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# ROLE OF MIRROR NEURONS IN SURGICAL SKILLS TRAINING

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**ABSTRACT** In the early 1990's, Italian researchers discovered that the monkey brain contains a special class of cells that fire when it sees or hears an action and when it carries out the same action on its own. These cells were termed as the 'Mirror Neurons'. Subsequent research in humans revealed that the human brain has multiple mirror neuron systems that specialize in carrying out and understanding the actions, intentions, emotions and behavior. The available scientific literature provides substantial evidence that Mirror neurons offer the basis to grasp the actions and intentions of others through direct imitation without the need for any conceptual reasoning. The discovery of Mirror neurons has added a new light to the understanding of culture, empathy, philosophy, language, imitation and autism.

The present paper gives a brief overview of the myriad applications of the concept and mechanism of mirror neurons. Here, we present an innovative concept of harnessing the functional mechanism of Mirror neurons to the domain of psychomotor surgical skill development essential for surgeons. We have illustrated this concept by extracting references and thought-models from previous works. However, none of the previous works have demonstrated the utility of application of Mirror mechanism in surgical training. This paper propounds the potential utilization of cognitive functioning of Mirror neurons to the psychomotor domain of surgical skill enhancement. This will not only open new concepts in skill learning for apprentice surgeons but will also enhance the surgical proficiency of skilled surgeons.

**KEYWORDS :** .Mirror Neurons; Surgical Training; Psychomotor Skills; Training of surgeons; surgical live workshops

**Discovery of Mirror Neurons;**

How does a baby learn to imitate a smile? Why is yawning contagious? Why do we feel empathy? Why do we get goose bumps while seeing a horror film? In an attempt to find a scientific basis to these sensations, a team of Italian researchers in the early 1990's discovered the Mirror neuron mechanism. Rizzollati and his colleagues studied Macaque monkeys and discovered a curious cluster of cells in the ventral pre-motor area of the brain's frontal lobes[1,2].The monkey fired the same set of Neurons when the monkey grabbed a peanut or watched somebody else grab a peanut. These neurons are what we now call as 'mirror neurons'. While observing monkeys' brains, they noticed that certain cells were activated both when an action is performed and when same action is watched. The observation of actions recruits in the observer monkey the same neural circuits normally involved in their execution, as if the monkey were actually performing those same actions. [3-5]

The mirror system, found in premotor and parietal cortices of human and monkey brains, is presumed to provide the basis for social interactions and to enable the development of theory of mind and language. [6-10]

**Evidence of Mirror Neurons:**

A large number of studies based on noninvasive electrophysiological (e.g. EEG, magneto encephalography [MEG]) or brain imaging (e.g. PET, functional MRI [fMRI]) techniques have demonstrated the existence of the mirror mechanism in humans. Brain imaging studies have enabled the mirror areas to be located.[11-15]These studies showed that the observation of transitive actions done by others results in an increase in blood oxygen level-dependent (BOLD) signal not only in visual areas, but also in the IPL and the ventral premotor cortex, as well as the caudal part of the inferior frontal gyrus (IFG). These latter three areas have motor properties and closely correspond to the areas that contain mirror neurons in the monkey. These experiments demonstrated that Broadmann's premotor cortex area 44 can be the most probable homologue of monkey brain area F5 accountable for the mirroring responses.[16-17]. This discovery challenged the classical view of segregate sensory and motor functions in the brain, indicating that perception and action, by sharing the same neuronal substrates, enables individuals to have a direct route into others' experience.

Researchers at U.C.L.A. made first direct recording of mirror neurons in human brain where the patients had been implanted with intracranial depth electrodes used to identify seizure foci for potential surgical treatment [18]. The experiment included three parts: facial expressions, grasping and a control experiment. Activity from a total of 1,177 neurons in the 21 patients was recorded as the patients both observed and performed grasping actions and facial gestures The researchers found that the neurons fired or showed their greatest activity both when the individual performed a task and when they observed a task. The mirror neurons making the responses were located in the medial frontal cortex and medial temporal cortex.

Researchers at University College of London's Institute of Cognitive Science stimulated hand-related portions of motor-cortex of human volunteers using Trans-Cranial Magnetic Stimulation (TMS) in which magnetic pulses were passed through the skull to induce brief electrical currents in the underlying brain tissue while they watched videos of hand performing movements of the index or little finger. It was found that when a volunteer watched index finger movement, motor-cortex stimulation by TMS led to stronger electrical signals in the participant's own index finger compared to the pinky, and vice-versa when watching pinky finger movement. These experiments reflected that the mirror neurons were found in several areas of the brain, including the pre motor cortex, the posterior parietal lobe, the superior temporal sulcus and the insula[19]

**Applications of Mirror Neurons**

Humans have mirror neurons that are far smarter, more flexible and more highly evolved than any of those found in monkeys, a fact that scientists say reflects the evolution of humans' sophisticated social abilities. Eminent Neuroscientist Dr. V S Ramachandran made the startling prediction that mirror neurons would do for psychology what DNA did for biology by providing a unifying framework and help explain a host of mental abilities that have hitherto remained mysterious and inaccessible to experiments.[20]

Mirror neurons provide clues to how children learn: they kick in at birth. Dr. Andrew Meltzoff at the University of Washington has published studies showing that infants a few minutes old will stick out their tongues at adults doing the same thing, imitating simple facial expressions [21]. More than other primates, human children are hard-wired for imitation, he said, their mirror neurons involved in observing what others do and practicing doing the same things.

Everyday experiences are also being viewed in a new light. Mirror neurons reveal how children learn, why people respond to certain types of sports, dance, music [22] and art, why watching media violence by children may be harmful.[23]

Language is based on mirror neurons, according to Michael Arbib, a

neuroscientist at the University of Southern California. One such system, found in the front of the brain, contains overlapping circuitry for spoken language and sign language.[9,24]

**Mirror neurons and Performance:**

Professional athletes and coaches, who often use mental practice and imagery, have long exploited the brain's mirror properties perhaps without knowing their biological basis. Observation directly improves muscle performance via mirror neurons. Similarly, millions of fans who watch their favorite sports on television are hooked by mirror neuron activation. Dr. Iacoboni has commented that in someone who has never played a sport - say tennis - the mirror neurons involved in running, swaying and swinging the arms will be activated.[25].

But in someone who plays tennis, the mirror systems will be highly activated when an overhead smash is observed. Watching a game, that person will be better able to predict what will happen next, he said. This concept can be used for training athletes, in the concerned sport.

**Mastery:**

Now, after a brief overview of the concept of Mirror neurons and their myriad implications, we try to extrapolate the functional mechanism of Mirror neurons to the domain of psychomotor surgical skill development essential for surgeons. Robert Greene, in his book "Mastery", mentioned the term Mirror neurons in the process of achieving Mastery in any field[26]. In this book, he has studied the life histories of several masters in the world and has thereby professed that all the masters progress through 3 phases viz. Apprenticeship, Creative Active Phase and Mastery, to ultimately become Masters.

The author opines that as an apprentice, the most critical part is to 'practice towards acquisition of skills. In acquiring any kind of skill, there exists a natural learning process that coincides with the functioning of our brain. According to Greene, the natural model for learning largely based on the power of Mirror neurons and comes from watching and imitating others and then repeating the action over and over. However, this book does not mention the probable utility of the Mirror Neuron concept for surgical training.

**Translation of Cognitive to Psychomotor Skills:**

Dr. Shiralkar in his book titled "Cognitive Simulation-techniques to enhance surgical skills", considers that acquisition of any skill goes through four phases of competency [27]In the first phase of 'Unconscious Incompetency', there is inability to perform skill. In the second phase of 'Conscious Incompetency', one realizes the reason behind the inability and a conscious awareness to overcome it is made. In the third phase of "Conscious Competency", a surgeon becomes technically proficient enough to perform what he is asked to do, but this proficiency needs to function sub-consciously in order to reach the final phase of competency. In the final phase of Unconscious competency, the neural pathways necessary for the performance are being laid down, making the skill automatic. At this stage, a surgeon performs most skillfully without making any conscious efforts. For a surgeon, the journey from ignorant incompetency to efficient competency involves associating cognitive skills to psychomotor surgical skills. Surgical skill is a psycho-motor process and the cognitive part can be well tutored harnessing the mirror mechanism.

It can be propagated that the mechanism of Mirror neurons may prove a potential connecting link for translating a skill from cognition to psychomotor level by providing a direct understanding of the actions and emotions of others without higher order cognitive mediation.

**Conversation of Self 1 and Self 2:**

Sports psychology author Timothy Gallwey has referred to these contributing mental factors as the "Inner Game'. In his book 'The Inner Game of Tennis', he has beautifully elaborated the concept of Self 1 and Self 2 i.e. existence of two selves within each player. Each player has 2 "selves". Self 1 is ego-mind or "teller" ("Hit the ball like") & Self 2 is natural ability or "doer" (the actual movement of the muscles to hit the ball). To Self 2, a picture is worth a thousand words. It learns by watching the actions of others, as well as by performing the actions itself. [28]

This concept of Self 1 and Self 2 can be extrapolated to the domain of cognitive surgical training. This will help us to find out how motor center of Self 2 could be used for creating perfect involuntary movements as desired by Self 1. Self 1 needs to be relaxed for better performance of Self 2. Self-2 has developed far before (Paleo Cortex) than Self 1 (Neo Cortex). It is imperative to appreciate that Self 1 understands our routine language but Self 2 does not. Self-2 needs to be given instructions by actually doing that action. If a surgeon wants to acquire a stage of unconscious competence, then those instructions have to done by Self 1 understanding the movement and dictating to Self-2 in its language. An apprentice surgeon has to not only acquire but also master the surgical skills. Here, a stepwise path to surgical skill development has been proposed by unifying various ideas hitherto enumerated.in

An apprentice surgeon may watch another skilled surgeon perform a procedure and focus on specific components of his action. (Table 1) As he observes the movements of the skilled surgeon keenly, his mirror neurons will get fired exactly in a manner that they would fire when he himself would perform the surgery. It is expected that the apprentice vividly visualizes the entire procedure in his mind with imagining the splitting of every action to the minutest of details. He should then perform the action himself with complete psychomotor integration. This observation-execution of surgical actions leads to repeated firing of the Mirror Neurons responsible for these actions. Obviously surgical area around surgeon and operating table should be open for free watching

This repeated firing of the Mirror neurons may lay down the neuro-motor pathways necessary for the performance, making the skill automatic without requiring any conscious effort. The laydown of these pathways is called as "grooving", which implies the acquisition of unconscious competency.

When Mastery is achieved by the surgeon where he is 'Unconscious Competent', the mirror neurons are trained to such an extent that all instruments become integral part of his arm. He is able to perform surgeries at lower cerebral level with perfect reflexes.

The use of these action-observation based protocols for training the surgeons could represent a new skill-enhancement strategy to inculcate psychomotor surgical skills of the finest proficiency. The role of visualization cannot be underestimated in this entire process and the acuity of perceptual abilities is an imperative link to skill development.

**Table 1**

| The steps on how to use mirror neurons for surgical skill training |
|---|
| • Watch each surgeons movement carefully; |
| • Watch both hand movements of surgeons as well as effect of that movement; |
| • Mirror neurons will be fired; |
| • Visualisation of that movement by repeating same action in mind |
| • Actual doing that movement will demonstrate action to Self 2; |
| • Two different areas in brain get stimulated through Mirror Neurons; |
| • Say in mind the splitting of movement; |
| • Repeated steps will create 'grooving' in motor cortex. |
| • Grooving of movement will acquire 'unconscious competence' |

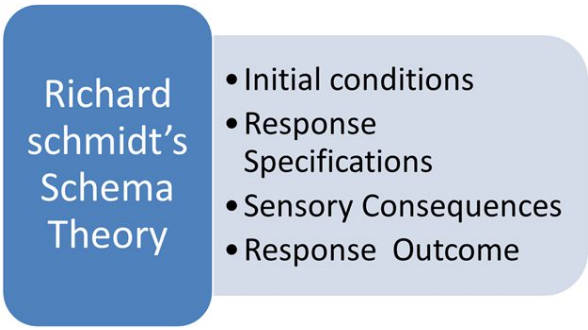
**'Schema Theory' of perceptual abilities in performance:**

Richard Schmidt's 'Schema Theory' provides a framework to understand importance of perceptual abilities in performance. [29] His theory for perceptual abilities has been explained with reference to surgical skills. He outlines four categories of information necessary for the execution of a skill.( Figure 1)

- Initial conditions – consists of information received from various senses prior to an action. E.g. proprioceptive information about the position of hand prior to incision.
- Response Specifications – In this, the performer needs to specify detailed requirements before the movement can commence. E.g. stretching the skin with one hand and starting the incision with the other hand from point A to B.
- Sensory Consequences – This consists of actual feedback received from the eyes, proprioceptors, etc. E.g. the completed incision from point A to B, bleeding from the incision and the tissue exposed after the incision.
- Response Outcome – This arises from information the surgeon receives after the action and consists of knowledge and results of his action.

- This theory reflects the path in which the learner will be able to comprehend the data in the appropriate mental model harnessing perceptual abilities and then be able to correct the next performance.

**Figure1**

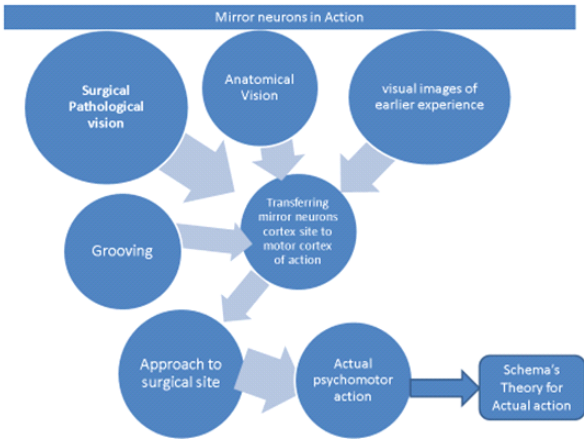



**Hypothesis for mirror neurons in psychomotor skill training**

The proposed hypothetical sequence of stages from cognition to psychomotor surgical skills can be stated as follows: (Ref Figure 2)

For a surgeon, when he is about to perform on a surgery site, the visual and other sensory images of the site that he has seen earlier with anatomical, pathological, surgical detailing are recollected. All this Imagery is mediated through Mirror mechanism. If he has repeatedly and keenly observed the psychomotor movements required to perform the surgery and visualized the splitting of each surgical step earlier, the grooves required for actual execution of those movements are already constituted through observation and visual execution of the action. This observation-execution through mirror neuron mechanism would certainly facilitate the surgeon to perform accurately and skillfully. Further actual action will follow schema's theory mentioned earlier

**Figure 2**




**Mirror neurons in surgical workshops:**

It is hypothesized that, in order to improve quality of psychomotor skill training by imitation in watching workshops, the cause and effect of movement, both, need to be seen vividly. It would need two screens, one to show action in surgical field and other to show actual hand movements, position of arm and other intricate details to show how the surgeon is actually involved in the surgical action.

Thereby, it is proposed that the theory of mirror neuron mechanism can be extrapolated to the surgical cognitive domain which can further be translated to psychomotor surgical skills. This will not only shorten the learning time for apprentice surgeons but will also enhance the surgical proficiency of skilled surgeons.

*"I am a brain, my dear Watson, and the rest of me is a mere appendage."*
— Sherlock Holmes

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