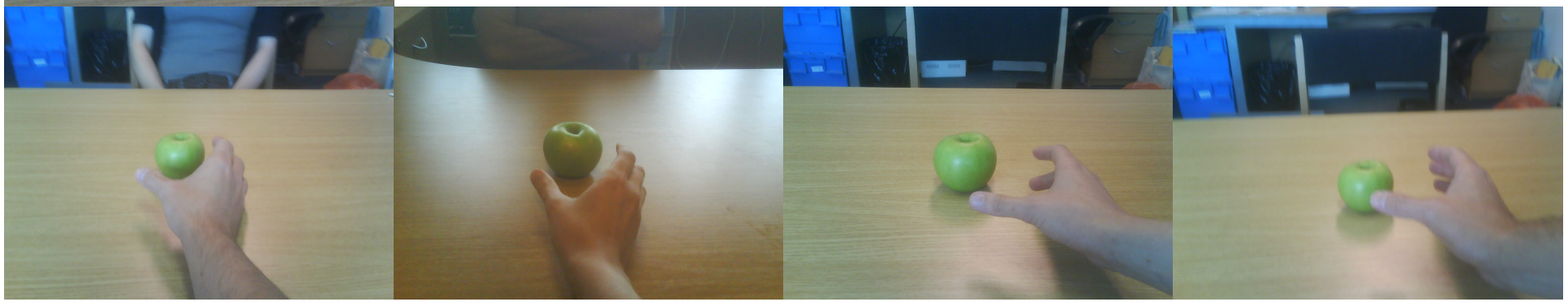
Link between mirror neurons and tool use may be what separates us from non-human apes

But there are two problems with this:

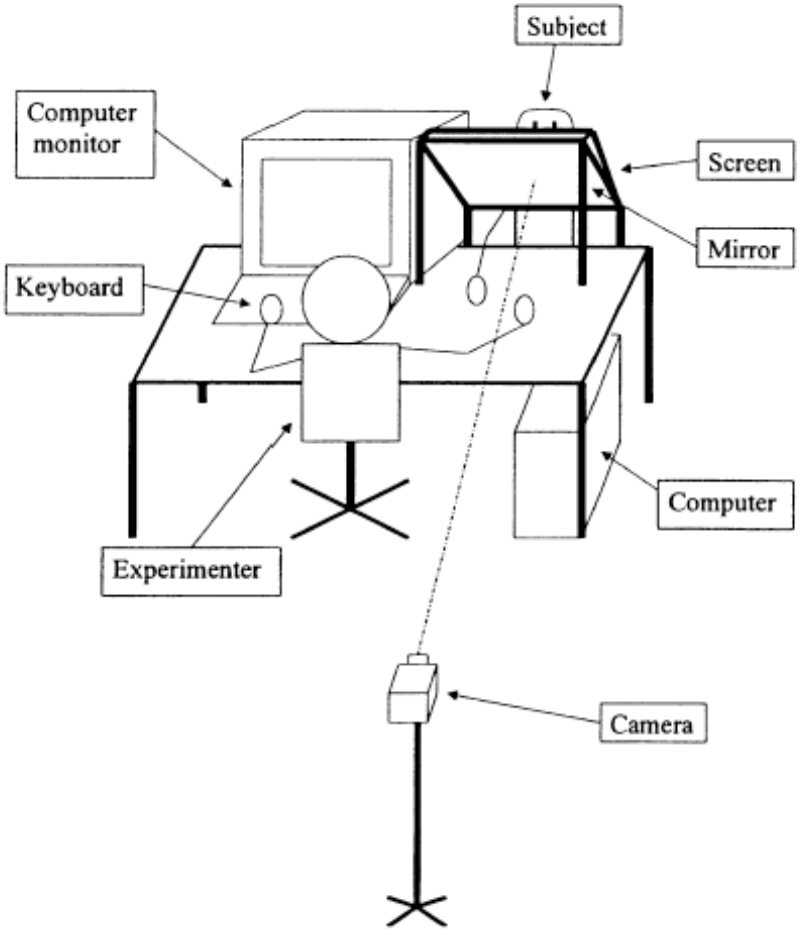
1. They can't explain everything

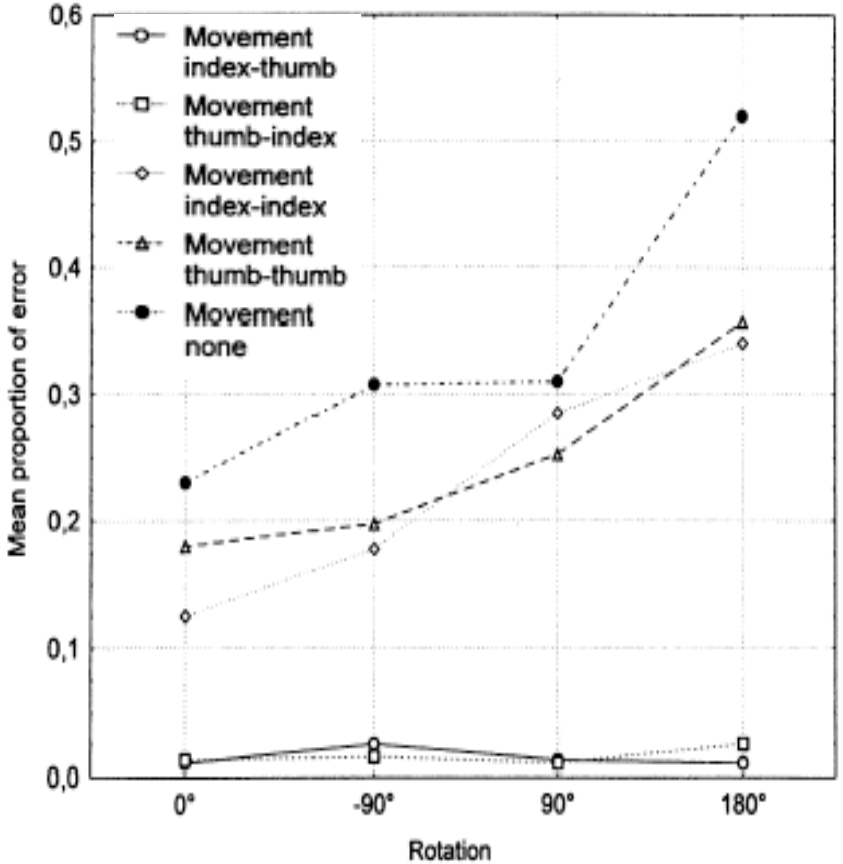
2. If the same parts of my brain are active when I pick up an apple as when I see someone else pick up an apple - how does my brain know who is picking up the apple?

There must be other mechanisms involved



Experiencing oneself as the cause of an action (the sense of agency)
experiencing another person as being the cause of that action.

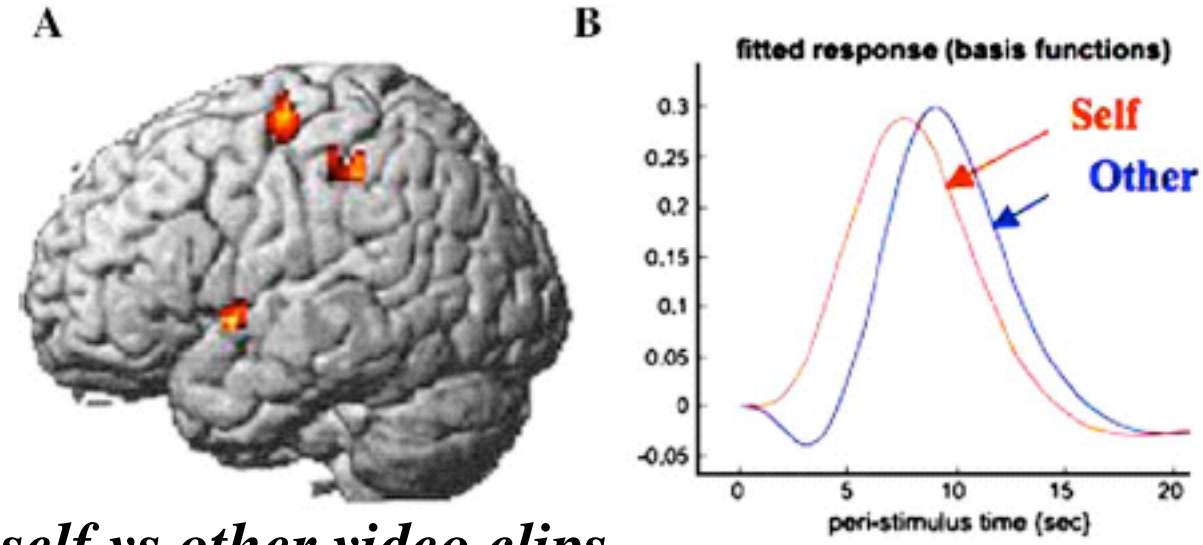




Van den Bos and Jeannerod, 2002

Interpreting our own actions: a possible mechanism

Grezes et al., 2004



Watched self vs other video clips

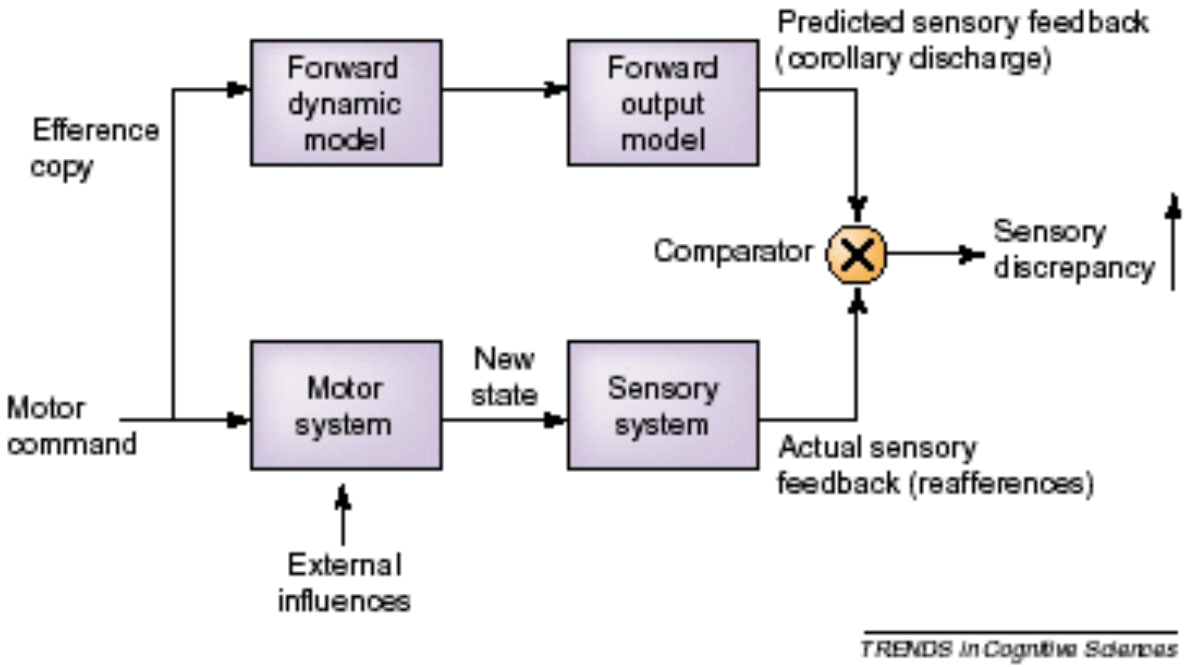
Differences in the dynamics of neural responses.
Haemodynamic response to self generated movements occur earlier than those to other generated movements

Interpreting our own actions: a possible mechanism

When we intend to perform an action we make predictions about its outcome

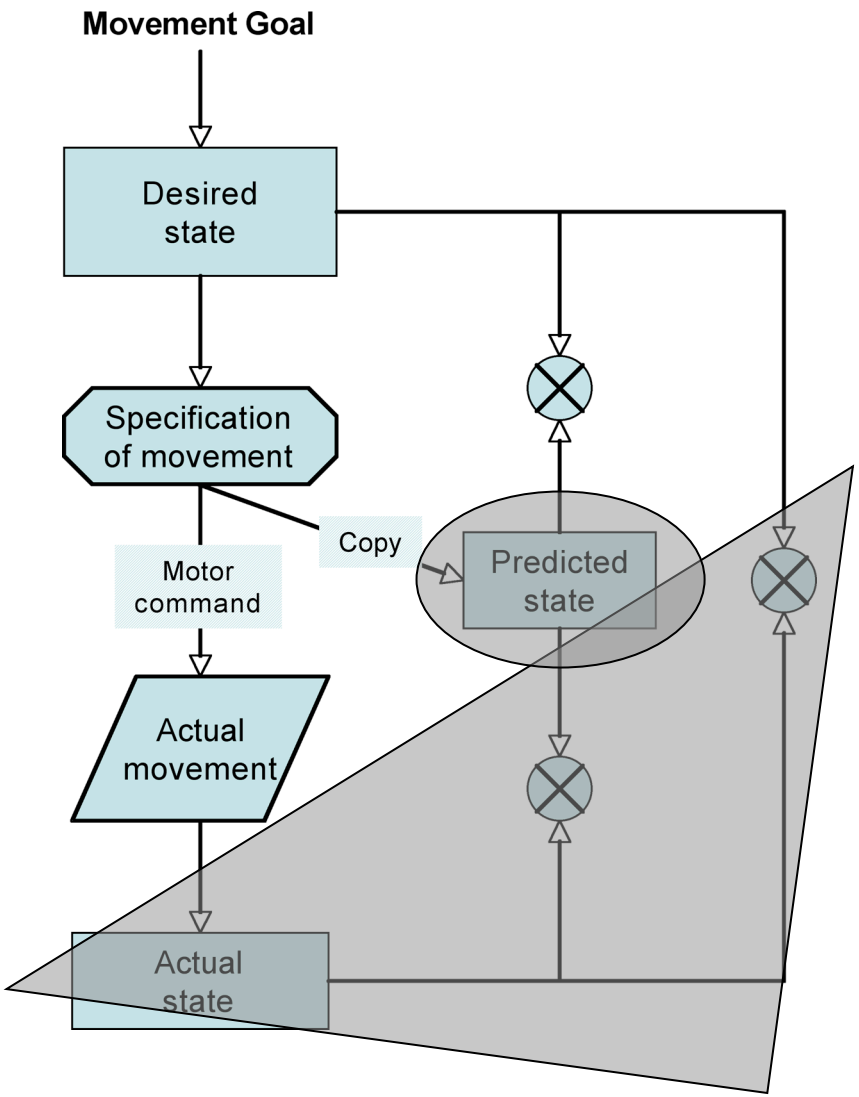
If the outcome does not match our prediction then we make on-line corrections to the movement

If the discrepancy is too large we attribute the action to someone else.



Distinguishing representations of t self from the other

Comparator Models



Schizophrenia

disorder characterised by abnormal beliefs, behaviours and experiences - including

delusions of alien control

over intentional movements

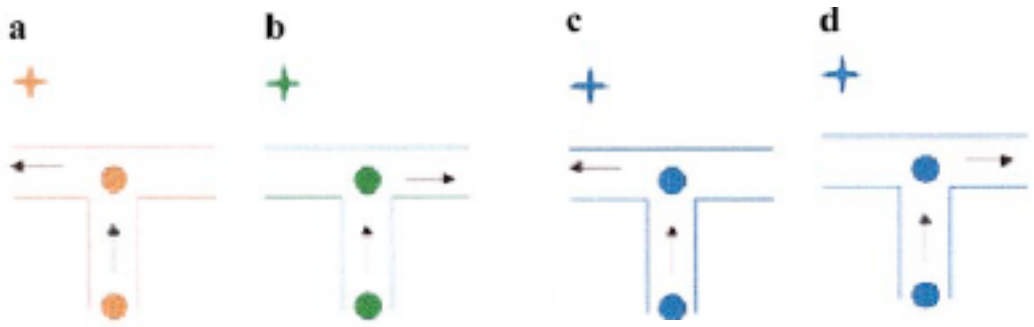
Anosognosia

Denial of impairment

Doctor: 'Can you clap?'
F.D.: 'Of course I can clap.'
Doctor: 'Will you clap for me?'
The patient proceeded to make clapping movements with her right hand as if clapping with an imaginary hand near the midline.
Doctor: 'Are you clapping?'
F.D.: 'Yes, I am clapping.'

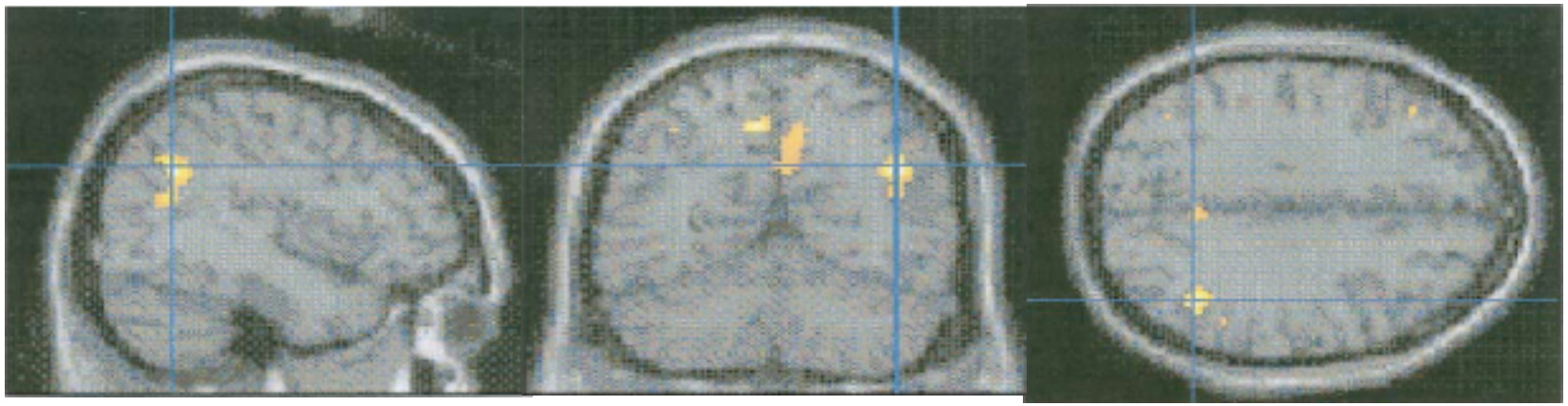
(Ramachandran 1996, p. 124)

Agency attribution
Underlying mechanisms

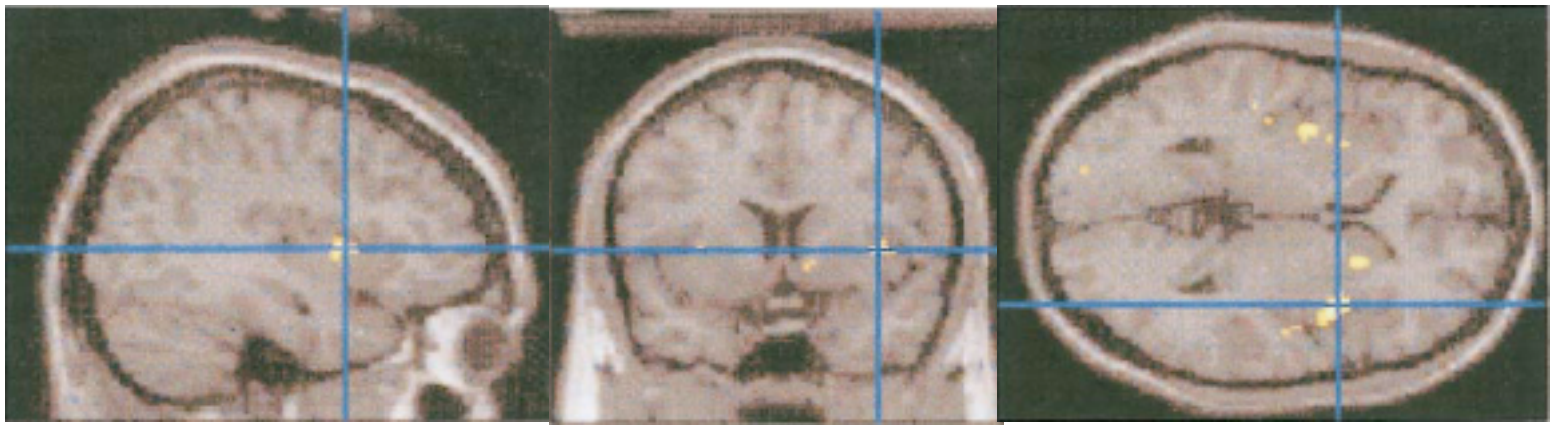


Farrer and Frith 2002

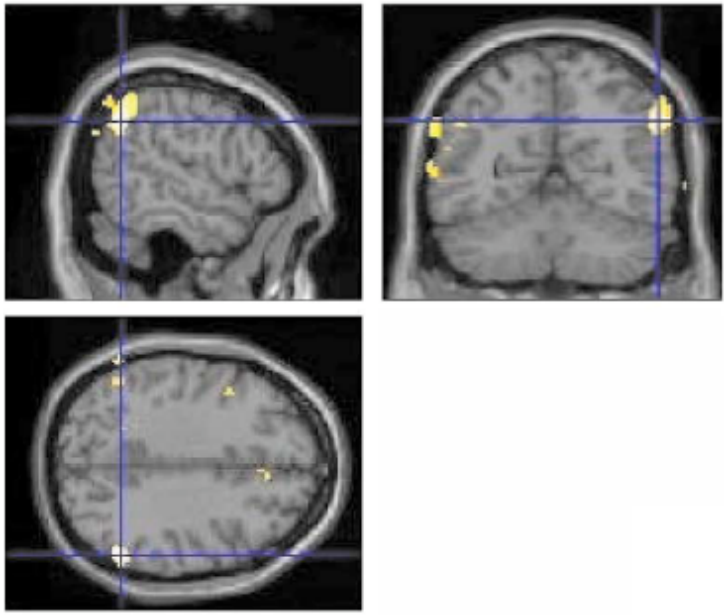
Predictable *Unpredictable*

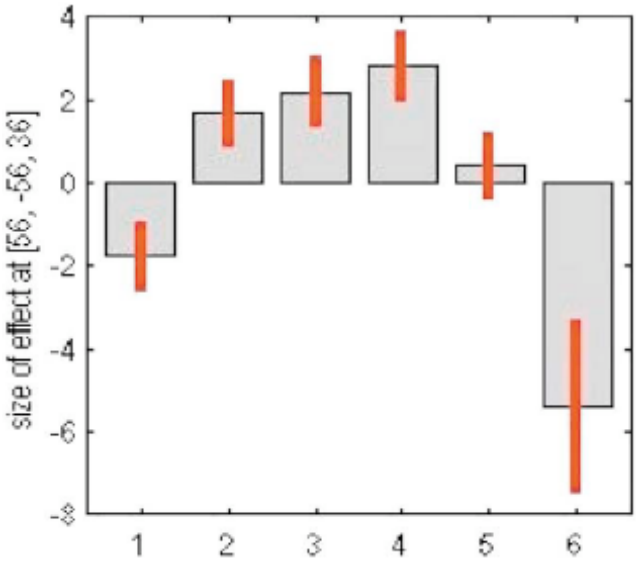


Attributing to other (Angular gyrus)



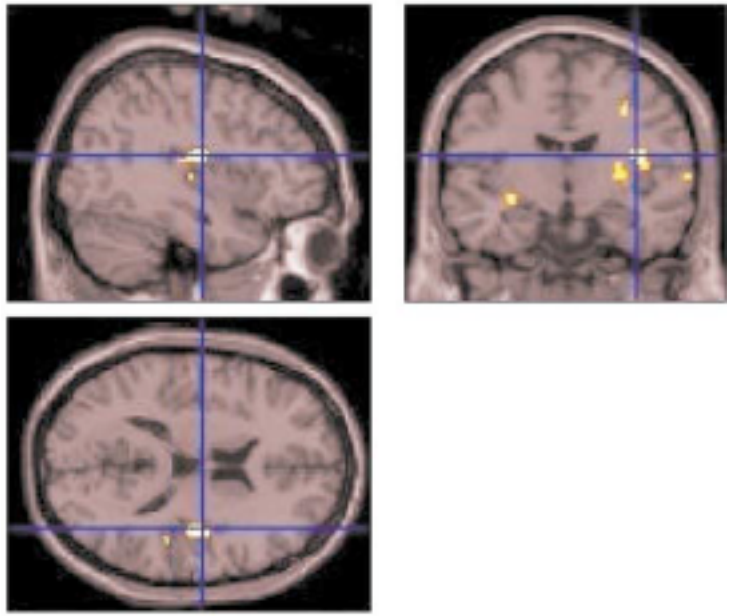
Attributing to self (Anterior insula)

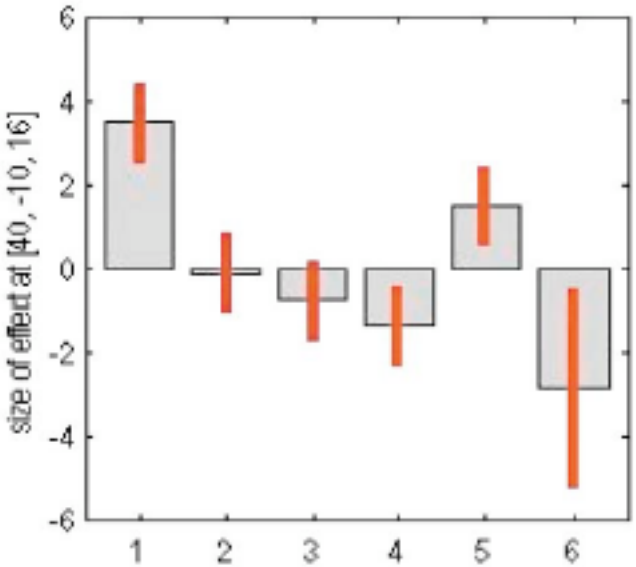




Farrer et al. 2003 (PET) Subjects moved joystick to control virtual hand (0°, 25°, 50°, Other)

Right IPL more active the less subjects felt in control of movements
reverse covariation for the insula





1=0°
2= 25°
3=50°
4=Other
5=C1
6=C2

Neural correlates of self/other: imaging studies

Right IPL activity:
imagining someone else acting (Ruby and Decety, 2001).
reading words and hearing the sound of someone else's voice (McGuire *et al*., 1996).

1Hz rTMS to rIPL disrupts recognition of self from other faces
Uddin et al., 2006

Left anterior insula activity
Imagining yourself acting (Ruby and Decety, 2001).
reading words and hearing the distorted sound of your own voice (McGuire *et al*., 1996).

Right anterior insula activity
recognizing own face or descriptions of self in words (Kircher *et al*.)
Identifying own memories Fink *et al*. (1996)

Neural correlates of self/other: patient studies *Right IPL involvement*

Neurological syndromes associated with disturbances in feelings of belonging in the limbs following right inferior parietal lobe damage:

alien hand : the limb is not only outside the control of the subject, but is also perceived to be under the control of another person

anosognosia: patients sometimes deny ownership of their limbs

somatoparaphrenia delusional beliefs about their limbs (distorted or belonging to specific others)

Psychiatric disorders:
hyperactivity in the right inferior parietal lobule observed in:
schizophrenic patients when experiencing alien control (feeling of being controlled by another agent) and
depersonalization disorder (loss of the sense of self)

SUMMARY

Mirror Neurons (found in premotor and parietal cortex) provide an automatic mapping between our own actions and the actions of others

This allows us to automatically understand the actions of others because we automatically understand our own actions

Such shared representations also allow us to simulate our own and others' actions my mental or covert action execution

These shared representations cause problems if we can't tell our own actions from others'

Low level mechanisms in the IPL help to distinguish self from other

Human cortical representations for reaching: Mirror neurons for execution, observation, and imagery

Rationale

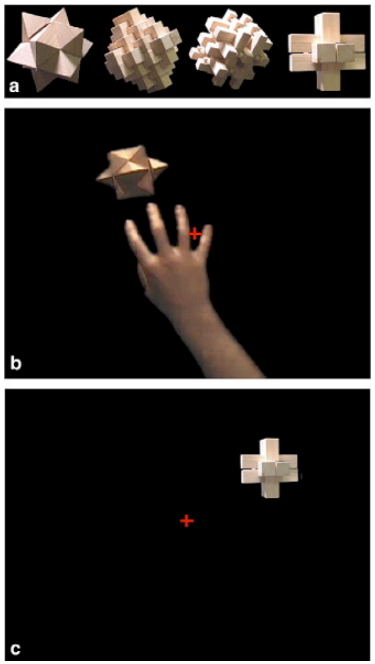
We know a lot about monkey MNs for reaching and grasping

No studies to date have examined reaching (not grasping) in humans

Is there evidence for human MNs for reaching?

Methods

fMRI comparing actual reaching towards (execution), observation of reaching towards and and imagined reaching towards (all vs objects alone)



Results

Overlap observed for all 3 types of reaching in premotor and parietal regions (but slightly different to grasping areas and matching monkey reaching areas

Misattribution of Movement Agency Following Right Parietal TMS

Rationale

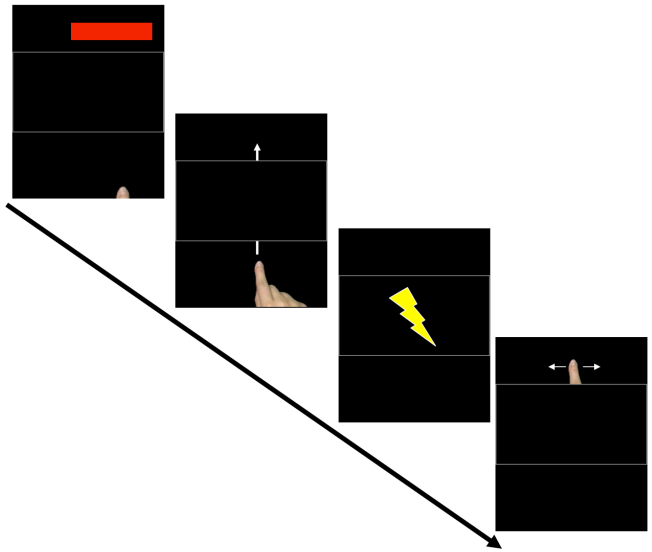
The right IPL has been implicated in agency attribution

One of the mechanisms of agency is thought to be movement prediction mis-match

Will rIPL disruption of movement prediction disrupt agency attribution?

Methods

TMS over rIPL at time crucial to prediction



Results

rIPL TMS disrupted agency so prediction is component of agency attribution

Schizotypal personality traits and prediction of one's own movements in motor control: What causes an abnormal sense of agency?

Rationale

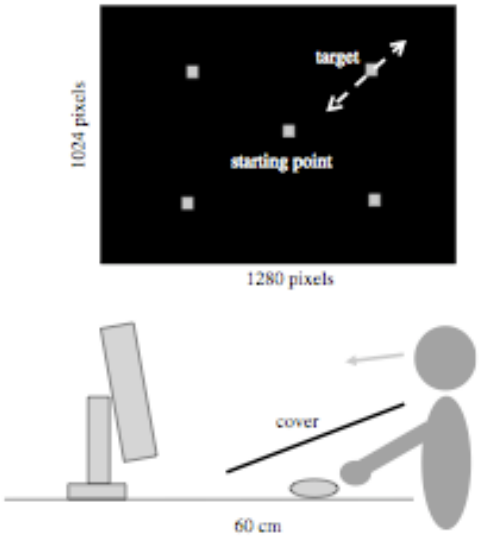
Positive Schz symptoms, esp. passivity phenomena, including auditory hallucinations, may be caused by an abnormal sense of agency

These symptoms are also sometimes seen in schizotypal pers. traits

Do schz pers. trait participants show abnormal movement prediction?

Methods

Questionnaires
Sub groups
mouse



Results

High Auditory Halucination Experience associated with poor movement prediction (underestimation of dist).

Autumn

29 09	06 10	13 10	20 10	27 10	03 11	10 11	17 11	24 11	01 12	08 12	15 12	22 12	29 12	05 01	12 01
L	L	L			r ?		D 4pm	L	L		X	X	X	X	E
Emotions								Actions							

Spring

19 01	26 01	02 02	09 02	16 02	23 02	02 03	09 03	16 03	23 03	30 03	06 04	13 04	20 04	27 04	04 05
E	f ?			D 4pm	L	L			f ?		X	X	X	X	D 4pm
Actions					Minds										

Next session:
Whenever we decided earlier.

Remember: any questions must be submitted by the end of the Wednesday before the lecture to guarantee a reply.

Out of bounds:
Language
ToM
Empathy
Emotion