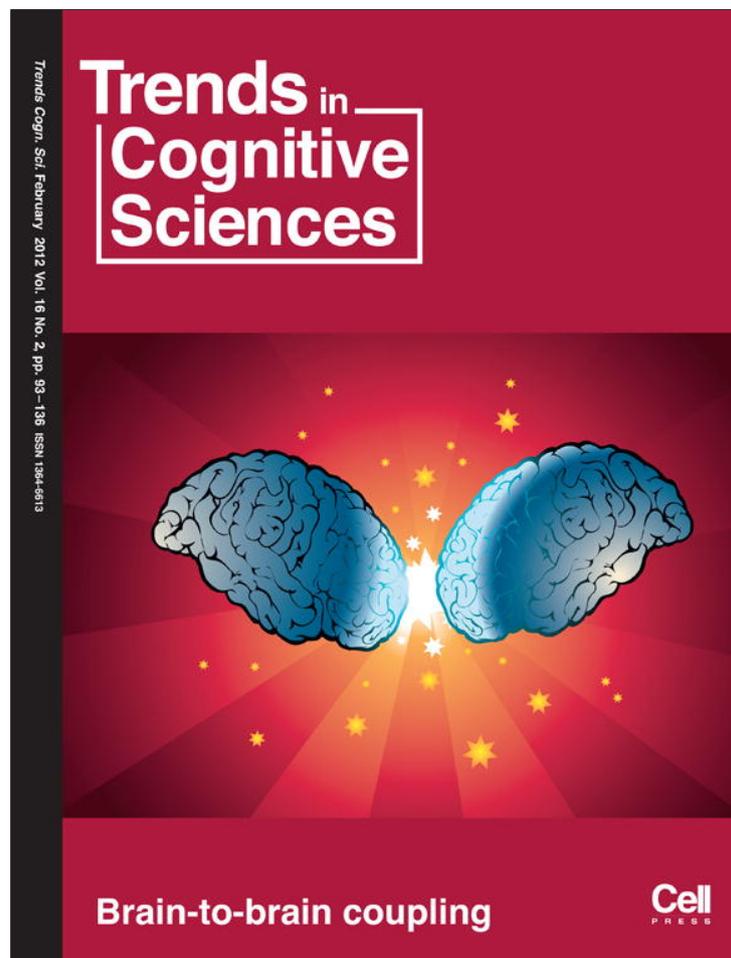


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reuse. On a resemblance account, simulation requires interpersonal resemblance; that is, one's own mental states have to match the mental states of the person that one is trying to understand in some significant respect [2]. On a reuse account, simulation involves intrapersonal reuse: that is, one reuses processes in one's own system that are primarily used for motor planning and control to simulate the mental states of others [3].

Empirical evidence has counted against simulation as resemblance or matching (see [4,5] and Csibra, G. (2005) Mirror neurons and action observation. Is simulation involved? <http://www.mendeley.com/research/mirror-neurons-and-action-observation-is-simulation-involved/>). Accordingly, Gallese and Sinigaglia argue for simulation as reuse, implemented by a 'mirror-mechanism' (MM). Yet, they also suggest that simulation depends on 'inter-personal sharing of the same kind of neural and cognitive resources'. When this sharing is limited or missing, one does not have the 'suitable' mental states or processes for reuse, and simulation is severely impaired or even impossible. This suggests that reuse, supposedly the core of simulation, still involves resemblance. Moreover, in processes of learning where imitation is involved, the motor use of such mechanisms may be derived from a primary interpersonal use; that is, the reuse may just go the other way, in which case MM does not explain intersubjective understanding but instead presupposes it.

Gallese and Sinigaglia propose that the nature and range of what can be achieved by simulation is constrained by bodily formatted representations and that 'the bodily format of these representations enables their reuse for making sense of others'. In this way simulation is supposedly 'embodied'. However, this is a very minimal form of embodiment, because bodily formatted representations are nothing other than brain processes (e.g. mirror neuron

activations) that, according to Goldman and Vignemont [6], do not require any non-neural bodily involvement. Furthermore, it is not clear that the concept of bodily formatted representations provides any explanatory power in regard to how simulation works, because the motoric aspect is what makes these representations bodily formatted. The claim seems to be this: simulation is a reuse of bodily formatted representations, but this just is what the MM involves: bodily formatted representations that are (re-)used for different conditions (action observation versus action production). Therefore, the MM generates simulations. It is not clear, however, how this explains social cognition conceived as mindreading or attribution of mental states, or how it goes beyond a definitional claim; simulation is just this kind of MM activation, which is just a functional attribution of mental states.

To sum up, it would be helpful if Gallese and Sinigaglia could explain how notions of reuse and bodily formatted representation shed new light on what is already known about mirror mechanisms, and how such neural processes scale up to mental state attribution, which simulation is meant to explain.

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Response to de Bruin and Gallagher: embodied simulation as reuse is a productive explanation of a basic form of mind-reading

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In their letter to *TiCS*, de Bruin and Gallagher [1] suggest that the view of embodied simulation (ES) put forward in our recent article [2] lacks explanatory power. We argue instead that the notion of reuse of mental states represented with a bodily format provides a convincing simulation account of the mirroring mechanism (MM) and its role in mind-reading. Most of the arguments put forward in [1] appear to stem from a misunderstanding of the

functional properties of the MM, and from a misconception of the defining features of both the notion of simulation and of embodiment.

First, the available empirical evidence does not in fact argue against the direct matching hypothesis [3]. For instance, de Bruin and Gallagher [1] quote a transcranial magnetic stimulation (TMS) study by Catmur et al. [4], in which selective motor training was used to manipulate the responses of the motor system during finger movement observation. However, this study does not reveal a proper

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mirror phenomenon, but simply shows mere associative motor inhibition; this explains why the supposed counter-mirror activation only occurred with a TMS pulse delivered much later with respect to that normally used to study the MM. In addition, Catmur *et al.*'s findings [4] do not say anything about the role of the MM in social cognition, because this study dealt with movements only and not with motor goals and intention understanding (see [5]).

Second, our reuse account of the MM does not imply downplaying the role of resemblance in simulation [6]. Indeed, by accounting for the simulational nature of mirroring phenomena in terms of mental state reuse, we make reference to the intrapersonal resemblance or matching between one's mental state when acting or experiencing an emotion and when observing others' actions and emotions. The situation is different when resemblance is exclusively or primarily understood as interpersonal. Interpersonal resemblance *per se* is neither necessary nor sufficient to account for the MM. Furthermore, interpersonal resemblance should not be confounded with what we define as interpersonal sharing of the same kind of neural and cognitive resources. The latter is neither an ingredient nor the outcome of the simulation process. Rather, it constrains its range.

Third, being neurally implemented is not what makes a mental representation embodied. A representational format is typically associated with characteristic processing profiles. These profiles (motor, visceromotor and somatosensory) characterize a bodily formatted representation, distinguishing it from, say, a propositional representation, even in the presence of (partially) overlapping content.

Therefore, we accounted for the MM as a specific kind of ES ([2], but see also [7,8]), being characterized by one's reuse of one's own bodily formatted representations in functionally attributing them to others. Accordingly, we

proposed that MM-driven ES plays a constitutive role in a basic form of mind-reading. This form of mind-reading does not require the involvement of any propositional attitude, being mapped onto mental representations with a bodily format (i.e. motor representations of goals and intentions as well as visceromotor and somatosensory representations of emotions and sensations).

Of course, the account of MM in terms of ES can and must be challenged further. Such challenges, however, should be more robust and convincing than those suggested in [1].

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