This article was an invited commentary on a reprinted article, "Functions of the Mirror Neuron System: Implications for Neurorehabilitation."



# Reflections on Mirror Neurons and Rehabilitation

(*Cogn Behav Neurol* 2018;31:243–253)

"Functions of the mirror neuron system: implications for neurorehabilitation" (Buccino et al, 2006) was written at peak promise in the wake of the discovery of the mirror neuron system (MNS). This promise grew out of the MNS's potentially wide theoretical and practical implications. As the authors review, in the mid-1980s, investigators in Parma discovered a set of neurons in rostral monkeys' premotor cortex, area F5, that were active when the monkeys executed hand-and-mouth, goal-directed movements as well as when the monkeys observed these same actions. Similar neurons were later discovered in the monkeys' inferior parietal cortex. These "mirror neurons" contrasted with neurons within the superior temporal sulcus that responded only to the observation—not the execution—of goal-directed actions.

In the subsequent decades, an analogous system was found in humans, as evidenced from behavioral, electrophysiological, imaging, and noninvasive stimulation studies (Cattaneo and Rizzolatti, 2009). The fundamental question arising from these observations was "What is the functional significance of mirror neurons for human cognition and behavior?" Theoretically, the MNS aligned well with a turn in psychology (Barsalou, 1999), in which cognition was increasingly viewed as being embodied by our motor and sensory systems. The MNS offered a physiological account of embodied cognition. As enthusiasm for this idea grew, further research began to implicate mirror neurons not just for the understanding of goal-directed motor behavior, but also for actions at every level of abstraction, for the acquisition of language in general, for mechanisms underlying empathy, and even as a motor resonance explanation of esthetic experiences (Freedberg and Gallese, 2007; Rizzolatti, 2005).

A fundamental challenge for embodied and MNS accounts of cognition was how to explain the human ability to abstract. These challenges led many investigators to advocate a more restricted view of the role of mirror neurons in cognition (Hickok, 2009) and a more graded view of embodiment (Chatterjee, 2010; Dove, 2009; Mahon and Caramazza, 2008). However, the role of the MNS, specifically in motor rehabilitation, would seem still viable. Buccino et al (2006) presented a plausible account of how the MNS could be parlayed into treatment. Specifically, they advocated that the observation of actions is critically important in being tethered to the execution of actions. The prediction is based on ideas that observing and imitating actions (a) involve multiple sensory modalities (visual, auditory, and proprioceptive) that serve as different inputs to support the motor system; (b) increase the excitability of corticospinal pathways even in the absence of overt movements; (c) tackle learned and ecologically valid movements that are goal directed, rather than fragments of movements; and (d) incorporate motor imagery, which may have its own salutary effects.

Does action imitation work better than conventional interventions as a means to restore goal-directed movements using the hand? The evidence to date remains sparse. Ertelt et al (2007) reported a clinical trial with 15 patients randomly assigned to an intervention and a control group. All patients had previously received conventional physical therapy. The action-observation group watched video sequences of everyday hand action sequences and then imitated the sequences. The sessions lasted 90 minutes and were conducted over 18 consecutive days. In the control condition, patients looked at geometric symbols and letters instead of action sequences. The researchers discovered that the action-observation group evidenced improvements that were not seen in the control group. This improvement was sustained for 8 weeks after therapy.

The target article is a classic, early, theoretical account that motivated a variety of interventions using action imitation, actual mirrors, virtual reality, and treatments aimed directly at apraxia (Carvalho et al, 2013; Ertelt et al, 2007; Garrison et al, 2010; Gillen et al, 2015). None of these interventions, to my knowledge, has been subjected to large randomized controlled trials. It was a bold move to advocate for a treatment that promised to go beyond compensating for a functional deficit to actually restoring original motor function. We can hope that this family of interventions will prove to be widely efficacious and become the standard of rehabilitation care. Until then, it behooves us to encourage our patients to imitate hand actions they observe in everyday life, outside of therapy sessions, even when sitting on a couch watching television.

## ACKNOWLEDGMENTS

*This commentary benefited from an informal conversation with A.M. Barrett, MD.*

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Received for publication October 29, 2018; accepted October 29, 2018.
Commentary on: Buccino G, Solodkin A, Small SL. 2006. Functions of the mirror neuron system: implications for neurorehabilitation. *Cogn Behav Neurol.* 19:55–63.
The commentator declares no conflicts of interest.

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