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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.

^aDepartment of Psychology, University of Turin, Turin, Italy

^bNeuroscience Institute of Turin (NIT), University of Turin, Turin, Italy

^c Department of Social Sciences and Humanities, University of Valle D'Aosta, Aosta, Italy

^dCalifornia School of Professional Psychology, Alliant International University, San Diego, U.S

***Correspondence to: luciano.giromini@unito.it**

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.

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

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 aesthetic 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, 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 et al., 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., 2006), 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 neuron activation, Giromini, Porcelli, Viglione, Parolin, and Pineda (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, 1944; 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 et al., 1999; Orlinksky, 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 rTMS over LIFG interferes with processes related to a mirror activity (Heiser et al., 2003; Pobric and Hamilton, 2006; Elfenbein et al., 2007) and eliminates the suppression of the 8-12 Hz EEG Mu rhythm during social perception tasks and increases the reaction time during an emotion recognition task (Keuken et al., 2011). Pineda (see review, 2005) also hypothesized that the Mu rhythm is dependent on IFG activity. Thus empirical evidence suggests that the LIFG may be linked to embodied simulation and MNS activity.

1.5 The current study

In the current study, we used rTMS to test the hypothesis that action perception and action simulation are intimately linked to each other, so that experiencing a “feeling of movement” while observing ambiguous visual stimuli would ground on an embodied simulation mechanism modulated by the MNS. Specifically, we investigated whether the LIFG, which is thought to include a large amount of mirror neurons, plays a crucial role in the attribution of human movement to the ambiguous, Rorschach inkblot stimuli static visual stimuli,

characterized by inkblot designs (which perceptually resemble some abstract artworks). We predicted that temporary disruption of LIFG by rTMS would reduce the spontaneous attribution of human movement (e.g., seeing “a person walking”) to the ambiguous Rorschach stimuli (Rorschach, 1921).

2. Results

2.1 Psychometric measurements

As reported in Table 1 and Figure 1, rTMS over LIFG, but not over Vertex, decreased the number of M codes produced by the participants during exposure to the Rorschach inkblots. In fact, a mixed, 2 (between-subjects factor, site: LIFG vs. vertex) by 2 (within-subjects factor, condition: baseline vs. rTMS) ANOVA revealed a highly significant interaction effect, [$F(1, 34) = 31.850, p < .00001, \text{Partial } \eta^2 = .484$]. Importantly, within the control group, the baseline and rTMS (vertex) conditions yielded a strikingly similar number of M codes [$t(17) = .615, p = .547, d = 2.07$]; conversely, within the experimental group, the number of M codes after rTMS (LIFG) was significantly lower than at the baseline [$t(17) = 7.200, p < .00001, d = 2.617$].

These effects could not be accounted for by general reduced verbal production following inhibitory rTMS of LIFG, as indicated by the fact that the number of verbal responses did not change across conditions. Indeed, given that the LIFG includes Broca’s area (BA 44, corresponding to F7 of 10-20 EEG system) (Nishitani and Hari, 2000), its offline inhibition through 1 Hz rTMS might affect the production of spoken language. Thus, we were concerned that rTMS over the LIFG might have artificially reduced the number of M responses as a result of a more general reduction in verbal production (i.e., a reduction in the overall number of responses). To prevent this from happening, we used Rorschach Performance Assessment

System (R-PAS; Meyer et al., 2011) administration procedures, which instruct respondents to try to produce two or three responses per card and do not allow for more than four responses per card¹. Furthermore, we also tested a 2 x 2 mixed ANOVA with site (LIFG, Vertex) as between-subjects factor and condition (baseline vs. rTMS) as within-subjects factor, and the total number of responses as the dependent variable. As reported in Table 2, these additional results showed that the experimental and control groups produced a strikingly similar, virtually identical total number of responses. In fact, the interaction effect was not statistically significant [$F(1,34) = .183, p = .671, \text{Partial } \eta^2 = .005$]. Thus, the reduction in the number of M responses after rTMS over LIFG cannot be explained by a general reduction of verbal production.

3. Discussion

Previous research has shown that attribution of human movement to the ambiguous, Rorschach inkblot stimuli associates to 8-13 Hz (Mu) frequency EEG band suppression over sensorimotor cortex (Giromini et al., 2010; Pineda et al., 2011; Porcelli et al. 2013), a putative index of mirroring activity in the brain (Pineda et al., 2011). Other research has also suggested that an embodied simulation mechanism modulated by the MNS may be responsible for the perception and appreciation of works of art (Freedberg and Gallese, 2007; Damasio, 2003; Sbriscia - Fioretti-Umiltà et al., 2012). In our view, a unifying hypothesis for this complex of findings is that action and perception are not separate domains, but integrated components of a same, complex system. Action itself contributes to perception (Ricci and Chatterjee, 2004; Ricci et al., 2005). Thus, when exposed to ambiguous or indefinite visual stimuli such as the

¹According to R-PAS procedures, when introducing the task the examiner asks the respondent to try to produce two or maybe three responses per card. Next, during the administration, if only one response is given to a card, the examiner “prompts” the respondent to produce a second response; if four responses are given, the examiner kindly “pulls” the card from the examiner and does not allow for additional responses (Meyer et al., 2011).

Rorschach inkblot designs or abstract artworks, in order *to see* a human movement in the stimuli, the observer would also need to *experience* a “feeling of movement” within his or her body. In line with this hypothesis, our experiment shows, for the first time, that inhibitory rTMS of the LIFG (a site postulated to include mirror neurons and thus to be crucial for embodied simulation) considerably reduced the attribution of human movement to the ambiguous, Rorschach inkblot stimuli.

These findings are important to the field of cognitive neuroscience, in that they suggest that there is an intimate link between action simulation and action perception (consistent with the embodied simulation hypothesis), and because, given the convergence between our findings and those obtained with the EEG (Giromini et al., 2010; Pineda et al., 2011; Porcelli et al., 2013) they also provide indirect support for the use of EEG to measure MNS activity. Our study is also important to the clinical psychology and personality assessment fields, in that they confirm that attributing human movement to the ambiguous Rorschach stimuli might reflect an embodied simulation mechanism, as speculated by several Rorschach authorities (Rorschach, 1921; Exner, 2003; Meyer, 2011; Mihura, 2012). Indeed, the human movement response is one of the most revealing Rorschach variables (Rorschach, 1921; Meyer, 2011; Piotrowski, 1957) because it involves the integration of different perceptual features and the ability to imagine (because the actual stimuli do not move) and to identify with a human being (Exner, 2003).

Nonetheless, a number of considerations should be kept in mind, while reading this article. First, the present experiment did not directly test the mirror neuron theory: our interpretation of the results as supportive of the embodied simulation theory only comes from indirect evidence. According to our hypotheses and on the basis of previous findings we anticipated that rTMS of the LIFG would reduce MNS activity, so that after rTMS over the LIFG

an individual would be less likely to experience a “feeling of movement”, and thus less likely to see a human movement in the ambiguous, Rorschach inkblots too. However, we did not directly measure the “feelings of movement”, but only recorded whether participants did or did not see human movements in the inkblot stimuli. Hence, some other, alternative accounts for our findings are possible too. For example, it is possible that the LIFG is implicated in the tendency to produce M codes, rather than in the generation of a “feeling of movement”. Along the same lines, it could also be that the production of M responses is mediated by an “understanding” or a “knowledge” of movement (e.g., Spunt, Satpute, & Lieberman, 2011), rather than by an embodied simulation, or “feeling” of movement. Relevant to these issues, however, it is important to note that Giromini et al. (2010), using a within-subject design, found that EEG mu suppression occurred not only when individuals were attributing M codes to ambiguous Rorschach-based stimuli, but also when they were observing clear representations of human movement in inkblot-based drawings. In our view, thus, it is unlikely that our findings are accounted for by the LIFG being responsible for the tendency to produce M responses when exposed to ambiguous stimuli. Instead, combining the previous results with the present findings make it more likely that the LIFG is associated with the embodied simulation process associated with production of M responses. Nevertheless, additional research is needed to rule out these (and other) alternative hypotheses.

A second limitation to keep in mind is that because we did not implement a neuronavigation system and individual MRIs, we cannot be certain that all participants were stimulated in the same exact cortical spot. Furthermore, given that different participants were stimulated in different areas, i.e., half were stimulated over the LIFG and the other half over the Vertex, future research should test whether similar results can be obtained when experimental and

control sites are stimulated within the same population. Lastly, in our study we applied rTMS over the left IFG but did not test the right IFG. Although it has been hypothesized that the neural system underlying action imitation and learning (MNS) may be an evolutionary precursor of the language system, MNS does not seem to be left lateralized (see Aziz-Zadeh et al 2006). In fact, in their studies with the Rorschach inkblots, Giromini and colleagues did not find any significant differences in mirroring activity between the left and right hemispheres (Giromini et al., 2010; Pineda et al., 2011; Porcelli et al., 2013). Thus, we expect that stimulation of the right IFG shall produce effects similar to those observed after stimulation of the left IFG (i.e. suppression of M responses).

4. Experimental Procedures

4.1 Participants

Forty right-handed healthy students with normal or corrected-to-normal vision were recruited from the Department of Psychology, University of Turin. The appointments with the students from an introductory psychology class were set on the phone and via e-mail. The supervisors of research provided that all subjects recruited were tested for TMS compatibility. They had no history of neurological or psychiatric illness and were never administered the Rorschach inkblot test before. Handedness evaluation was based on the Edinburgh Handedness Inventory (EHI) (Oldfield, 1971). Potential participants were screened against inclusion/exclusion criteria for a safety use of TMS (Rossi et al., 2009) and underwent the Italian version of Symptom Check List-90-R (SCL-90-R; Derogatis, 1994; Sarno, 2011) to assess the presence of overt psychopathology (see below for details). Four individuals, showing high levels of psychopathology on the SCL-90-R, were excluded from the study. Thus the final

sample comprised 36 subjects (9 males, 27 females; Table 3). Participants gave their written informed consent to participate in this study, which was approved by the Institutional Review Board of the University of Turin.

4.2 Procedures

Each participant was exposed to a set of ambiguous Rorschach inkblot designs twice, i.e., during a baseline (without rTMS) and soon after inhibitory rTMS (15 minutes, 1 Hz rTMS at 90% of Resting Motor Threshold). The time period between these two conditions was 4 weeks, and their order was balanced across subjects. The Rorschach administration, during baseline condition, occurred in a quiet room located in the psychodiagnostic lab, while the exposure to the Rorschach stimuli, soon after rTMS, was in quiet hospital room; the participants arrived separately. Half of the sample (experimental group, $n = 18$) was stimulated over the LIFG and the other half (control group, $n = 18$) over the Vertex. Consistent with the standard guidelines of the Rorschach task (Exner, 2003; Meyer et al., 2011) for each inkblot design participants were asked to answer the question “What might this be?” and responses were transcribed verbatim by the experimenter. Each response was then coded (also in line with the standard, Rorschach guidelines (Exner, 2003; Meyer et al., 2011), for the presence vs. absence of human movement (M); one of the most valid and reliable Rorschach variables (Mihura et al., 2012; Viglione et al., 2012). For example, if a participant reported to see, within a given inkblot, “a woman dancing with the hands up,” an M code was assigned; if a participant reported to see “a very colorful flower,” an M code was not assigned. The total number of M codes produced by the participants during exposure to each set of ambiguous, Rorschach inkblot stimuli was the dependent variable.

4.3 Measures

4.3.1 Symptom Check List -90-R.

The SCL-90-R is a 90-item self-report symptom inventory for the assessment of psychological symptoms and psychological distress. The major symptom dimensions are labeled as Somatization (SOM), Obsessive-Compulsive (OBS), Interpersonal Sensitivity (INT), Depression (DEP), Anxiety (ANX), Hostility (HOS), Phobic Anxiety (PHOB), Paranoid Ideation (PAR), and Psychoticism (PSY). The global indexes are referred to as the Global Severity Index (GSI), Positive Symptom Distress Index (PSDI), and Positive Symptom Total (PST).

The studies of the psychometric properties of the SCL-90-R have provided satisfactory results with respect to both test-retest and internal reliability (with alpha coefficients ranging from .79 to .90 for the different dimension scales in clinical and non-clinical sample) (Horowitz, 1998), as well as convergent and discriminant validity (Brophy, 1998). Consistent with Holi (2003) and Prunasandcolleagues (2012), individuals with a GSI score equal or more than 1 were excluded from the study. Also consistent with previous research, in our sample the GSI produced an alpha of .95.

4.3.2 Repetitive Transcranial Magnetic Stimulation

Repetitive transcranial magnetic stimulation (rTMS) was performed with a Magstim Super Rapid Stimulator (Magstim Company Ltd., Whitland, UK) and a 70 mm figure-of-eight coil. To define the resting Motor Threshold (rMT), for each participant, the coil was positioned over the participant's left primary motor cortex at the optimum scalp position able to elicit motor evoked potentials (MEPs) in the contralateral abductor pollicis brevis muscle (APB). RMT was defined as the minimum stimulus intensity that produced MEPs > 50 μ V (peak-to-peak

amplitude) in at least 5 out of 10 consecutive stimulations (Rossini, 1994). In the experimental group, 1 Hz rTMS was applied at 90% of rMT for fifteen minutes (900 pulses) over F7 (according to the standard 10-20 EEG system), an electrode site corresponding to the Left Inferior Frontal Gyrus (LIFG). In the control group, the same stimulation was applied over Cz (in the standard 10-20 EEG system), a site corresponding to the Vertex. Stimulation over Vertex is often used as control condition to test for non-specific rTMS effects (Nyffeler, 2006; Nowak, 2008). Participants were randomly assigned to either the experimental or the control condition. The identification of the LIFG and the Vertex sites was performed by an expert neuropsychologist and the headrest was used for accurate positioning of the coil.

Low-frequency rTMS was applied to induce long lasting suppression of neural activity (Ridding and Rothwell, 2009). This offline approach has the advantage of not requiring rTMS at the same time of task administration. In addition, it allows to remove non-specific effects of concurrent, online TMS. In general, the after-effects of low-frequency offline rTMS last approximately half the duration of the stimulation train, depending on the stimulation parameters and the coil characteristics (Mottaghy, 2003; Hansenne, 2004; Eisenegger, 2008; Robertson, 2003).

4.3.3 The Ambiguous, Rorschach Stimuli

The Rorschach test is composed of 10 ambiguous, inkblot designs. Typically, respondents are asked to communicate the examiner what they see in the inkblots, and their responses are then interpreted based on (a) what they see, (b) what, in the inkblot, made them see what they saw (e.g., the shape, the color, etc.), and (c) where in the inkblot they saw each of their percepts. According to various Rorschach theorists (Rorschach, 1921; Klopfer and Kelley, 1942), seeing a human movement (M code) in the ambiguous stimuli would rely on an ongoing identification

mechanism. Said differently, it is believed that when a person sees, for example, “an individual who is lifting an object that is way too heavy for him”, to some extent he or she is implicitly identifying with the character of the response, thus revealing important information about him/her-self.

Various data support the validity of the M response as related to an identification mechanism (Meyer, 2002). The inter-rater reliability of the M response also is satisfactory, indicating that two independent raters, blind to each other’s evaluation, code for the presence vs. absence of M reliably, with intraclass correlation coefficients (ICC) ranging from .96 to .97 (Viglione et al., 2012; Meyer, 2002; Viglione and Taylor, 2003). In the current study, two independent raters, blind to the experimental conditions, coded for the presence vs. absence of M responses. The percentage of agreement was 98%, the ICC was 0.98.

Given that the duration of rTMS after-effects is approximately half the duration of the total stimulation time (Mottaghy, 2003), we anticipated that only 7-8 minutes would be available for administering the Rorschach inkblots after rTMS. Thus, to maximize the variability in our dependent variable (i.e., the number of M responses) within that limited amount of time, we decided to select a small subset of stimuli from the entire set of Rorschach inkblots, and to constrain the maximum number of allowed responses per card. Consistent with Giromini et al. (2010), we selected the three Rorschach cards that more frequently (i.e., in about 30 to 50 percent of the cases) elicit spontaneous attribution of human movement, i.e., cards II, III, and VII. This choice aimed at avoiding an unwanted floor effect (i.e., lack of variability due to absence of M responses). Furthermore, because the total number of responses per card produced by the participants might act as confound, we adopted Rorschach – Assessment Performance System (R-PAS) (Meyer, 2011) administration procedures, and asked the participants to produce

two or three different responses per card. This ensured homogeneity in the number of responses across subjects, conditions and groups. The Rorschach test was administered by expert clinicians, blind to the experimental conditions.

Conflict of interest statement

Donald Viglione owns a share in the corporate (LLC) that possesses rights to Rorschach Performance Assessment System. The other authors report no actual or potential conflicts of interests.

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FIGURES CAPTION

Figure 1. Experimental and control groups performances on the Rorschach test.

Graphical representation of the number of human movement attributions (M codes) produced by the control and the experimental groups, at baseline and after inhibitory repetitive transcranial stimulation (rTMS). Disrupting the left inferior frontal gyrus (LIFG), but not Vertex, decreased the number of attributions of human movement to the ambiguous, Rorschach inkblot stimuli.

Author Contributions.

AA conceived and coordinated the study, reviewed and collected the Rorschach data, performed the data analysis and wrote the manuscript.

AS reviewed and collected the rTMS data and also wrote the manuscript.

LG contributed to the research design and helped analyzing and interpreting the data and wrote the manuscript.

RR helped with TMS study design and supervision and reviewed the manuscript.

CP helped analyzing data.

SC and **LF** helped drafting the manuscript.

DJV helped interpreting the data and reviewing the manuscript.

AZ conceived and supervised the study.

Figure 1

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Figure 1.

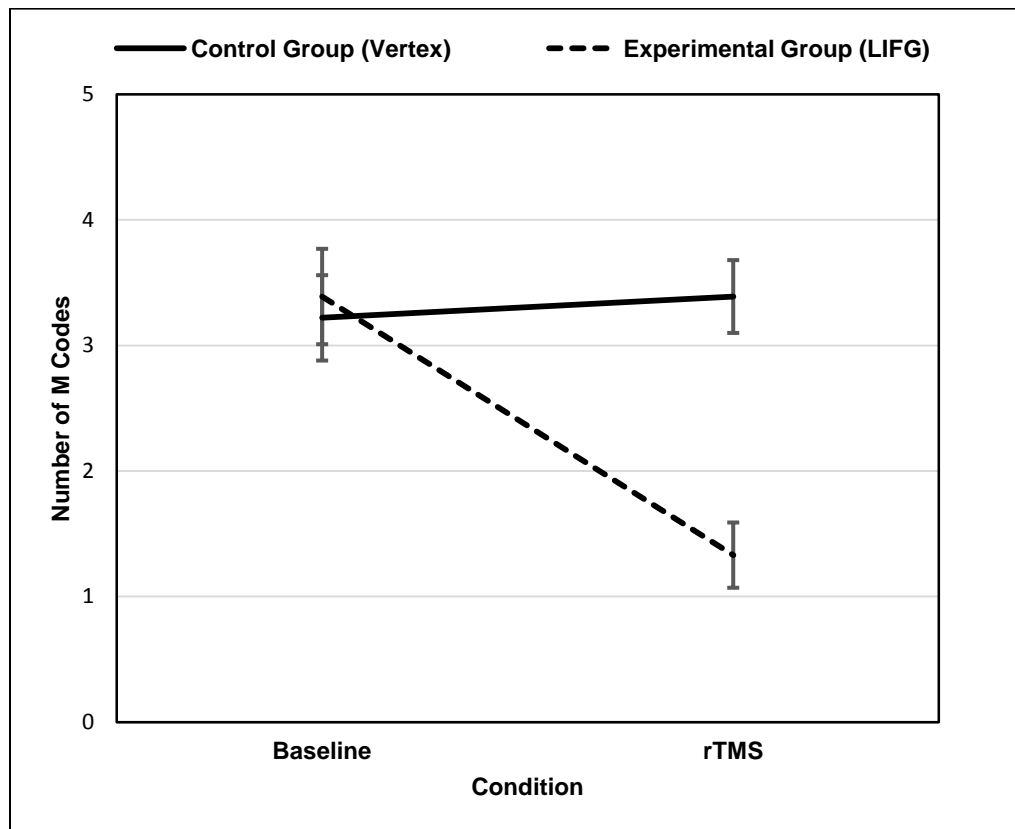


Table 1. Number of human movement attributions.

	Control	Experimental
	Group (Vertex)	Group (LIFG)
Baseline		
<i>Range</i>	1 – 7	0 – 7
<i>M</i>	3.22	3.39
<i>Median</i>	3.00	3.00
<i>S.D.</i>	1.44	1.61
rTMS		
<i>Range</i>	1 – 5	0 – 3
<i>M</i>	3.39	1.33
<i>Median</i>	3.50	1.00
<i>S.D.</i>	1.24	1.08

Descriptive statistics are reported for the number of human movement attributions (M codes) produced by the control and the experimental groups, at baseline and after inhibitory repetitive transcranial magnetic stimulation (rTMS).

Table 2. Number of responses to the Rorschach test.

	Control Group (Vertex)	Experimental Group (LIFG)
Baseline		
<i>Range</i>	6 – 11	6 – 12
<i>M</i>	8.61	8.72
<i>Median</i>	8.50	9.00
<i>S.D.</i>	1.42	1.90
rTMS		
<i>Range</i>	7 – 11	6 – 12
<i>M</i>	8.56	8.44
<i>Median</i>	8.50	8.00
<i>S.D.</i>	1.29	1.69

Descriptive statistics are reported for the number of responses produced by the control and the experimental groups at baseline and after rTMS.

Table 3. Demographic composition of control and experimental groups.

	Control Group (Vertex)	Experimental Group (LIFG)
Gender ($\phi = .19, p = .25$)		
M	$n = 12$ (66.67%)	$n = 15$ (83.33%)
F	$n = 6$ (33.33%)	$n = 3$ (16.67%)
Age ($t(20.19)^a = 1.35, p = .19$)		
Range	19 – 33	19 – 23
<i>M</i>	21.67	20.61
<i>SD</i>	3.18	.98
Years of Education ($t(34) = .82, p = .42$)		
Range	13 – 18	14 – 16
<i>M</i>	14.94	14.72
<i>SD</i>	1.00	.58

All participants were Italian undergraduate students, whose first language was Italian.

LIFG = Left Inferior Frontal Gyrus.