Review Article

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Neuro-cognition and social-cognition: application to exercise rehabilitation

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The discovery of mirror neurons has been recognized as one of the major developments in neuroscience, with possible implications for the explanation of many important cognitive functions, including action and perception understanding, imitation, and empathy. In the mirror neuron system, action observation, imitation, and empathy are represented in the same basic motor circuit as action execution. The present paper presents basic neurophysiological findings about mirror neuron system and discusses the effects of perceptual and motor resonance on other people's actions. Finally, this paper examines strategies informed by mirror neuron research in an empathy-fostering program for autism and in a motor rehabilitation program for stroke patients.

Keywords: Neuro-cognition, Social-cognition, Mirror neurons, Exercise rehabilitation, Autism, Stroke

INTRODUCTION

Recently, neuroscientists and cognitive psychologists have promoted the idea of the existence of a mirror system in our mind and brain. The mirror system simulates the actions we observe by mapping an observed action onto a motoric representation of the same action in the observer (Jeannerod, 2003). A mirror mechanism indicates that actions are intrinsically linked to perception. This modern motor theory of action and perception could be explained by the ideomotor model. The model proposes that actions are represented not only in terms of body movements but also in terms of the distal perceptual effects they aim to generate. In this way, action and perception are commensurate and are coded in a common representational medium (Prinz, 1997). Performing a movement creates an association between the motor pattern it has been generated by and the sensory effects it leads to. This association can also be used in a reverse direction to induce a movement by perceiving its sensory effects (Hommel et al., 2001). From this viewpoint, the potential motor and social roles of mirror mechanisms are stressed. Mirroring actions might help a person not only understand what another person is doing, but also explore how his or self-awareness is developing (Schütz-Bosbach and Prinz, 2007). These potential functions of action mirroring form a possible part of the mirror mechanisms from the perspective of the perceiver (Fig. 1).

Based on the ideomotor model, a growing body of research suggests that the mirror neuron system activates when an action is observed, imitated, and empathically understood (Rizzolatti et al., 2001; Rizzolatti and Craighero, 2004). The aim of this paper is to draw attention to basic neurophysiological findings about the mirror neuron system. The effects of perceptual and motor resonance on other people' actions were also discussed. These effects have so far been largely neglected in modern motor theories of neuro and social cognition. Finally, I will examine how basic concepts of the mirror neuron system could have clinical applications in exercise rehabilitation.

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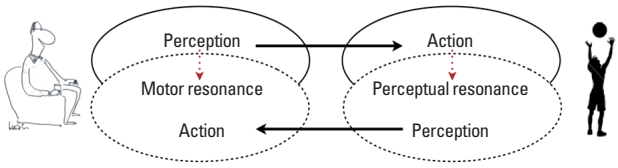

Fig. 1. Explanation of mirror mechanisms.

NEURO-COGNITION: MIRROR NEURON AND MOTOR PERCEPTION

When observing other people's performance, human brains simulate the performance of the observed action. This simulation process could reinforce sophisticated mental functions such as observational learning (Rizzolatti and Arbib, 1998). Researchers have reported that within the human premotor and parietal cortex, "mirror neurons" discharge both when the person performs an action and when the person observes another person performing the same action. The mere observation of a performance induces a selective increase in motor-evoked potentials (MEPs) from the muscles that would be active if the observed actions were performed (Rizzolatti, 2005). Rizzolatti and colleagues (2001) showed that the "mirror system" integrates observed actions of others with the motor repertoires of the individual. They hold that the human brain understands actions by motor simulation. Mirror neurons respond to the execution of an action, and to the observation of a conspecific carrying out that same action (Rizzolatti and Craighero, 2004).

Activation of mirror neurons is greater when observing "familiar" rather than "unfamiliar" movement. Neuroscience studies show that motor expertise modulates the activation of the human mirror system during the observation of dance movement. Neural activation is greater in those people who have direct motor experience of the observed dance movement. Therefore, observing other people's actions is imitative motor learning by a covert simulation of the very same action (Calvo-Merino et al., 2006). In addition, Aglioti and colleagues (2008) investigated the dynamics of action anticipation and its underlying neural correlates in professional basketball players, sports journalists, and novices. Their results showed that both visuomotor and visual experts demonstrated a selective increase of motor-evoked potentials during the observation of basket shots. However, only athletes show a time-specific motor activation during the observation of erroneous basket throws. This suggests that achieving excellence in sports is related to the fine-tuning of specific anticipatory "resonance" mechanisms that endow elite athletes' brains with the ability to predict others' actions ahead of their realization. This study shows that tuning of resonant action systems is important in the perceptual abilities shown by the movers engaging in the action.

SOCIAL-COGNITION: MIRROR NEURON AND EMOTION PERCEPTION

In humans, mirror neurons have a part in understanding not only other people's actions but also their emotions. Many neuroscience studies have shown that the mirror neuron system involving visceral-motor centers allows people to recognize each other's emotions, like one involving visual-motor centers allows people to recognize each other's actions (Gallese et al., 2004). Decety and colleagues (2004) used fMRI brain scans to compare how people perceive pain. They found that perceiving photographs of situations likely to cause pain was associated with significant bilateral changes in activity in several regions, notably the anterior cingulate, the anterior insula, the cerebellum, and to a lesser extent the thalamus, which are known to play a significant part in pain processing. The results suggest a direct linkage between perceiving emotion in another individual and experiencing it oneself.

Developmental studies have shown that young children can imitate various body movements in the sense that they appear to view human actions in terms of the relation between the agent, the means, and the goal of the action (Gergely et al., 2002). However, children with autism have often been found to be impaired at imitation due to a deficit in embodied simulation (Carpenter et al., 2001). In addition, some researchers showed that adults with Asperger's syndrome or high-functioning autism were impaired at imitating in a mirror-image manner (Avikainen et al., 2003; Leighton et al., 2008)

APPLICATION TO EXERCISE REHABILITATION

Empathy fostering program: autism

Empathy is defined as a sense of similarity between the feelings one experiences and those expressed by others. Empathy extends beyond simply understanding other people's emotional state to embodying the experience of that state (Singer et al., 2006). Empathy is an embodied affective resonance that involves some level of cognitive processing (Decety and Jackson, 2004; Lamm et al., 2007). Cognition and emotion are integral to the evolvement of empathy. The presumption is that neuronal connectivity between the prefrontal cortex and the limbic system function are vital units.

Researchers in the field of body psychotherapy have stressed that therapeutic interventions based on bodily expression can foster empathy and, more generally, develop interpersonal coordination (McGarry and Russo, 2011). Specifically, movement therapy research has focused on special-needs populations like people with autism (Berrol, 2006). It is known that the core deficits of autism, which are motor deficits, language impairment, and social impairment, are indicative of dysfunction of the mirror neuron system (Iacoboni and Dapretto, 2006). There are strong theoretical and empirical links between mirror neurons and language. Dysfunction of the mirror neuron system could account for the language disorders that autism is characterized by. Furthermore, the links between the human mirror neuron system and social cognition reviewed in the previous section of this paper suggest that mirror neuron dysfunction could also account for the social deficits in autism.

Dapretto and colleagues (2005) examined mirror neuron abnormalities in autism through observation and imitation of facial emotional expressions. This study has demonstrated strong correlations between the reduced activity in mirror neuron areas and the severity of the autism. They suggested that a dysfunctional "mirror neuron system" underlies the social deficits observed in autism.

Motor rehabilitation program: stroke

The activation of premotor neurons during mere observation of actions is a highly appealing feature for motor functions rehabilitation. Patients with severe stroke show chronic motor disorder; therefore, the use of movement learning by observation as a form of rehabilitation is highly suitable for stroke patients (Iacoboni and Mazziotta, 2007).

Ertelt and colleagues (2007) examined a new neuro-rehabilitative program, called "action observation therapy," that combined physical training and additional observations. Results showed that the experimental group demonstrated a significant improvement of motor functions compared with both the pretreatment baseline and control groups. Additionally, the effects of action observation therapy on the reorganization of motor system were investigated in this fMRI study, using an independent sensorimotor task consisting of object manipulation. Furthermore, Celnik and colleagues (2008) assessed the effect of action observation therapy on motor memory formation in patients with chronic stroke, using transcranial magnetic stimulation (TMS). Results indicated that the magnitude of motor memory formation was larger in the action observation group than in the group receiving physical training only. To date, few researchers have focused on the mirror neuron system in rehabilitation; however, existing studies have impressive results that are worthy of further investigation.

CONCLUSIONS

The discovery of mirror neurons has been recognized as one of the major developments in neuroscience, with possible implications for the explanation of many important cognitive functions, including action and perception understanding, imitation, and empathy. In the mirror neuron system, action observation, imitation, and empathy are represented in the same basic motor circuit as action execution. Providing an additional source of information to motor training could be useful in promoting recovery not only mentally but also physically in stroke patients. Through successfully translating basic concepts of mirror neuron to initial clinical applications in the exercise rehabilitation field, future work on the mirror neuron system could consolidate and expand the clinical applications.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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