Available online at www.sciencedirect.com
ScienceDirect
www.elsevier.com/locate/brainres

Research Report

Embodied simulation and ambiguous stimuli: The role of the mirror neuron system

Agata Ando'[a], *Adriana Salatino*[a], *Luciano Giromini*[a,*], *Raffaella Ricci*[a,b], *Claudia Pignolo*[a], *Stefania Cristofanelli*[c], *Laura Ferro*[c], *Donald J. Viglione*[d], *Alessandro Zennaro*[a]

[a]*Department of Psychology, University of Turin, Turin, Italy*
[b]*Neuroscience Institute of Turin (NIT), University of Turin, Turin, Italy*
[c]*Department of Social Sciences and Humanities, University of Valle D'Aosta, Aosta, Italy*
[d]*California School of Professional Psychology, Alliant International University, San Diego, USA*

ARTICLE INFO

Article history:
Accepted 14 October 2015
Available online 21 October 2015

Keywords:
Repetitive transcranial magnetic stimulation
Mirror neuron system
Embodied simulation
Rorschach

ABSTRACT

According to the "embodied simulation theory," exposure to certain visual stimuli would automatically trigger action simulation in the mind of the observer, thereby originating a "feeling of movement" modulated by the mirror neuron system (MNS). Grounded on this conceptualization, some of us recently suggested that when exposed to the Rorschach inkblots, in order *to see* a human movement (e.g., "a person running") in those ambiguous stimuli, the observer would need *to experience* a "feeling of movement" via embodied simulation. The current study used repetitive transcranial magnetic stimulation (rTMS) to further test this hypothesis. Specifically, we investigated whether temporarily interfering with the activity of the left inferior frontal gyrus (LIFG; a putative MNS area) using rTMS would decrease the propensity to see human movement (M) in the Rorschach inkblots. Thirty-six participants were exposed to the Rorschach stimuli twice, i.e., during a baseline (without rTMS) and soon after inhibitory rTMS. As for the rTMS condition, half of the sample was stimulated over the LIFG (experimental group) and the other half over the Vertex (control group). In line with our hypothesis, the application of rTMS over LIFG, but not over Vertex, yielded a statistically significant reduction in the attribution of M to the ambiguous stimuli, with large effect size. These findings may be interpreted as being consistent with the hypothesis that there is a link between the MNS and the "feeling of movement" people may experience, when observing ambiguous stimuli such as the Rorschach cards.

*Corresponding author.
E-mail address: luciano.giromini@unito.it (L. Giromini).

http://dx.doi.org/10.1016/j.brainres.2015.10.025

1. Introduction

Ambiguous visual stimuli and abstract artwork may elicit a feeling of physical involvement and empathetic engagement, which in turn may provoke a sense of esthetic experience in the observer. According to recent theories, a key role in this process may be played by the "embodied simulation" (Gallese, 2001), a pre-rational mechanism through which exposure to certain visual stimuli would automatically trigger action simulation in the mind of the observer, thereby originating a "feeling of movement" (Freedberg and Gallese, 2007). More specifically, it has been proposed that observation of abstract stimuli may be accompanied by activation of a physiological mirroring mechanism in the brain, which in turn would generate in the observer a feeling of physical reaction 'as if' his or her body was engaged in the perceptive process (Freedberg and Gallese, 2007; Damasio, 2003; Sbriscia-Fioretti et al., 2013; Umiltà et al., 2012).

1.1. *Mirror neurons*

Mirror neurons are cortical cells in the brain of the monkey that fire both when the monkey performs an action, and also when it sits still and observes another monkey performing a similar action (Rizzolatti et al., 1996; di Pellegrino et al., 1992; Gallese et al., 1996). Since the discovery of the mirror neuron system (MNS; di Pellegrino et al., 1992; Gallese et al., 1996; Rizzolatti et al., 1996), increasing attention has been paid to the role of mirror neurons in the development of complex cognitive and social behaviors. Some authors, in particular, have suggested that the MNS may be the neurobiological basis for higher cognitive, human abilities such as action understanding, perspective taking, and empathy (Gallese, 2003; Rizzolatti and Craighero, 2004; Oberman and Ramachandran, 2007; Iacoboni, 2009; Rizzolatti et al., 2001) and that it most likely represents the neural-physiological substrate of embodied simulation (Gallese, 2003). To date, however, the evidence for mirror neurons in humans is largely limited by the fact that single-cell recording is not typically performed in the human brain. As such, most of the available information is rather indirect, and the debate on the existence of a link between social cognition and a presumed human MNS is far from being settled (see, for example, Dinstein et al., 2007; Hickok, 2009).

1.2. *Mirror neuron system and EEG*

Given that single-cell recording is not typically performed in the human brain, to investigate the activity of the human MNS, a number of authors have suggested to use electroencephalography (EEG). Specifically, it has been proposed that suppression in the 8–13 Hz EEG frequency range over the somatosensory cortex (also referred to as mu wave suppression) might index an ongoing mirror matching mechanism analogous to that of the MNS (for a review, see Pineda, 2005). Similar to the activity of the MNS, indeed, the EEG mu waves respond to both self-initiated and observed movements (Babiloni et al., 1999; Cochin et al., 1998; Gastaut, 1952; Oztop and Arbib, 2002), are largely affected by motor act preparation (Pfurtscheller et al., 1997), demonstrate more sensitivity to biological rather than non-biological motion (Oberman et al., 2005; Ulloa and Pineda, 2007), and show greater fluctuations for actions in the presence of target objects compared to pantomimed actions (Muthukumaraswamy and Johnson, 2004).

Support for the link between EEG mu suppression and mirroring activity in the brain also comes from a number of EEG studies conducted in association with other neuroimaging techniques (such as functional magnetic resonance fMRI; e.g., Braadbaart, et al., 2013). Consistent with this position, Keuken and colleagues (2011) using rTMS, showed that interfering with the activity of the left inferior frontal gyrus (LIFG, presumably implicated in mirroring activity) decreased the performance in an empathy-related task, while also eliminating the EEG mu suppression.

1.3. *Mu suppression and ambiguous, Rorschach stimuli*

Using EEG mu suppression as a proxy marker for mirror neurons activation, Giromini et al. (2010) have recently suggested that "strong internal representation of the feeling of movement may be sufficient to trigger MNS activity even when minimal external cues are present" (p. 240). Specifically, by conducting an EEG study with the Rorschach inkblot designs, the authors showed that attributing, identifying, and observing human movement yielded greater EEG mu suppression than attributing, identifying, or observing any other static scenarios, regardless of the experimental condition (Giromini et al., 2010). Said differently, in their study EEG mu suppression occurred in concomitance with the participants perceiving/feeling human movement, regardless of whether they were spontaneously attributing it to the ambiguous inkblot stimuli, they were identifying it in the same inkblots upon suggestion of the examiner, or they were actually observing it in unambiguous stimuli. Importantly, these initial findings were later replicated by a second study with an independent sample (Pineda et al., 2011), and then further confirmed also by subsequent, additional analyses on the same data (Porcelli et al., 2013).

According to the Rorschach theoretical tradition (e.g., Exner, 2003; Klopfer and Kelley, 1942; Piotrowski, 1957; Rapaport et al., 1946; Witkin et al.,1962), as well as to a large body of empirical data (e.g., Hix et al., 1994; Porcelli and Meyer, 2002; Porcelli and Mihura, 2010; Ferracuti and Lazzari, 1999; Orlinsky, 1966; Gallucci, 1989; Wood et al., 2003; Steele and Kahn, 1969; Di Nuovo et al., 1988; Exner and Andronikof-Sanglade, 1992; Weiner and Exner, 1991), the spontaneous attribution of human movement to the ambiguous Rorschach stimuli (M response) depends on an embodied simulation mechanism, and reflects an higher cognitive functioning related to social cognition and empathy. As such, the observed association between Rorschach M responses and EEG mu suppression may be interpreted as an additional evidence for the role of the MNS in social cognition.

1.4. *The LIFG as target site*

The pars opercularis of the IFG is considered to be the human homolog of the monkey area F5, which is the area where mirror neurons were first discovered (Rizzolatti and Craighero, 2004; Geyer et al., 2000). Previous research has shown that