Available online at www.sciencedirect.com

ScienceDirect

Cognitive Systems Research 34–35 (2015) 18–34

Cognitive Systems RESEARCH

www.elsevier.com/locate/cogsys

Beyond sensorimotor segregation: On mirror neurons and social affordance space tracking

Action editor: Vasant G. Honavar

Maria Brincker

Philosophy Department, University of Massachusetts Boston, 100 Morrissey Blvd., Boston, MA 02125-3393, United States

Received 8 July 2014; received in revised form 3 January 2015
Available online 30 July 2015

Abstract

Mirror neuron research has come a long way since the early 1990s, and many theorists are now stressing the heterogeneity and complexity of the sensorimotor properties of fronto-parietal circuits. However, core aspects of the initial 'mirror mechanism' theory, i.e. the idea of a symmetric encapsulated mirroring function translating sensory action perceptions into motor formats, still appears to be shaping much of the debate. This article challenges the empirical plausibility of the sensorimotor segregation implicit in the original mirror metaphor. It is proposed instead that the teleological organization found in the broader fronto-parietal circuits might be inherently sensorimotor. Thus the idea of an independent 'purely perceptual' goal understanding process is questioned. Further, it is hypothesized that the often asymmetric, heterogeneous and contextually modulated mirror and canonical neurons support a function of multisensory mapping and tracking of the perceiving agents affordance space. Such a shift in the interpretative framework offers a different theoretical handle on how sensorimotor processes might ground various aspects of intentional action choice and social cognition. Mirror neurons would under the proposed "social affordance model" be seen as dynamic parts of larger circuits, which support tracking of currently shared and competing action possibilities. These circuits support action selection processes—but also our understanding of the options and action potentials that we and perhaps others have in the affordance space. In terms of social cognition 'mirror' circuits might thus help us understand not only the intentional actions others are *actually* performing—but also what they *could* have done, *did not* do and *might do* shortly.

Keywords: Affordance perception; Mirror neuron systems; Sensorimotor; Teleology; Social cognition; Decision-making

1. The caricature view of mirror neurons and the ensuing debate

Mirror neurons were initially discovered by Giacomo Rizzolatti and colleagues in Parma (di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992; Gallese, Fadiga, Fogassi, & Rizzolatti, 1996; Rizzolatti, Fadiga, Fogassi, & Gallese, 1996).[1] The core finding that inspired the name was that certain single cells in the macaque premotor cortex were modulated both by the execution of some goal-directed actions and by the perception of others performing similar actions. Such action-sensitive sensorimotor modulations were also found in parietal areas known to be highly anatomically and functionally

---

E-mail address: Maria.Brincker@umb.edu

[1] I shall for reasons of simplicity refer to this group of researchers collectively as "the Parma group".

http://dx.doi.org/10.1016/j.cogsys.2015.07.002

interconnected with the premotor area F5. Additionally, indirect behavioral and imaging findings suggested homologue modulations in humans. The Parma group soon hypothesized that these fronto-parietal neurons together formed a mirror system by which we understand the perceived actions and perhaps intentions of others by mapping them onto our own motor system. Here a formulation from a 1996 article:

> These data suggest that area F5 is endowed with an observation/execution matching system. When the monkey observes a motor action that belongs (or resembles) its movement repertoire, this action is automatically retrieved. The retrieved action is not necessarily executed. It is only represented in the motor system. We speculated that that this observation/execution mechanism plays a role in understanding the meaning of motor events.
>
> [Rizzolatti et al., 1996, p. 132]

The central mirroring idea is that the perceived action is ‘matched’ with the perceiver’s movement repertoire. Through the notion of observation/execution ‘mirroring’, ‘matching’ ‘mapping’ or ‘translation’, grew the idea that mirror neurons provide a relatively symmetric link between respectively (1) perception and action *within* the perceiver and (2) other and self, thus a social mirroring *between subjects*. (See also Uitol, van Rooij, Bekkering, & Haselager, 2011a). Thus ‘mirroring’ is seen as relating social and motor cognition, which, as recently suggested by Ferrari and Rizzolatti, has been incredibly important in igniting the interest in mirror neurons.[2]

1.1. Motor processes as ‘moonlighting’ for perception?

The discovery of mirror neurons and the hypothesized ‘mirror mechanism’ as sensorimotor mapping and motor simulation of perceived actions of others has generally been seen as a challenge to the classical cognitivist ‘input-cognition-output’ view[3] and as providing an ‘embodied’ alternative (e.g. Gallese, 2007). The idea being that mirroring as processes in motor formats (rather than a-modal symbolic representations) functionally appear to serve not just the production of action outputs but social perception and central cognitive action understanding. Hitherto fronto-parietal circuits had mainly been seen as supporting action planning and “perception for action” rather than “perception for understanding”.[4] In other words, the discovery of mirror processes in motor ‘output’ systems now contradicted the simple conception of forward-flowing information processing from sensory modules to central cognition to action implementation, as motor neurons here might contribute to both action perception and central cognitive intention understanding.

However, the question is to what extent the classic formulations of the mirror theory represent a move away from the modular input–output framework. Is not the output system of motor cognition here merely given an *extra* and *separate job* in service of cognition and social perception beyond its primary job in action execution? Is not this extra job theorized as based on a *separate mechanism* (i.e. mirroring), which might yield a cognitive understanding of goals and intentions *behind* the *perceived* action of others? The standard mirror neuron interpretation appears to maintain much of the core cognitivist structure, in particular the neat functional segregation between sensory and motor systems[5] and the idea of the intention somehow being behind the actually performed action.[6]

Over the last decades however, the picture of mirror neurons and their functional place within the broader fronto-parietal sensorimotor circuits has evolved tremendously. Many new studies have appeared, which together alert us to a much more complex and heterogeneous set of neurons and much less symmetric and modular population functions (see Casile, Caggiano, & Ferrari, 2011 for a review). While researchers in interesting ways have made adjustments to the classic mirror hypothesis, I see the basic framework as needing an explicit overhaul that matches the many new findings. I shall in this article first look at the plausibility of separate sensory and motor goal representations and then present some evidence for

---

[2] The discovery of mirror neurons has indeed been one of the most influential events in neuroscience in recent decades. Ramachandran has perhaps been the least shy about his expectations, as he hypothesized that “mirror neurons will do for psychology what DNA did for biology” (2000). Ferrari and Rizzolatti write on the question why the notion of mirror neurons has had such an impact across fields: “Two reasons are the most likely. The first is that their discovery put the problem of how we understand others at the forefront of neuroscience. The second is that, by showing that mirror neurons were basically motor neurons, they suggested a rather unexpected solution to this problem: the motor system is involved in understanding the actions and intentions of others.” (Ferrari & Rizzolatti, 2014)

[3] Susan Hurley has famously dubbed this cognitivist information processing view “the classical sandwich” as cognitive processes are conceived as sandwiched between input and output modules (Hurley, 1998). I shall in the following refer to this view as either the sandwich or input–output view.

[4] E.g. there is a wide range of evidence that multisensory-motor integration and pragmatic and spatial functions depends on parietal areas, whereas e.g. object and facial recognition depend on temporal areas (Milner & Goodale, 1995).

[5] See also Dewey’s (1896) classic critique of sensorimotor segregation and simple feedforward analyses.

[6] See also Gallagher (2008, 2007) and Zahavi (2008) for a critique of simulative interpretations of mirror neurons and the assumption that intentions cannot be perceived.