Commentary to: T. Iachini, Mental imagery and embodied cognition: A multimodal approach (2011), JMI.
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Simulating the elimination of simulation: the case of language comprehension

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In her target article Tina Iachini (2011) proposes to adopt an embodied multimodal approach to account for classical psychological and more recent neuroscientific results on mental imagery. Her proposal is challenging, and I share with the author the persuasion that the times are mature to introduce and defend an embodied approach to mental imagery. While the challenge has well known antecedents in the area of motor imagery (e.g., Jeannerod, 1994), it strikes me as quite new if we consider the research field of mental imagery as a whole (for a related proposal see Grush, 2004).

Even though I deeply appreciate the effort made by the author to combine the two perspectives, my task here consists of addressing some unsolved issues that I think should be pointed out. Therefore in my commentary I will briefly start with three critical observations/proposals, then I will focus on a crucial point: the notion of simulation.

1. Action, productivity, and bodily extension

In this first section I will briefly address two points on which I do not fully agree with the author's perspective. The first concerns the scarce emphasis on the role of action, the second the supposed reconciliatory role played by simulation based on mental imagery. In a third point, I will address some issues that, in my opinion, could be further developed as an extension of the target article.

Iachini proposes substituting a vision of mental imagery as unimodal, primarily visual, with a multimodal view of mental imagery. I fully agree with this position. However, somehow in the paper an overly strong emphasis is given to brain processes compared to bodily states. The author stresses the role of sensorimotor processes, but no primacy is given to motor processes and action. Even the focus on motor

imagery pertains more to movement than to action. Moving from an embodied cognition perspective, I am incline to stress the importance of the body and of action (see Wilson, 2002), and to view the brain as part of the body.

Even if I favour an embodied view of imagery, it is unclear to me why this view would reconcile the two different aspect of simulation, one focused on action-body and the other on grounding. I don't see this as a specificity of mental imagery: the same conciliation is possible for all cases in which the notion of simulation is used. In principle I think that the focus on action, which guarantees automatic and fast responses, and on multimodal experience, which guarantees flexible responses, are not in opposition at all, as I have argued elsewhere (Borghi, 2005). The point is simply that different authors, starting from different perspectives, have emphasized one aspect or another.

Finally, I believe that an embodied theory of mental imagery should deal with two fundamental functions of mental imagery that the author addresses, but only briefly. A peculiar, ubiquitous and crucial function of mental images lies in their combinatorial power, their productivity and their flexibility. Iachini treats this point in passing, referring to her interesting research work. However, I think the productivity guaranteed by mental imagery should be granted more space and treated more extensively.

A second aspect the author might want to consider is the relationship between mental imagery and sense of body ownership, of bodily borders, of bodily operational space. As demonstrated in a variety of studies, with neglect patients and with controls, and with a variety of paradigms, our sense of body is plastic and our bodily borders can be extended, for example when using a tool to reach for objects located outside our peripersonal space (for a review, see Maravita & Iriki, 2004). What is the relationship between this bodily extension and mental imagery?

2. Which kind of simulation?

In this section I will discuss one of the crucial points the paper makes, i.e. the notion of simulation. Tina Iachini clearly outlines the distinction between a simulation occurring a posteriori, mediated by mental imagery, and what she calls a mirror simulation, which would occur automatically and in a not deliberate way. As I understand it, the goal of the author is to underline the importance of simulation as "a core form of computation in the brain". Referring to Barsalou's (1999) claim, according to which mental imagery is a well known case of simulation mechanism, she argues that both mental images and perceptual symbols are "instances of embodied simulation", since, despite their differences, they are grounded in the sensorimotor system, they are to a certain extent schematics, and they imply a transformation process.

While I appreciate the "unification" effort made by the author, I think some clarifications are necessary. To support my claims, I will refer to embodied and grounded (EG) cognition research on language comprehension (however, a similar story can be told for action understanding). Indeed, one of the most debated issues in this area concerns the role of simulation, which has been accorded various attributes: mental, embodied, motor, or simulation tout court. According to the EG view, during language comprehension we would simulate, i.e. the same neural perception, action and emotion systems recruited while perceiving and interacting with objects and entities in the world would be activated (for a review, see Fischer & Zwaan, 2008). However, a number of aspects in the use of the term are vaguely defined or unclear. I will address these ambiguities below.

A first issue concerns the neural underpinnings of simulation. It has been proposed (e.g., Gallese, 2008) that the mirror neuron system represents the neural basis underlying embodied simulation, both at the vehicle level (phono-articulatory aspect) and at the content level (word meaning). More specifically, in the case of language the canonical neuron system would be more activated for nouns, while the mirror neuron system would be more active during verb comprehension (e.g., www.rossiproject.eu). The combined activation of the canonical and mirror neuron system would be at the basis of sentence comprehension. Not everyone identifies the simulation with the activation of the mirror neuron system. In a slightly different perspective,

it has been observed that the canonical and mirror neuron systems represent only a subset of the neural areas subtending the simulation mechanism. This is mostly the view of people adopting a grounded cognition perspective. As clarified by Pezzulo et al. (2011), grounded cognition is a broader term than embodied and situated cognition, as grounding implies not necessarily grounding in bodily states but also activation of situations, visual experiences etc. (Barsalou, 2008). So far research is insufficient to determine whether the neural basis underlying simulation can be equated or reduced to the activation of the canonical and mirror neuron system (for different positions see Jirak et al., 2010; Toni et al., 2008; Willems & Hagoort, 2007).

A second issue concerns the extent to which simulation is necessary for language comprehension. Mahon and Caramazza (2008) have argued that activation of the motor system might be present but not necessary for language comprehension. In order to defend the proposal advanced by the proponents of embodied cognition that activation of the motor system is a constitutive part of the comprehension process, two main arguments have been made. The first highlights that studies on patients with lesions of the inferior frontal cortex reveal that this area is necessary for processing action related words (Pulvermuller & Fadiga, 2010). Notice, however, that this does not necessarily mean that the involvement of the motor system is necessary for language comprehension overall. The second argument focuses on timing: it has been claimed that action words activate the motor system automatically, very soon, and in a somatotopic way (for a review, see Borghi, Gianelli & Scorolli, 2010). This has led researchers to consider the timing of the motor system activation informative as to the necessity of the process. In fact, it has been argued that, if simulation occurs earlier, this would somehow represent a proof that simulating is a necessary and constitutive part of the comprehension process, while this is not the case for simulations occurring later. Actually, thanks to a computational model (Chersi, Thill, Ziemke & Borghi, 2010), we have proposed that early interference and late facilitation are two faces of the same coin, as they both reveal that the motor system is recruited during sentence comprehension (for recent evidence in the same direction, see Liepelt et al., 2011). Specifically, interference would be the product of the contemporary recruitment of the same resources by the linguistic and the motor system, while facilitation would be the results of delayed processing (Boulenger et al, 2006; Buccino et al, 2005; Scorolli & Borghi, 2007). Importantly, both early and late activation (simulations?) occurring during language comprehension are not deliberate and are unconscious.

For a moment, let us leave aside the issue, of whether the (early or late) activation of the motor system (simulation?) is necessary for action and language comprehension. Let us concentrate on what appears as a crucial difference between the activation of the motor system (simulation?)occurring during language comprehension and the simulation occurring during mental imagery. As pointed out by Iachini, the second kind of simulation is effortful and deliberate. But neither the early nor the late simulations occurring during (action and) language comprehension are effortful and deliberate.

A related point concerns the role of predictive aspects in simulation. As highlighted by Tina (see also Borghi & Cimatti, 2010; and Borghi, in press, for details), notions of simulation differ as some emphasize the role of re-enactment, others underline the role of prediction. According to Barsalou (2008), a simulation is “the re-enactment of perceptual, motor, and introspective states acquired during experience with the world, body, and mind” (pp. 618–619). Other authors (e.g., Gallese, 2009) underline the fact that simulation is predictive, as it is useful for action preparation. In this sense Grush (2004) proposes the emulation theory, according to which, the motor areas must be driving an emulator of the body to produce imagery.
Now, Iachini correctly argues that mental images have predictive character, however it should be clarified to what extent this is compatible with their rather late appearance. Surely mental imagery is a signal of human capability of detachment from the hic and nunc: as argued by Glenberg (1997), a peculiarity of humans lies in their ability to suppress the contribution of the environment to conceptualisation, allowing memory (in forms of mental imagery?) to guide it. Consider the role played by the online and the offline simulation mediated by the effortful use of mental imagery. To interact with the computer in front of me I might need to deliberatively reactivate mental imagery to re-evoke previous experience with computers. The process is different when it occurs online, automatically, once I am in front of a computer. In both

cases the simulation is predictive, but in the first case this prediction is deliberate and related to (rather) explicit goals, while in the second case it is automatic and not controlled.

3. Doing without simulation?

In conclusion: I think Tina Iachini has achieved her aim to provide an embodied and grounded account of mental imagery. This deserves attention and credit. At the same time, I think the notion of simulation has become too vague to be used, as it covers too many phenomena, that differ both with regard to their neural substrate and to their function. This is not a problem of the author, it is a problem of the term as used in the scientific literature.

Now let's play a game: what would happen if we banned the extended use of the term simulation? (I have personally used the term many times, but I am starting to become aware that it is too broad and under-specified). Would it be a real problem for the scientific understanding of the phenomena it typically refers to? Which is the advantage to have an umbrella-term for covers processes that are different in nature, in underlying neural bases, in time course, etc.? After all, the term "simulation" is used in different contexts, to refer to visual and motor aspects; to deliberate and non-deliberate processes; to predictive and non-predictive processes.

One advantage of using a common term is that it highlights, in line with neural reuse theories (Anderson, 2010), that the same systems are recruited at different levels, i.e. that the (early and late) "simulation" evoked during action and language comprehension and the "simulation" related to mental imagery are both embodied and grounded.
At the same time, however, there are marked differences both in timing (early, late, very late) and in automaticity/control. Furthermore, it is scientifically fruitful to use different terms to refer to online processes, on which the majority of embodied cognition research has focused, and offline processes, such as those mediated by effortful mental imagery. Language comprehension represents an intermediate case, since the process occurs offline but it is not effortful and deliberate: thus, reading or hearing "Grasp the apple!" activates the motor system preparing for a situated action in an uncontrolled way. Using the notion of simulation in the case of language might produce (and has produced) a further disadvantage: it induces the thought that language comprehension is mediated by mental imagery, i.e. by an intentional process. Instead, there is plenty of evidence that this is not the case and that the perception, action and emotion systems are automatically activated (notice that this does not imply they are not flexibly modulated by the context and by the task).

Let's build a simulation. Imagine a world in which the term simulation is used only for well defined and clear contexts, such as that of mental imagery, and is not extended to other phenomena. Suppose we use it only to refer to deliberate imagery processes (Decety & Grèzes, 2006) which occur offline. Imagine to avoid using it to refer to the (early and late) activation of the sensorimotor system during observation of objects and actions, and during language comprehension. Simulation would be primarily a form of voluntary goal-based re-enactment of previous experience, that is detached from the hic et nunc and can have a predictive value but that occurs offline, thus it is not preparatory for an immediate online action. Wouldn't it all be much easier?

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