Human Movement Responses to the Rorschach and Mirroring Activity: An fMRI Study

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Abstract

It has been suggested that the Rorschach human movement (M) response could be associated with an embodied simulation mechanism mediated by the mirror neuron system (MNS). To date, evidence for this hypothesis comes from two electroencephalogram (EEG) studies and one repetitive transcranial magnetic stimulation (rTMS) study. To provide additional data on this topic, the Rorschach was administered during fMRI to a sample of 26 healthy adult volunteers. Activity in MNS-related brain areas temporally associated with M responses was compared to such activity for other, non-M Rorschach responses. Data analyses focused on MNS regions of interest (ROI) identified by Neurosynth, a web-based platform for large-scale, automated meta-analysis of fMRI data. Consistent with the hypothesis that M responses involve embodied simulation and MNS activity, univariate ROI analyses showed that production of M responses associated with significantly greater activity in MNS-related brain areas when compared to non-M Rorschach responses. This finding is consistent with the traditional interpretation of the M code.

Keywords: Rorschach; Human Movement; fMRI; Mirror Neurons; Embodied Simulation.

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The Rorschach inkblot test (Rorschach, 1921) is one of the most well-known and frequently used personality tests (Camara, Nathan, & Puente, 2000; Cook et al., 2017; Ready & Veague, 2014; Wright et al., 2017) but also one of the most criticized (Lilienfeld, Wood, & Garb, 2000). Indeed, doubts concerning its validity were raised several decades ago and continued to be debated for years (e.g., Cronbach, 1949; Jensen, 1965; Lilienfeld, Wood, & Garb, 2000; Meyer, 2004; Meyer & Archer, 2001; Society for Personality Assessment, 2005; Viglione, 1999). At the moment, however, the largest, most comprehensive, and most recent multiple meta-analyses on this topic (Mihura, Meyer, Dumitrascu, & Bombel, 2013) suggest that early criticisms of the Rorschach validity would apply to a subset of Rorschach variables only, as 30 interpretatively significant variables have demonstrated either *good* ($r \geq .21$, $p < .05$, *Fail-Safe N* ≥ 10) or *excellent* ($r \geq .33$, $p < .001$, *Fail-Safe N* > 50) empirical support, when using external or performance-based, rather than self-reported criteria (see also Wood, Garb, Nezworski, & Lilienfeld, 2015; and Mihura, Meyer, Bombel, & Dumitrascu, 2015).

Since the introduction of the Rorschach inkblot test in 1921, one variable that has continually been considered as one of the most important, informative, and revealing sources of information of the entire test is the human movement (M) response (e.g., Beck, 1944; Exner, 1969, 2003; Klopfer & Kelley, 1944; Mayman, 1977; Meyer et al., 2011; Piotrowski, 1957, 1977; Rorschach, 1921). Technically, this variable is coded when the respondent perceives a response object as being engaged in a human movement or human activity (e.g., "a woman watering plants," "two people dancing together," "an old man playing a saxophone"). Because the Rorschach inkblots are static stimuli, it is speculated that the apparent movement or M would reflect a particular creative or imaginative process, in which the respondent would 'add something' (i.e., the movement) to the stimulus, drawing on his internal representations, emotions and thoughts. More specifically, it is thought that the M response would rely on an identification or embodied simulation mechanism, so that when a respondent sees "an individual crying because someone he loved left him," to some extent he identifies with the character depicted in the response in some psychological meaningful way, thus revealing important and unique information about that respondent. This is the main reason why the M response has received so much attention in the Rorschach literature.

Human Movement and Mirror Neurons

About twenty years ago, a group of Italian researchers discovered a set of cortical cells – later named "mirror neurons" – that fired both when a macaque monkey performed an action, and when it stayed motionless observing another biological agent performing the same action (di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992; Gallese, Fadiga, Fogassi, & Rizzolatti, 1996; Rizzolatti, Fadiga, Gallese, & Fogassi, 1996). Since the discovery of this neurological network – typically referred to as the "mirror neuron system" (MNS) in humans – increasing attention has been paid to the role of mirror neurons in the development of complex cognitive and social behaviors. Some authors have suggested that the MNS may be the neurobiological mechanism involved in higher cognitive functions such as action understanding, perspective taking, and empathy (Ferrari et al., 2009; Gallese, Keysers, & Rizzolatti, 2004; Rizzolatti & Craighero, 2004; Oberman, Pineda, & Ramachandran, 2007; Iacoboni, 2009; Rizzolatti, Fogassi, & Gallese, 2001). Along the same line, data also indicate that anomalies in the MNS might underlie clinical conditions, such as autism spectrum disorders or schizophrenia, in which perturbed social behavior represents one of the core characteristics (Buccino & Amore, 2008; Dapretto et al., 2006; Oberman et al., 2005).

According to Gallese (2003), the MNS may serve as the neurological substrate of the ability to empathize with others in that it would allow for embodied simulation of other people's actions. In this view, when one sees another individual performing an action, the MNS automatically prompts internal representations of the body states associated with that same action, as if the observer was involved in that same movement or was performing that same action. This process, in turn, allows us to pre-rationally make sense of the actions – and possibly also of the emotions and sensations – of others, thereby facilitating our understanding of these social stimuli. As such, action understanding, imitation learning, and empathy might be deeply grounded in the experience of a lived body and might depend on mirror-matching mechanisms (or embodied simulation) mediated by the MNS. This hypothesis is commonly referred to as the "shared manifold of intersubjectivity," or MNS theory (Gallese, 2003).

It must be said, however, that not all authors agree with the idea that the MNS is the primary neurological underpinning for action understanding (e.g., Hickok, 2009). In particular, Caramazza, Anzellotti, Strnad, and Lingnau (2014) recently suggested that classical, nonembodied theories of cognition might account for MNS-related findings as much as the shared manifold of intersubjectivity hypothesis does. In their opinion, the fact that mirror neurons are involved in action understanding does not prove that they actively produce it: The frequently reported activation of MNS regions during both action recognition and action production might also be explained, for example, by the fact that any given action, whether it is observed or performed, likely associates with an abstract, conceptual representation of it. As such, what has often been referred to as the MNS, might in fact simply reflect a higher-level, conceptual processing of nonsensorimotor, abstract representations of actions. The fact that several populations of mirror neurons have been found also outside the classic, fronto-parietal, MNS network (e.g., see Mukamel et al., 2010), to some extent seems to corroborate this hypothesis.

Regardless of what the real function of the MNS is, most authors would agree that action observation and action production are not completely separate, independent domains, so that action perception would influence action production, and action production would influence action perception (Sim, Helbig, Graf, & Kiefer, 2014; Witt, 2011). Likewise, it is fairly accepted that observation of a given action associated with embodied simulation of that same action would likely engage MNS regions (Gallese & Sinigaglia, 2011). Accordingly, and based on the idea that the Rorschach M response may depend on an identification or embodied simulation mechanism, we recently suggested that spontaneously attributing human movement to ambiguous or partially unstructured visual stimuli, such as the Rorschach inkblots, would associate with a MNS-like, mirroring activity in the brain. To date, this hypothesis has been tested by two electroencephalogram (EEG) studies and one repetitive transcranial stimulation (rTMS) study.

In the first study (Giromini, Porcelli, Viglione, Parolin, & Pineda, 2010) we collected EEG data while 15 participants were exposed to a subset of four Rorschach inkblots and images designed to be similar. Because suppression of the 8-13 Hz wave at scalp locations C3, Cz and C4 (mu suppression; Gastaut, 1952) is presumed to be an index of mirroring activity in the brain (Fox et al, 2015; Pineda, 2005), we hypothesized that attribution, identification, and observation of human movement would associate with increased EEG mu suppression, compared to the control conditions. Results supported this hypothesis ($\eta^2 = .06$), leading to the conclusion that internal representation of the "feeling of movement" may be sufficient to trigger MNS activity even in the presence of minimal external cues. In a subsequent EEG trial (Pineda, Giromini, Porcelli, Parolin, & Viglione, 2011; Porcelli, Giromini, Parolin, Pineda, & Viglione, 2013), all ten Rorschach cards, rather than just a subset, were investigated in a larger sample. In this study whose procedure more closely mimicked standard Rorschach administration, M responses, again, were significantly associated with increased mu suppression when compared to other (i.e., non-M) responses to the Rorschach cards ($\eta^2 = .17$).

More recently, an rTMS study provided additional data supporting the link between M responses, embodied simulation, and mirroring activity in the brain. Specifically, Ando' et al. (2015) administered a subset of Rorschach inkblots to a sample of 36 nonclinical adults during a baseline condition (without rTMS) and soon after inhibitory rTMS. Half of the participants (i.e., the experimental group) were stimulated over the left inferior frontal gyrus (LIFG; a putative MNS area), while the other half (i.e., the control group) were stimulated over the vertex (a control site). In line with the hypothesis that producing M responses associates with mirroring activity in the brain, disrupting LIFG, but not vertex, yielded a statistically significant reduction in the propensity to see human movements in the ambiguous Rorschach inkblots, compared to the control condition ($d = 2.62$).

The Current Study

Thus, an emerging set of findings is consistent with the hypothesis that Rorschach M responses may be mediated by MNS-like activity in the brain. To further test this hypothesis and its consistency with traditional interpretations of M responses, the current study used a different method, fMRI. We tested whether producing an M response to the Rorschach would associate with increased activity in MNS-related brain areas.

Materials and Methods

The same fMRI data described below have been used recently to describe in a more general form, without focusing on any coded variables, what brain areas get involved when one is administered the Rorschach (see Giromini et al., 2017). The entire research project, however, was originally designed specifically to test the relationship between production of M responses and activity in MNS-related brain regions, which is uniquely the focus of our current article.

Participants

Participants were 26 American volunteers (13 men), aged 17 to 28 years (M = 21.4, SD = 2.3). Twelve of the participants were Caucasian, ten Asian or Indian, and four Hispanic. Most of the subjects were undergraduate students recruited from the Psychology Department's subject pool at the University of California, San Diego (UCSD). The remaining were volunteers recruited through flyers posted at the Alliant International University (AIU) in San Diego. All participants were right-handed and had normal or corrected-to-normal vision; none had a history of psychiatric or neurological disease.

All UCSD students (N = 22) received class credits and each earned $15 for participation; the remaining four participants, who were recruited through flyers posted at the AIU, did not receive class credits but each earned $18 for participation. The study was approved by the relevant institutional review boards, and all participants gave written consent for participation in accordance with the Helsinki Declaration.

Experimental Design

Before the scanning session, participants were told that during fMRI they would look at the ten Rorschach cards, with the instruction to think of what they might represent, "what they might be." This is modeled after the standard Rorschach response phase. Participants were asked to think of just one response during each exposure to a card and to think of a different response each time the same card would appear (each card appeared twice). Additionally, they were informed that later, outside the scanner, they would be asked about what they thought about while observing each card, and that speaking or moving was not allowed during scanning itself.

Each scan session began with a high-resolution whole-head T1-weighted anatomical scan upon which functional activations would be overlaid. This was followed by a functional scanning session during which each participant was exposed twice to the ten Rorschach cards, each lasting ten seconds. Card I was presented first, followed by Card II, and so on, ending the sequence with Card X. Then, the entire sequence was repeated, such that the ten cards were presented one more time, again beginning with Card I and ending with Card X. A 16-second rest period during which a fixation cross was displayed on the screen was presented before each Rorschach card. During this session, a total of 20 Rorschach responses (i.e., two different Rorschach responses per card) were expected to be produced by each participant.

At the end of the functional scanning each participant was immediately accompanied to a separate room, where the Rorschach cards were shown again on the screen of a computer. For each card, the participant was asked to tell the experimenter what he or she thought the first time and the second time the card was presented while in the scanner. The participant was also asked to report how certain he or she was about the correctness of what they were reporting, i.e., for each first and second responses, the participant was asked to tell the experimenter if he or she was sure about what they were recalling. A ten point scale (10 = "totally sure") was used for this purpose, and only responses that obtained a score of ten (i.e., 92.5% of the total number of responses) were analyzed. All responses were recorded, transcribed verbatim, clarified and subsequently coded according to standard Rorschach procedures (Exner, 2003; Meyer et al., 2011)[1].

Rorschach Interrater Reliability

An expert Rorschach user, who had previously passed the Rorschach Performance Assessment System (R-PAS; Meyer et al., 2011) Coding Proficiency exam (see www.r-pas.org), coded all Rorschach responses. This coder was blind to the purposes of the research and had no access to the fMRI data. His coding was ultimately used in the study.

To address interrater reliability, a group of six advanced, graduate students, who had been in training with the first author for months, independently provided a second set of codes for 16 of the 26 Rorschach protocols included in the study. These coders were blind to the original codes provided by the first coder. Thus, one person coded all the responses and one of six independently coded each response of 16 protocols a second time. These data were then used to calculate inter-rater reliability.

Inter-rater reliability for all scores under investigation (see below) was next inspected by calculating Cohen's kappa (for response-level data) and intraclass correlation (for protocol-level data) coefficients (ICCs). In line with previous studies on the inter-rater reliability of R-PAS scores (e.g., Viglione et al., 2012), kappas ranged from .75 (for nonhuman movement responses, i.e., FM/m) to .97 (for M) (*M* kappa = .90, *SD* = .08) and ICCs ranged from .86 (for shading responses, i.e., YTVC') to .96 (for M) (*M* ICC = .90, *SD* = .04). These statistics indicate

[1] When these data were collected, the person who administered the Rorschach was not proficient in the Rorschach Performance Assessment System (R-PAS; Meyer et al., 2011). As such, he collected these records using Comprehensive System (CS; Exner, 2003) procedures. All protocols were then re-coded in R-PAS by a proficient coder, as noted below. It should be noted, however, that given the atypical method of administration used in this study to accommodate the collection of fMRI data, the procedures to collect the Rorschach responses in this study would be the same using either CS or R-PAS.

excellent reliability for all scores under investigation – for kappa's and ICC's interpretative benchmarks, see Cicchetti (1994) and Shrout and Fliess (1979).

Imaging

Images were acquired on a 3 T Siemens Trio Tim Scanner. A five-minute magnetization prepared, rapid-acquisition gradient echo image (MPRAGE) was acquired for anatomic overlays of functional data and spatial normalization. Hearing was protected using ear plugs and motion was minimized using soft pads fitted over the ears. During anatomical scanning, 160 T1-weighted slices covering the whole brain were acquired. Field of view (FOV) was 240 x 240 x 160, with a voxel size of 1 mm^3. Blood-oxygen level dependent (BOLD) imaging used a 33 T2-weighted slice whole-brain, single-shot gradient echo (GE) echo-planar (EPI) sequence (TR/TE = 1969/25 ms, FA = 90°, FOV = 240 mm, matrix = 64 x 64, slice thickness/gap = 4/0 mm). This sequence delivers a nominal voxel resolution of 3.75 x 3.75 x 3.75 mm. The first two volumes were excluded due to T1 equilibrium effects so that, for each participant, a total of 260 time points (i.e., 520 seconds) was available for data analysis.

Statistical Analyses

M Responses and MNS Areas Activity. The primary hypothesis of the study was that attributing an M response to the Rorschach inkblot designs would associate with activity in MNS areas. Indeed, such an association would be consistent with both theoretical considerations (e.g., Piotrowski, 1977; Rorschach, 1921) as well as empirical findings obtained from EEG (Giromini et al., 2010; Pineda et al., 2011; Porcelli et al., 2013) and rTMS (Ando' et al., 2015). Thus, prior to conducting data analysis, we identified brain areas associated with MNS activity (i.e., our region of interest, or ROI), by using Neurosynth (see www.neurosynth.org), a web-based platform for large-scale, automated synthesis of fMRI data.

Briefly, Neurosynth analyzes data from numerous, published fMRI studies, and generates a meta-analysis of available studies based on keywords. Importantly, rather than using classic forward inference, and selecting the voxels to be included for a given map based on their positive association with a given term, Neurosynth uses Bayesian reverse inference that takes into account also all negative findings (i.e., the presence of activations in the absence of the keyword), thereby allowing for a greater specificity. Neurosynth generated images are then corrected for multiple comparisons by using a false discovery rate (FDR) criterion of .01, meaning that only about 1% of the voxels might be expected to be false positives.

For the current study, we used the keyword "mirror neurons," and obtained results from 72 published studies, encompassing 3220 locations[2]. Areas generated by meta-analysis of these 72 studies were thus used as our ROI.

Next, we preprocessed functional data with BrainVoyager QX 2.8 (Brain Innovation, Maastricht, The Netherlands). Specifically, we performed mean intensity adjustment, head motion correction, 3D spatial smoothing (FWHM = 6mm), linear trend removal, high pass filtering (cutoff 0.004 Hz) and temporal smoothing (FWHM = 2.8 s)[3]. These data were then co-registered, for each subject, with his 3D high-resolution anatomical scan, and transformed into Talairach space (Talairach & Tournoux, 1988) by using a home-made script in Matlab that utilizes a ICBM2TAL transform (for details, see: http://www.brainmap.org/icbm2tal/). The conversion from MNI to Talairach space was necessary to utilize the Neurosynth map in BrainVoyager.

[2] Data analysis completed on 12/17/2014.

[3] Slice timing correction was not performed in this study, as each analyzed block included at least 6 TRs and we were not interested in investigating any specific, single TRs. Thus, we decided to avoid introducing any sources of unneeded, interpolation errors (for background, see Soares et al., 2016).

Lastly, we performed univariate ROI-analysis, to assess statistically significant activation differences between M and Non-M responses inside our pre-defined region of interest. To do so, a first-level (i.e., individual subject) analysis was performed using a ROI-based general linear model with blocked design to model blood-oxygenation level-dependent (BOLD) signal changes. First, BOLD signal changes induced by production of M responses relative to fixation (i.e., M>fixation) were analyzed by averaging, for each of these two conditions (i.e., M and fixation), all the MNS ROI voxels in the run (as noted above, the duration of the active blocks was 10s, and 16s for the rest blocks). Then, BOLD signal changes induced by production of Non-M responses relative to fixation (i.e., Non-M>fixation) were examined by using this same analytic approach (i.e., by averaging all the MNS ROI voxels in the run for the Non-M and fixation conditions). Results from this first-level analyses were then submitted to a second level (i.e., group) analysis, in which participants were treated as a random effect, thus allowing inference to the general population (Friston, Holmes, Price, Büchel, & Worsley, 1999). More in detail, by using a random effect GLM, the mean contrast values of the voxels inside the MNS ROI were tested using a paired t-test, to evaluate differences between the M and Non-M conditions (M>fixation vs. Non-M>fixation).

Examination of Other Rorschach Responses and Brain Regions. In addition to testing the association of M responses to BOLD signal changes in our MNS ROI, we also examined other classes of responses theoretically unrelated to the MNS. In particular, we were interested in testing Rorschach variables involving, for example, non-human movement (e.g., "a dog moving its tail"; "an airplane flying in the sky") or non-moving human contents (e.g., "a person, this is the head, this is the body, and these are the arms, legs, and feet"). Indeed, because human mirror neurons are known to be more responsive to human movements, rather than to other types of movement not belonging to the human motor repertoire, we anticipated that only the M response (and none of the other variables) would associate with significant MNS ROI activations.

In line with Porcelli et al. (2013), we thus investigated the following classes of Rorschach responses: 1) non-human movement responses (FM/m; e.g., "a bat flying"); 2) non-moving human content responses (Non-M H Contents; e.g., "just the shape of a human being"); 3) responses in which the chromatic colors of the blot determine or contribute to the response (FC/CF/C; e.g., "I see a banana, because it is yellow, and it has the shape of a banana"); 4) responses in which the achromatic colors or the shadings of the blot determine or contribute to the response (Y/T/V/C'; e.g., "It is a cloud, the gray shading here makes it look like a cloud"); 5) responses that are based on the shape of the blot only (Pure F or F; "The shape makes it look like a star"). For each of these additional codes, the same univariate ROI-analyses performed to compare M vs. Non-M responses were implemented. So, for example, to test whether the non-human movement Rorschach responses (FM/m) would associate with increased activity in MNS-like areas, we performed univariate-ROI analyses contrasting FM/m>fixation vs. Non-FM/m>fixation.

To better contextualize our MNS ROI findings, we also tested the extent to which any of these variables would associate with increased activity in the motion sensitive, visual system region often referred to as "MT+" (Dukelow et al., 2001; see also Born & Bradley, 2005). Indeed, we were concerned that seeing human movement in the inkblots could associate with increased activity in the MT+ region, which in turn could possibly influence the results of our MNS-based ROI analyses. More in detail, MT+ is typically triggered by both MNS as well as non-MNS, motion-related tasks, such as observing moving dots or lines. To address this possible confound, we thus tested whether the hypothesized association between M responses and MNS-areas activation would persist also after removing from our MNS ROI all voxels included in the MT+ ROI. Accordingly, in addition to our MNS ROI, we also considered two extra ROIs, for these additional analyses: 1) "MT+ ROI," which was generated by utilizing the same procedure we followed to generate our MNS ROI, i.e., by entering "MT+" in Neurosynth (thus, this ROI was based on an automated meta-analysis of 125 studies, encompassing 4927 activations); 2) "MNS w/out MT+," which was generated by removing from our MNS ROI all voxels included in the MT+ ROI. Figure 1 shows an extract of these three ROIs under investigation at the Talairach coordinates x = 51, y = 6, z = 22.

Effect Size Computation. With paired samples designs like ours, it may be challenging to decide whether to report standard independent samples *d* versus Morris and DeShon's (2002) corrected value. Because we were more interested in calculating the actual effect size, rather than in determining the power that would be needed to detect an a priori established effect size, in line with Dunlap et al.'s (1996) recommendations, we decided to calculate Cohen's *d* effect size of our comparisons using standard independent samples *d* formula.

Furthermore, it should be pointed out that because our univariate ROI analyses compared, within each participant, MNS brain activity associated with the *presence* versus the *absence* of a given score, these contrasts were only possible if the target variable (i.e., the variable under investigation) was present in some responses but absent in others. As such, some of our analyses did not include all the 26 participants (for example, because three participants did not provide any nonmoving human content responses, the analyses of this variable included 23 subjects only). In these cases, in addition to reporting the effect size based on all available data, we also reported the effect size based on all participants (n = 26), by placing participants with no target scores in the control (i.e., absence) condition.

Results

The mean number of M responses per protocol was 4.69 (*SD* = 2.36), whereas the mean number of Non-M responses was 13.81 (*SD* = 2.51). All participants produced at least two M responses, so that all were eligible for the analysis. In line with our main hypothesis, the ROI analysis comparing activity during production of M vs. non-M responses indicated that M responses associated with increased activation in the selected MNS areas, $t(25) = 4.372$, $p < .001$, $d = .45$. Noteworthy, the size of this effect may be characterized as *medium*, according to standard benchmarks (Cohen, 1988).

We thus examined whether this pattern of brain activations was specific to M responses or if it would also apply to other classes of responses theoretically unrelated to MNS, and whether it persisted after removing from our MNS ROI all voxels included in the MT+ ROI. The results of these additional analyses, reported in Table 1, show that M responses were positively and significantly ($p < .01$) associated with greater activity not only in our MNS ROI, but also in the MT+ and MNS w/out MT+ ROIs. Similarly – but in the opposite direction – F responses associated with reduced activity in all three ROIs ($p \leq .03$), whereas non-human movement responses (FM/m) associated with marginally significantly ($p = .05$) increased activity in MT+, but did not produce significant associations with our MNS or MNS w/out MT+ ROIs.

With respect to the significant results of F, it is important to note that of the 315 Non-F responses in the dataset, 193 (i.e., about 60%) were M responses, and 230 (i.e., over 70%) included human (M), animal (FM), and/or inanimate (m) movement. Thus, it is possible that the association between F and the activity in our MNS ROI was moderated (if not even mediated) by the fact that several Non-F responses in fact contained some type(s) of movement (human, animal, or inanimate). To inspect this hypothesis, we performed two additional analyses. First, we compared brain activity in our ROIs for all F responses (which, by definition, do not include movement) vs. those Non-F responses that did not include human movement. The results of this first, additional analysis were nonsignificant for the two MNS-related ROIs (i.e., for MNS and MNS w/out MT+), $p \geq .16$, but remained statistically significant for MT+, t (25) = -2.11, p = .04, d = -.25. Next, we compared brain activity in our ROIs for all F responses vs. those Non-F responses that did not include any types of movement, neither human (M), nor animal (FM), nor inanimate (m). The results of this second, additional analysis were nonsignificant for all the three ROIs, $p > .75$. Accordingly, the negative associations between F and our MNS-related ROIs are probably accounted for by the fact that many Non-F responses are M, and the negative association between F and our MT+ ROI is probably accounted for by the fact that many non-F responses are M, FM, or m responses.

Examination of Clusters of Activity within the MNS ROI

Because our MNS ROI included distinct clusters, we also inspected whether different MNS areas would associate with M to different degrees. These analyses, in other words, aimed at understanding which MNS areas more closely associated with production of M responses, so as to better contextualize our main finding that M responses associated with increased activity in MNS-like areas.

After excluding clusters with less than 12 voxels in functional resolution, 17 clusters with contiguous voxels were obtained. The comparison between M vs. Non-M responses for each of these clusters is reported in Table 2. For 16 clusters, the results were in the expected direction, i.e., greater activity for M than Non-M responses. According to binomial theorem, the probability that more than 15 out of 17 results are in the same direction by pure chance is lower than .001. Thus, our large, MNS ROI may be considered as relatively homogeneous. On the other hand, only 5 clusters (i.e., clusters 4, 5, 6, 14, and 16) were statistically significant at p = .05. Cohen's d effect size ranged from -.13 to .48, with 7 clusters presenting effect sizes greater than the classically adopted threshold of d = .2 for characterizing an effect size as "small" (Cohen, 1998). These 7 clusters are represented graphically in Figure 2.

Discussion

We recently proposed that the Rorschach human movement (M) response might be associated with an embodied simulation mechanism mediated by the mirror neuron system (MNS) (Giromini et al., 2010; Pineda et al., 2011; Porcelli et al., 2013). In the current study, we further explored this hypothesis by inspecting, for the first time to our knowledge, fMRI data. In line with our predictions, MNS brain areas were significantly more active when participants produced M responses than when they produced other (i.e., non-M) responses. Taken together, these findings provide additional support to the hypothesis that the Rorschach M response is associated with increased activity in an MNS-like network.

In the Rorschach literature, the cognitive process involved in producing an M response is presumed to involve identification or embodied simulation, although other terms may be used (e.g., Beck, 1944; Exner, 1969, 2003; Klopfer & Kelley, 1944; Mayman, 1977; Meyer et al., 2011; Piotrowski, 1957, 1977; Rorschach, 1921). Furthermore, the implied ability to identify with and to describe an imaginary human being leads to empathy and social cognition being fundamental to the standard interpretation of M (Exner, 2003; Meyer et al., 2011). A large body of empirical data is in line with this position (e.g., Greenwald, 1991; Hix et al., 1994; Porcelli & Meyer, 2002; Porcelli & Mihura, 2010; Ruhe & Lynn, 1987). From this perspective, our results are congruent with what has been reported in the Rorschach literature for years. Given the presumed association between embodied simulation and mirror neurons, the association between production of M responses and activity in MNS-like areas suggests a biological foundation for the hypothesis that the M associates with an ongoing identification or embodied simulation mechanism (Porcelli & Kleiger, 2015). Also, because mirror neurons are presumed to be implicated in empathy and social cognition (e.g., Ferrari et al., 2009; Gallese et al., 2004; Rizzolatti & Craighero, 2004; Oberman et al., 2007; Iacoboni, 2009; Rizzolatti et al., 2001), the link between M and MNS activity may provide support for the traditional interpretation of M responses as related to social cognition.

As noted in the Introduction, however, some authors (e.g., Caramazza et al., 2014; Lingnau, Gesierich, & Caramazza, 2009) have suggested that the great majority of MNS-related empirical findings might in fact be accounted for also by classical, nonembodied theories of cognition, not involving the MNS theory. In this view, the engagement of MNS areas during action recognition and action production would not depend on a low-level, embodied simulation mechanism, but rather on a higher-level conceptual processing. Indeed, using Caramazza et al.'s (2014) words, "every cognitive theory assumes that perception and action, comprehension and production are bridged through shared, abstract conceptual representations" (p. 11).

Obviously, if this alternative explanation of MNS-related literature turned out to be true, then our conclusions on what our empirical findings really mean to the field of Rorschach-based, psychological assessment would need to be revised. On the other hand, in this case the association between MNS activity and production of M responses would still support the notion – reported in the R-PAS manual (Meyer et al., 2011) – that Rorschach M responses reflect the respondent's "mentalization of one's own and others' experiences and actions" (p. 445). Indeed, even if the MNS was engaged by more abstract conceptual representations of human actions, rather than by lower-level, embodied simulation mechanisms, our own representations of human actions are probably ground on our experiences of human actions and movements, our knowledge and perception of human interactions, and so forth. Thus, regardless of whether the activation of MNS areas reflected an ongoing, low-level, embodied simulation mechanism or a higher-level, abstract conceptualization of human actions, the association between M responses and MNS activity would still support the traditional interpretation of Ms as very informative indexes on the respondent's unique way to see, experience, and conceptualize human behaviors and interactions.

Our study has important implications for cognitive neuroscience as well. In recent years, it has been suggested that suppression of the 8–13 Hz EEG frequency band over the somatosensory cortex (i.e., mu suppression) might reflect mirroring activity in the brain possibly associated with the MNS (for a review, see Pineda, 2005; Fox et al., 2015). In fact, consistent with what may be observed when investigating mirror neurons with other techniques, mu suppression: (a) occurs for both self-initiated and observed movements (Babiloni et al., 1999; Cochin, Barthlemy, Lejeune, Roux, & Martineau, 1998; Gastaut, 1952; Oztop & Arbib, 2002); (b) is affected by motor act preparation (Pfurtscheller, Neuper, Andrew, & Edlinger, 1997); (c) responds more strongly to biological rather than nonbiological motion (Oberman et al., 2005; Ulloa & Pineda, 2007); and (d) is increased when the target of an action is visible, compared to pantomimed actions (Muthukumaraswamy & Johnson, 2004). Furthermore, studies conducted with EEG together with fMRI (Braadbaart, Williams, & Waiter, 2013; Arnstein, Cui, Keysers, Maurits, & Gazzola, 2011), rTMS (Keuken et al., 2011), and a recent meta-analysis (Fox et al., 2015) also support the link between EEG mu suppression and mirroring activity. Since the current study used procedures designed to mimic those used by Pineda et al. (2011) and given the convergence of the results, our study provides further evidence for the hypothesis that MNS activity can be measured with EEG. Indeed, Pineda et al. (2011) compared EEG activity during production of M and Non-M responses to the Rorschach, and reported that M responses associated with significantly higher mu suppression. Similarly, the current study analyzed fMRI activity in MNS-like areas during production of M and Non-M responses to the Rorschach, and results indicated that M responses associated with increased activity in the MNS-like areas.

Although our study was not designed to provide any definitive conclusion regarding discriminant validity, it did offer some relevant data. In fact, in addition to M, we inspected some additional classes of Rorschach responses, and we used some different ROIs. In line with Porcelli et al.'s (2013) findings, M is the only response that associated in a meaningful way with our proxy-marker for mirroring activity in the brain. Indeed, it continued to associate with increased activity in our Neurosynth-derived, MNS ROI even after removing from that ROI all MT+ voxels. None of the other variables under investigation produced similarly convincing associations with our MNS-related ROIs. Furthermore, not only M, but also FM/m – albeit with a smaller effect size – associated with increased activity in MT+. Because MT+ is a motion-sensitive, visual area (Dukelow et al., 2001), and perhaps also part of an expanded MNS network (for a meta-analysis, see Caspers et al., 2010), this pattern of findings is not surprising. It confirms that spontaneous attribution of any types of movement (human, animal, or inanimate) to the Rorschach associates with increased activity in MT+, whereas only the human type of movement associates with increased activity in typical MNS regions.

Lastly, the results reported in Table 2 and Figure 2 offer some additional considerations. First, in addition to some typical, MNS fronto-parietal clusters of activations, compared to non-M responses, M responses also activated several clusters in the temporal cortex that are external to classic fronto-parietal, mirror regions. This datum is in line with emerging findings suggesting that the medial temporal lobe (MTL) might play a particularly important role in the human MNS. For example, Mukamel et al. (2010) recorded extracellular activity from 1177 cells in human cortex while their patients were asked to either execute or observe hand grasping actions and facial emotional expressions, and one of the most intriguing findings they reported was that a set of action observation/execution matching neurons was found exactly in that region, i.e., the MTL. Likewise, Tarhan, Watson, and Buxbaum (2015) recently reported on a study they conducted on 131 chronic left-hemisphere stroke patients, in which fronto-parietal lesions associated with disproportionately impaired performance on action production, compared to action recognition. In line with the hypothesis that the temporal cortex might play a key role in human mirroring activity, the authors noted that lesions in the posterior middle temporal gyrus associated with similar impairment on both action production and action recognition.

A second, final consideration that deserves mentioning, is that among the frontal clusters taken into consideration (i.e., clusters 2, 3, 16, and 17 of Table 2) for our additional analyses, only those located in the left hemisphere (i.e., clusters 16 and 17) produced a Cohen's *d* effect size greater than .2 when comparing M vs. non-M responses. This finding also is in line with emerging research on mirroring activity in the brain, suggesting that there might be a left-hemispheric bias for mechanisms associated with perception and production of movement. In particular, Haberling, Corballis and Corballis (2016) have shown that BA 44 tends to show greater left-lateralization than BA 45 in the production of action, and have proposed that the MNS may have become increasingly left-lateralized in the course of evolution.

Limitations

We are aware of several limitations that constrain our interpretations. In particular, it is important to note that our procedure differs from typical fMRI research studies. Indeed, administering the Rorschach task during fMRI presents a number of challenges. First, Rorschach administration usually involves the examinees who describe their responses aloud while looking at the inkblots. Such a procedure is not possible with fMRI designs since examinees typically do not speak during functional scans so as to minimize head movements and associated noise and error. Related to this, the percepts an individual might experience with any given inkblot are virtually infinite, and spontaneously producing a Rorschach response is a very different psychological process (Exner, 2003; Meyer et al., 2011) from the more structured tasks often employed in fMRI studies, such as multiple-choice methods. Additionally, the official Rorschach inkblot designs are ten, so that – for the sake of ecological validity – only ten stimuli could be selected for this study. Conversely, fMRI studies usually present more stimuli repeated many times to detect activation in specific brain areas. Likewise, in fMRI research designs the stimuli are typically presented using randomized sequences, while the order of presentation of the ten Rorschach cards is fixed in real life assessment situations. Thus, to preserve ecological validity for the Rorschach assessment procedure and task, our procedure to some degree is an atypical fMRI design.

To balance ecological validity with the technical constraints associated with administering the Rorschach during fMRI, we adopted the following solution: We let the examinees look at each of the ten inkblots twice, during functional scans. Afterwards, when they were outside the scanner, we asked them to verbalize what they had seen in each inkblot, while in the scanner. The choice to present each inkblot twice mimics the procedures used in previous EEG studies (Pineda et al., 2011; Porcelli et al., 2013) derived from the Rorschach literature suggesting that about 2 responses per card is optimal (Meyer et al., 2011; Reese et al., 2014). Moreover, showing the Rorschach stimuli more than twice would likely make it difficult for participants to fully recall both what they saw in each card (i.e., their response) and when they saw it (i.e., at 1st, 2nd, …, or nth, exposure). Accordingly, we believe we adopted the most reasonable, available solution. However, a limitation is that our study analyzes fewer data points than the typical fMRI studies, which obviously reduces statistical power, and does not allow to test a number of potential confounds (such as the presence of repetition suppression effects in BOLD responses to the second presentation of each card).

Our assumption that our MNS-ROI implicates mirror neuron activity might be questioned since there is some uncertainty as to where mirror neurons are located (Molenberghs et al, 2009, 2012). However, it should be pointed out that the method we used to select the ROI is objective and potentially innovative. Rather than arbitrarily selecting maps believed to associate with mirror neurons, we used large-scale automated synthesis of fMRI data and a solid, Bayesian approach to generate ROIs (Yarkoni, Poldrack, Nichols, Van Essen, & Wager, 2011). Indeed, while the Neurosynth selection method may lead to some errors compared to classic forward inference, our use of the reverse inference guarantees greater specificity. Currently, the only way to statistically perform a Bayesian reverse inference on voxel based meta analytic data is Neurosynth (Poldrack, 2011). Thus, even though selecting an accurate ROI for an fMRI study is not an easy task, we believe we have adopted the best available solution at this time. Our additional analyses suggesting that our ROI was activated most specifically by M responses only, and not by other, non-MNS related Rorschach responses, also supports our methodological choice. On the other hand, of course, our study does not provide definitive evidence of an exclusive relationship between M and our ROI.

Conclusion

Rorschach and Mirror Neurons

With a completely different and third method, the current study adds to previous findings obtained with EEG and rTMS that the human movement Rorschach response is associated with MNS activity. For the first time to our knowledge, by using fMRI method our findings showed that feeling of human movement spontaneously generated by static and unstructured perceptual stimuli as the Rorschach cards triggers activity in MNS-like areas. Since the same mirroring activity was not shown when different classes of responses were used, our results provide further support to the embodied simulation hypothesis underlying human movement responses to the Rorschach test, consistent with the interpretation of this response in the assessment literature. Because the MNS is deemed by some authors to be implicated in empathy and social cognition, our findings might also suggest that M reflects some empathetic or interpersonal abilities in the respondent. With respect to this point, however, it should be noted that the propensity to mentalize and envision human activity and experience it by attributing it to a static external design (M) leaves open the possibility that one could also positively care about the experiences of another or manipulatively use that understanding for one's selfish gain. Said differently, while it is likely that M would associate with cognitive empathy (i.e., with an accurate understanding of the experiences of another), additional research is needed to understand whether it also associates with affective empathy (i.e., with an emotion-based sharing of those experiences) (Vachon & Lynam, 2016). Furthermore, it should be noted that not all Ms are thought to indicate good cognitive or affective empathy skills. For example, in all Rorschach traditions, M responses with poor or distorted form quality (M-) are deemed to reflect an atypical or distorted understanding of others' behaviors or communications. As such, these 'less optimal' M responses might not be associated, or perhaps they might associate to a lower extent, with mirroring activity in the brain, compared to the 'more optimal' M responses (e.g., Ms with ordinary form quality). Unfortunately, though, because all of our participants were nonpatient volunteers, very few M- responses were available in our dataset (14 participants had no M- responses), and therefore we could not test this hypothesis empirically. As such, additional research would be useful, to further explore this possibility.

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Table 1. Results of univariate ROI analyses for all Rorschach responses and all ROIs under investigation.

	n	MNS			MT+			MNS w/out MT+		
		t	*p*	*d*	*t*	*p*	*d*	*t*	*p*	*d*
Human movement responses (M)	26	4.37	<.01	.45 / .45	4.33	<.01	.34 / .34	3.31	<.01	.38 / .38
Nonmoving human contents (Non-M H)	23	.61	.55	.10 / .11	.26	.79	.04 / .04	.45	.66	.08 / .04
Nonhuman movement responses (FM/m)	25	.83	.42	.10 / .12	2.05	.05	.19 / .23	.87	.39	.11 / .14
Color responses (FC/CF/C)	23	-1.09	.29	-.17 / -.24	-1.07	.30	-.12 / -.19	-1.12	.28	-.21 / -.29
Shading responses (Y/T/V/C')	22	-.74	.47	-.14 / -.16	-.63	.54	-.08 / -.11	-.62	.54	-.12 / -.13
Pure Form responses (F)	26	-2.61	.02	-.29 / -.29	-3.71	<.01	-.30 / -.30	-2.26	.03	-.27 / .27

Note: Cohen's *d* effect size was calculated using formula for independent samples (for details on this choice, see Dunlap et al., 1996). Values on the left of the slash were calculated using available data only, values on the right were calculated using all data (n = 26), by placing participants with no target scores in the control (i.e., absence) condition.

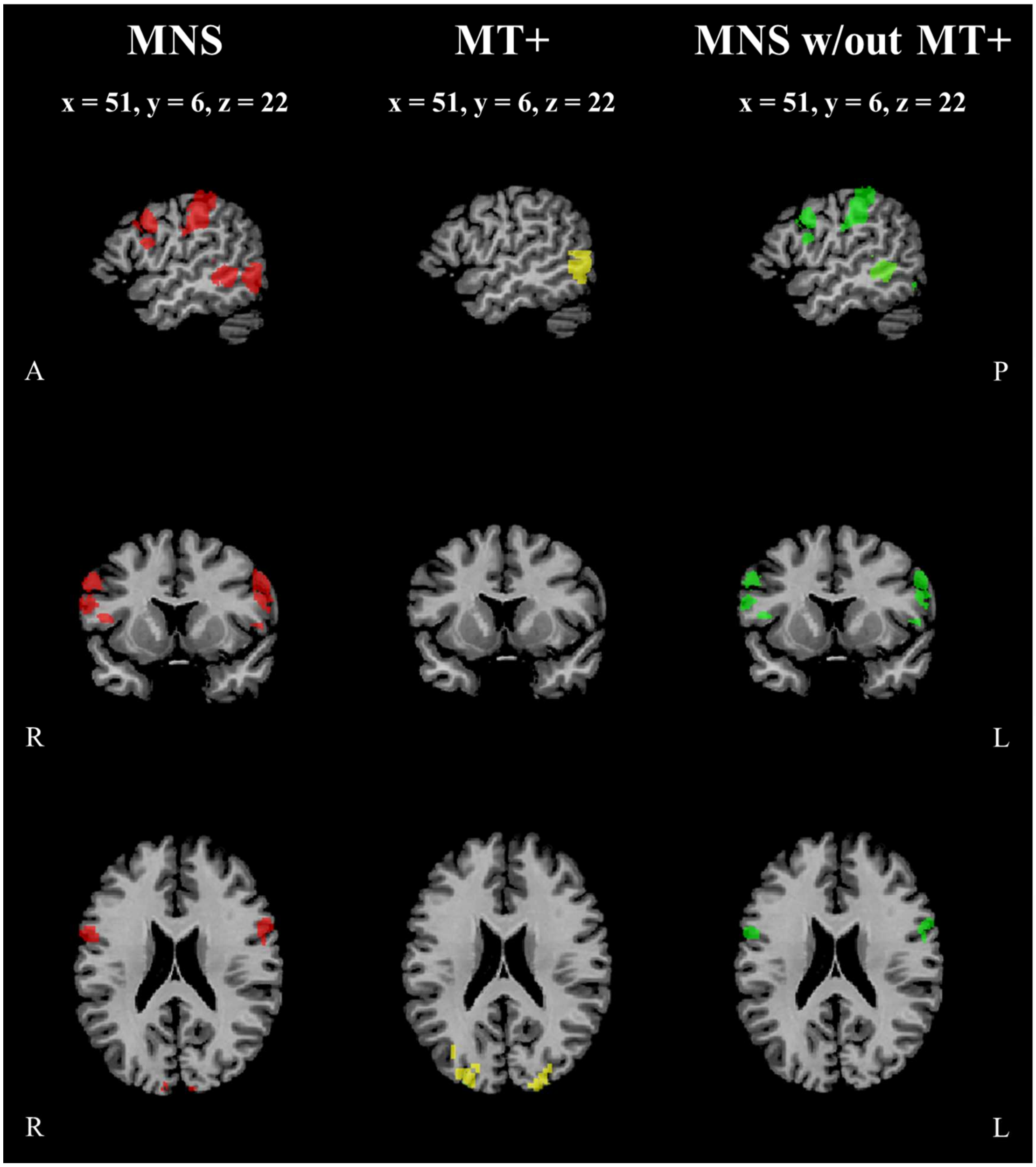
Table 2. Results of univariate ROI analyses comparing M vs. Non-M responses for all clusters of activation within the MNS ROI.

	Center of gravity (Talairach coordinates)			*Label*	*t*	*p*	*d*
Cluster 1	x = 56	y = -25	z = 41	Parietal Lobe, Postcentral Gyrus, BA1 (right)	1.29	0.21	0.16
Cluster 2	x = 57	y = 7	z = 21	Frontal Lobe, Inferior Frontal Gyrus, BA9 (right)	0.24	0.82	0.02
Cluster 3	x = 53	y = 6	z = 35	Frontal Lobe, Middle Frontal Gyrus, BA9 (right)	0.70	0.49	0.07
Cluster 4	x = 47	y = -60	z = 2	Temporal Lobe, Middle Temporal Gyrus, BA37 (right)	6.14	<0.01	0.34
Cluster 5	x = 51	y = -44	z = 1	Temporal Lobe, Middle Temporal Gyrus, BA22 (right)	2.94	0.01	0.25
Cluster 6	x = 28	y = -48	z = 58	Parietal Lobe, Superior Parietal Lobule, BA7 (right)	3.42	<0.01	0.33
Cluster 7	x = 34	y = -34	z = 36	Parietal Lobe, Inferior Parietal Lobule, BA40 (right)	0.98	0.34	0.08
Cluster 8	x = 23	y = -84	z = 32	Occipital Lobe, Cuneus, BA19 (right)	1.65	0.11	0.09
Cluster 9	x = 17	y = -77	z = -5	Occipital Lobe, Lingual Gyrus, BA18 (right)	0.55	0.59	0.02
Cluster 10	x = 5	y = -88	z = 17	Occipital Lobe, Cuneus, BA18 (right)	-0.99	0.33	-0.13
Cluster 11	x = -15	y = -87	z = 34	Occipital Lobe, Cuneus, BA19 (left)	0.34	0.73	0.02
Cluster 12	x = -21	y = -51	z = 64	Parietal Lobe, Postcentral Gyrus, BA7 (left)	1.47	0.15	0.24
Cluster 13	x = -36	y = -39	z = 49	Parietal Lobe, Inferior Parietal Lobule, BA40 (left)	1.60	0.12	0.16
Cluster 14	x = -45	y = -55	z = 17	Temporal Lobe, Superior Temporal Gyrus, BA 22 (left)	3.48	<0.01	0.48
Cluster 15	x = -53	y = -26	z = 35	Parietal Lobe, Postcentral Gyrus, BA2 (left)	1.20	0.24	0.11
Cluster 16	x = -50	y = 15	z = 11	Frontal Lobe, Inferior Frontal Gyrus, BA44 (left)	2.13	0.04	0.38
Cluster 17	x = -52	y = 7	z = 31	Frontal Lobe, Inferior Frontal Gyrus, BA9 (left)	1.88	0.07	0.22

Note: Cohen's *d* effect size was calculated using formula for independent samples (for details on this choice, see Dunlap et al., 1996). Labels were assigned using Talairach Client - Version 2.4.3 (see http://www.talairach.org), and refer to the center of gravity of the cluster only.

Rorschach and Mirror Neurons

Figure 1. Regions of Interest (ROIs) under investigation. "MNS w/out MT+" was obtained by removing from MNS ROI all voxels in the MT+ ROI.



Rorschach and Mirror Neurons

Figure 2. Clusters within the MNS ROI for which the difference between M and Non-M responses consisted of a Cohen's of $d \geq .20$.