

PSHA – Neuroscience Applications to Clinical Practice

Martha Burns

Part 3

Mirror Neurons and Clinical Practice

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Part 3

- Mirror Mechanisms and neurorehabilitation
 - * What are mirror neurons?
 - * What mirror mechanism disorders may have to do with ASD
 - * Treatment research using Mirror Therapy

Giacomo Rizzolatti, Maddalena Fabbri-Destro and Luigi Cattaneo

Mirror neurons and their clinical relevance

Nature Clinical Practice NEUROLOGY 2009 5(1)

- Mirror mechanism - neural system that unifies action perception and action execution
- Mirror mechanism is organized into two main cortical networks, formed by
 - the parietal lobe and premotor cortices
 - the insula and anterior cingulate cortex
- Role of the Mirror Mechanism - to provide a direct understanding of the actions and emotions of others without higher order cognitive mediation
 - “action understanding” theory

Video Clip

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- Limited development of the mirror mechanism seems to determine some of the core aspects of autism spectrum disorders
- There is a recently demonstrated link between limited development of the mirror mechanism and that of some aspects of the motor system
 - this suggests that rehabilitation in children with autism spectrum disorder should take into account both motor and cognitive strategies

Views that oppose MSM impairment hypothesis in ASD

- Recently, some behavioral studies have challenged this view of MNM impairment in ASD
 - The studies showed that the capacity of children with ASD to understand the goal of observed motor acts — a function of mirror neurons — is preserved
 - Therefore, the mirror hypothesis of ASD should therefore be considered incorrect

How can the discrepancy between imaging and electrophysiological findings and behavioral data be explained?

- answer provided by a study in which children with ASD were asked to grasp a piece of food
 - either for eating or for placing in a container (see next figure)
 - and, in another set-up, to observe an experimenter performing these actions
- The activity of the mylohyoid (MH) muscle, which is involved in mouth opening, was recorded to produce an electromyograph (EMG).

Cattaneo, L. et al. (2007) *Proceedings of the National Academy of Sciences* **104**: 17825-17830

- Measured EMG activity in the mylohyoid muscle (opens the mouth) [Corollary to the monkey study on grasping to eat vs. grasping to place]

- during observation of grasping to eat
- During the action of grasping to eat

Giacomo Rizzolatti & Corrado Sinigaglia (2010) conclude

- The interpretation is straightforward:
 - children with ASD have a severe impairment in motor organization that includes a deficit in chaining motor acts into intentional actions.
- During action observation the intentional motor chains are not activated.
 - Therefore, the intentions of others do not ‘intrude’ into the mirror system of children with ASD and
 - these intentions are not understood ‘from the inside’ but only ‘from the outside’.

Further support from:

- Boria, S. *et al.* Intention understanding in autism. *PloS ONE* 4, e5596 (2009).
- A recent study showing that to understand the intentions of other people,
 - children with ASD do not rely on the observed motor behavior
 - but on the semantics of the object that is being manipulated
 - or on the context in which the motor act takes place

Other findings in ASD

- TMS study - Impaired motor facilitation during action observation in children with ASD (Theoret H, et al., 2005)
- Children with ASD tend not to imitate others in a mirror fashion when viewing them face-to-face (Avikainen, S. et al., 2003)
 - Regarded as demonstrating that children with ASD have difficulty superimposing another’s movements on their own

ASD and problems understanding the intention of an action (Rizzolatti G et al (2008))

- Children with ASD and TD children observed an actor performing goal directed motor acts and asked to report
 - “what the actor was doing” -recognition

- “why he was doing it” – intention
- Both groups recognized what the action was but ASD group failed to recognize why
 - ASD group attributed action to the semantics derived from the object (if actor used a scissors the children said the actor was cutting) regardless of how the object was grasped

Other possible explanations for these findings?

- Two-year-olds with autism orient to non-social contingencies rather than biological motion Klin, et al., *Nature* May 14, 2009
 - Researchers propose that saliency of coincident light and sound (which may be genetically driven) over complex information of biological motion leads to perceptual preferences that alter the developmental brain trajectory

- Video demonstrations

Neural activity was significantly correlated with empathic abilities

- Self differentially activated MPFC, Posterior cingulate and temporo-parietal junction
 - Act as key players in evaluation of one’s own emotional state
 - Supports view that mirror neurons are not just involved in motor cognition but also emotional interpersonal cognitions
 - Interplay between TOM and mirror neuron mechanisms may maintain self-other distinction during empathic interpersonal face to face interactions

Caggiano, V., Fogassi, L., Rizzolatti, G., Thier, P. & Casile, A. **Mirror neurons differentially encode the peripersonal and extrapersonal space of monkeys. *Science* 324, 403–406 (2009).**

Caggiano et al. (2009) Importance of goals in mirror neuron system

- The results showed that many F5 mirror neurons were differentially modulated by the location of the observed motor act.
 - Some neurons were selective for actions executed in the monkey's peripersonal space,
 - whereas others were selective for stimuli in the extrapersonal space.
- These findings indicate that mirror neurons may encode the goal of the motor acts of

- another individual in an observer-centered spatial framework,
- this provides the observer with crucial information for organizing their own future behavior ***in cooperation or competition with the observed individuals.***

Mirror neurons as precursors of speech – revival of the motor theory of speech perception

- However, another argument concerns the functional role of mirror neurons in creating a common code,
 - a parity, between observer and actor like that between the sender and the receiver of a message
 - Specifically, the involvement of motor structures in perception as demonstrated by mirror neurons was first suggested in the motor theory of speech perception
 - the objects of speech perception are the intended phonetic gestures of the speaker, rather than the acoustic cues of speech sounds
- A series of recent [transcranial magnetic stimulation](#) (TMS) and functional MRI studies has provided evidence for the activation of motor speech areas during speech perception..

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- The use of action-observation-based protocols could represent a new rehabilitation strategy to treat motor deficits after stroke
- Mirror mechanism - basis for imitation and learning through imitation
- “Building of motor memories”
 - Stefan K. et al. (2005) (2008) *J. of Neuroscience* **25 & 27** -- motor memory facilitated through action observation

Mirror Mechanism applied to neurorehabilitation

- Ertelt D et al. (2008) Action observation has a positive impact on rehabilitation of motor deficits after stroke *Neuroimage* **36(supp 2)**: T164-T173
 - 18 day cycle of motor training upper limb with two groups of hemiplegic patients with lesions in LMCA
 - Test group performed exercises with movies – control did not
 - Significant improvement in upper limb movement in the test group compared to the control group
- “Mirror Therapy” Moseley GL et al. (2008) *Pain* **138**: 7-10
 - Patients required to perform movements with their nonparetic hand while watching the hand and its reflection
 - Gives the illusion of movement of the paretic limb –preliminary promising results

Opposing views

- Antonia, Hamilton, Brindley and Frith (2006) Imitation and action understanding in autistic spectrum disorders: how valid is the hypothesis of a deficit in the mirror neuron system? *Neuropsychologia* **11(22)**
 - Saw no deficits in imitation but did see deficits in TOM
- Antonio Damasio & Kaspar Meyer (2008) Behind the looking-glass. *NATURE* **454**, 10 July 2008
 - “The neurons are not so much like mirrors, after all. They are more like puppet masters, pulling the strings of various memories.”

Opposing views (continued)

- Gregory Hickock (2009)
 - Eight Problems for the Mirror Neuron Theory of Action Understanding in Monkeys and Humans *Journal of Cognitive Neuroscience* 21:7, pp. 1229–1243
 - Provides research to support contention that
 - evidence that Mirror Neurons “understand action” is lacking parallels between monkeys and humans has not been empirically determined
 - there are dissociations between action production and understanding in humans (lesion studies) –
 - lesions in IFG do not lead to problems with action understanding
 - Motor theory of speech perception is problematic on empirical grounds
- Giacomo Rizzolatti & Corrado Sinigaglia respond in NRSS 2010

Some (pseudo) problems for the mirror mechanism

- **From the following article:**
- [The functional role of the parieto-frontal mirror circuit: interpretations and misinterpretations](#)
- Giacomo Rizzolatti & Corrado Sinigaglia
- ***Nature Reviews Neuroscience* 11, 264-274 (April 2010)**
 - Problem 1 - individuals were trained to move their fingers in a manner incongruent to that of the 'teacher'.
- Experiment in which, after training, motor-evoked potentials were greater in muscle involved in incongruent response than congruent.
- Authors claimed:
 - they discovered of a new class of mirror neurons.
- It probably shows that one can;
 - inhibit a natural (mirror) response and
 - voluntarily organize a different response to comply with instructions
- However, regardless of what this experiment tells us about the role of the mirror mechanism in imitation,
 - its results are unrelated to action understanding because there was nothing to understand:
 - the investigated movements were meaningless.
- Problem 2 - If the mirror system were involved in action understanding, motor syndromes following its damage (for example, ideomotor apraxia) would be accompanied by a deficit in action recognition
- The assumption is – that there is a one-to-one correspondence between motor and mirror sectors in the parieto-frontal circuit.
 - This assumption is wrong.
 - As clearly shown by electrophysiological mapping, there are motor sectors in the monkey inferior parietal lobule (and even in area PFG) with and without mirror neurons.
 - Thus, dissociations between motor deficits and action understanding deficits can and do occur.
- It is the opposite result — that specific action recognition deficits can occur following motor circuit damage — that is striking and that provides a compelling argument for

the crucial role of mirror neurons in this function.

Problem 3 - saxophone playing shows that the mirror view of action understanding is “untenable”

- No motor competence is required to understand that someone is playing a saxophone.
- This is true, but such competence leads to a different understanding of saxophone playing.
 - The non-motor-based understanding implies a mere semantic knowledge of what a saxophone is for,
 - Whereas the motor experience allows an individual to understand what saxophone playing really means — that is, it provides a musical knowledge 'from the inside'

Giacomo Rizzolatti & Corrado Sinigaglia (2010)- Conclusions

- The mirror mechanism provides a basic mechanism that unifies action production and action observation, allowing the understanding of the actions of others from the inside.
- Such motor-based understanding seems to be a primary way in which individuals relate to one another
- Furthermore, this mechanism indicates the existence of a profound natural link between individuals that is crucial for establishing inter-individual interactions
- Finally, preliminary evidence suggests that the impairment of this natural link may be one of the causes of the striking inability of people with autism to relate to other individuals

Summary and conclusions

- The discovery of a possible human mirror mechanism is exciting and compelling. But part of the appeal is the:
 - Simplicity of the notion that our brains are designed to learn from others
 - Concept that imitation is not only “the highest form of flattery” but also a primary neurological mechanism for motor planning and motor understanding
 - Hypothesis that it is “hard wired” into the typical human brain
- But, the proposed mirror mechanism is likely neither that simple nor that explanatory by itself
- Rather it creates a new paradigm for exploring assessment of typical and treatment of disordered
 - human cognitive potential, especially motor function & language
 - human interaction and empathy (including TOM)

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Part 4

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Frontal Lobe functions

Frontal lobes and Limbic System

- Frontal lobes - 1/3 of hemispheres - three parts
 - Motor and PreMotor
 - Paralimbic sector
 - ventral medial
 - anterior cingulate
 - parolfactory gyrus
 - posterior orbitofrontal
 - Heteromodal
 - Heteromodal + Paralimbic = Prefrontal Cortex

Pre-frontal Lobes

- Ventromedial – connected to limbic system
 - Important in delayed gratification
 - Empathy
- Dorsolateral –
 - Organization, planning, flexibility
 - Working memory
 - Processing speed

Dorsolateral Pre-frontal Cortex

- Executive function
- Working memory
- Complex Problem Solving

Volition

- Complex process of determining what one needs or wants and conceptualizing some kind of future realization of that need or want. [the capacity for intentional behavior]
 - Motivational capacity
 - Capacity for self-awareness
 - Physical status, environmental and situational context, social awareness

Purposive Action

- The translation of intention or plan into productive, self-serving activity
- Seen as problematic in impulsivity
- Dissociation between verbalized intentions and actions
- Includes:
 - Self regulation for productivity
 - Self regulation for flexibility and the capacity to shift

Purposeful interaction with problem solving

- PT - Motor planning – sequencing and adaptation
 - Ideation – conceive a plan relative to the demands of the environment
 - Motor sequencing
 - Motor execution
 - Adaptability
- OT - Sensory modulation – regulation and sensory discrimination

Executive Function Goals – Effective Performance

- PT – measure reaction time, speed of execution, mastery
- OT – use timers to increase task completion
 - decreasing rigidity
- Speech – increase processing speed and working memory on tasks such as concentration; holding to a script
- Outcome measures should include:
 - Self-direction
 - Self-regulation

Medial Frontal Lobe

Right Hemisphere connections to Medial Pre-frontal Lobe

- Video

Mindblind Eyes: An Absence of
Spontaneous Theory of Mind in
Asperger Syndrome

- Atsushi Senju, Victoria Southgate, Sarah White, Uta Frith
- *SCIENCE* VOL 325 14 AUGUST 2009