

Mu suppression and human movement responses to the Rorschach test

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Electroencephalographic μ wave suppression was investigated using all 10 static, ambiguous Rorschach stimuli. In an earlier study using four Rorschach stimuli, the two stimuli that elicited feelings of movement were associated with μ suppression. In this study, we replicated this relationship using all 10 Rorschach stimuli while overcoming a number of other earlier limitations. The results strongly support the hypothesis that internal representation of the feeling of movement is sufficient to suppress the μ rhythm even when minimal external cues are present. This outcome increases the generalizability and ecological validity of this approach and gives support to the traditional interpretation of the Rorschach human movement responses as being associated with cognitive

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Introduction

The discovery of mirror neurons in area F5 of the macaque monkey – cells that discharge when the monkey performs a motor act or when at rest observes another monkey or human being performing a similar motor act – and the subsequent discovery of a mirror neuron system (MNS) in humans [1,2] has increased interest in the neural basis of social cognition. Current social cognition models suggest that motor and emotional brain regions contribute to our perception of others by simulating or mirroring other people's actions and emotions [3] and may underlie the ability both to understand the other's perspective (cognitive component) and share their feelings (affective component) [4].

Electroencephalography (EEG) has been used to investigate MNS activity in humans, by recording and analyzing the μ rhythm, namely the 8–13 Hz oscillations recorded over the sensorimotor cortex. The μ rhythm reaches maximal amplitude when individuals are at rest and is reduced by actual, imagined, or observed movement, and therefore, its suppression has been hypothesized to reflect frontal mirror neuron activity [5]. Recent data support this link [6] and suggest that μ suppression reflects the presence of a rapid, multimodal resonance mechanism modulating motor cortex activity [7]. Furthermore, results from our laboratory using repetitive transcranial magnetic stimulation have recently shown that when the activity of

the left inferior frontal gyrus (which is thought to include mirror neurons) is temporarily disrupted in normal individuals, the reaction times during an emotion recognition task increase, and μ suppression disappears [8]. Other data, however, suggest that μ suppression may also be associated with the recruitment of resources needed for task performance. For example, both μ and α suppressions were recently found to be modulated by task difficulty, and not distinctively by attention to another person's intention [9].

In an earlier study [10], we attempted to investigate the link between mirroring activity, μ suppression, and ambiguous stimuli by evaluating EEG μ wave suppression during the exposure to a few Rorschach inkblot stimuli. μ suppression and MNS activity have typically been investigated during the execution or the observation of actual or filmed movements. In contrast, our earlier study [10] investigated whether μ suppression occurs in the same way when actions are generated 'internally,' as part of the individual's inner experience or 'feeling of movement' (in Rorschach literature, human movement is traditionally considered either an internal representation of a kinesthetic feeling or a perceptual image issued from a general impression of movement) [11]. Here we use this term broadly to indicate the sense of movement internally induced by the perceptual and cognitive processing of external, ambiguous stimuli, triggered only by minimal indirect cues. When observing the Rorschach cards – ambiguous static images formed from inkblots – the individual is requested to state freely what the picture might be.

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Many responses rely on purely perceptual features (shape, colors, shading). Other responses involve actions or movements that are not present in the actual, static inkblot stimuli, but are ‘internally’ generated, with the individual feeling that a human being is seemingly acting (e.g. ‘it looks like two women dancing together’). As hypothesized, our data showed that μ suppression accompanied these human movement responses (M responses [11]).

Nevertheless, several factors limited the implications of those findings. First, only four inkblot stimuli were used, two Rorschach cards with the highest frequency and two with the lowest frequency of M responses [12]. Accordingly, the two conditions (M vs. non- M) were visually different, a possible confound, and this visual difference may have caused the small significant differences found at occipital sites. Second, the baseline condition (looking at a white card on a computer screen) was recorded during a short, 25-s period without assessing the individual’s level of attention to the task. Conceivably, distraction, free thinking, and boredom might have affected attentional levels later in the exposure period. Finally, with only four Rorschach stimuli and small sample size, limited amount of data were analyzed.

The primary goal of this study was to examine the relationship between M responses to Rorschach inkblots and the suppression of EEG μ rhythms. Thus, the intent was to provide a more definitive test of the hypothesis than our earlier study in a more ecologically valid way, with more data, while addressing limitations. Accordingly, we used all the 10 cards of the standard Rorschach test, a more appropriate control for baseline attention, and longer data collection periods.

Methods

Participants

Participants were 24 undergraduate students (17 female) recruited from the Psychology Department’s subject pool at the University of California, San Diego (UCSD). Age ranged from 18 to 25 years, with a mean of 20.4 years [standard deviation (SD) = 1.9]. All participants received class credit and gave written consent. The study was approved by the Institutional Review Board at UCSD.

Procedure

Stimuli were shown on a screen situated at a distance of 96 cm, at a size of 17 × 24 cm, similar to the original Rorschach cards. During exposure, participants were instructed not to talk or move (visual inspection confirmed that participants did not move). The baseline stimulus was 90 s of visual white noise. To ensure that participants attended to the screen, they were asked to engage in a continuous performance task. Randomly, the screen turned red five times and blue four times, each color change lasting for 1 s, during the 90 s baseline

period. Participants were asked to count the number of times the screen turned red. Their counts at the end of the baseline session were 100% accurate. In the experimental condition, participants viewed all 10 Rorschach cards, one at a time, with the instruction to think of what they might be, consistent with the standard instructions of the Rorschach Comprehensive System (RCS) [11]. Each Rorschach card was presented on the computer screen for 30 s. Participants were instructed to focus on their response for the entire period. After 30 s, the image disappeared from the screen and participants were asked to verbalize their response to the stimulus. This entire sequence was repeated once with only one change. Participants were instructed to think, for each card, of a different response from what they had articulated earlier. This second sequence allowed us to aggregate more data: 20 responses and 600 s of EEG data (30 s per response).

Electroencephalography data acquisition and analysis

Data were collected from 13 electrodes embedded in a cap, at scalp positions: F3, Fz, F4, C3, Cz, C4, P3, Pz, P4, T5, T6, O1, and O2, using the international 10–20 method of electrode placement. EEG was recorded and analyzed using a Neuroscan Synamps system (Neuroscan Inc., North Carolina, USA) (band pass 0.1–30 Hz). Data were collected for 690 s (90 s for the baseline and 600 s for the experimental condition) at a sampling rate of 500 Hz. After removing artifacts for each cleaned segment, the integrated power in the 8–13 Hz range was computed using a Fast Fourier Transform. Data were segmented into epochs of 1 s beginning at the start of the segment and Fast Fourier Transforms were performed on the epoched data (256 points). Mu suppression over sensorimotor cortex was calculated as the ratio of the power during the experimental condition divided by the power during the baseline condition [13,14]. A log ratio transform controlled for variability in absolute μ power and the inherent non-normal distribution of ratio data. A μ suppression index at each scalp location was computed for each inkblot, corresponding to the log ratio of μ power during the observation of the inkblot over μ power during the baseline. A log ratio of less than zero indicates suppression. A two-way repeated-measures analysis of variance compared the mean μ suppression using response (M and non- M) and scalp location (C3, Cz, and C4) as within-subject factors.

Results

Participant responses were transcribed verbatim and coded according to RCS standards. Two experts (authors P.P. and L.P.) independently coded each transcription and reached 100% agreement about the presence versus absence of M responses. The mean of M responses was 4.3 (SD = 2.2; range = 1–9). A highly significant main effect of response was obtained [$F(1,23) = 18.755$, $P < 0.001$, $\eta^2 = 0.17$], with M responses eliciting a mean

μ suppression ($M = -0.24$) greater than the non- M responses ($M = -0.17$) (Fig. 1). Scalp location and interaction (scalp location \times response) were not significant.

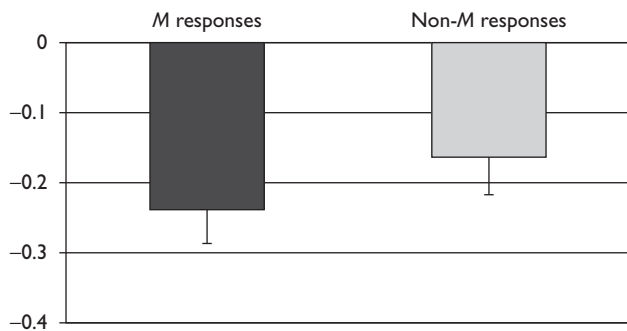
To rule out general global desynchronization effects on other α -like rhythms (e.g. occipital α), the central site analysis strategy was applied to the posterior sites (scalp electrodes O1 and O2). Neither response [$F(1,23) = 0.557$, $P = 0.46$, $\eta^2 = 0.01$], scalp location [$F(1,23) = 1.074$, $P = 0.311$, $\eta^2 = 0.02$], nor the interaction were significant [$F(1,23) = 0.476$, $P = 0.50$, $\eta^2 < 0.005$]. Thus, 8–13 Hz frequency band suppression was specific to central and not occipital sites for M compared with non- M responses.

Additional analysis

To determine whether the observed movement-related suppression was evoked by the initial subjective response processes underlying M and non- M responses, event-related desynchronization (ERD) analyses were undertaken. For each trial, the first 500 ms were used as reference point, and the ongoing μ power computed relative to that baseline. M and non- M responses were then averaged for each participant. Given that no significant effect of scalp location was found, C3, Cz, and C4 were averaged. Finally, averages among all participants were computed. The resulting ERDs were then smoothed using the moving median technique (which is more robust to outliers than the moving mean) on a 500 ms time span basis. As shown in Fig. 2, the differences in μ power are substantially early on and remain so for the entire exposure time.

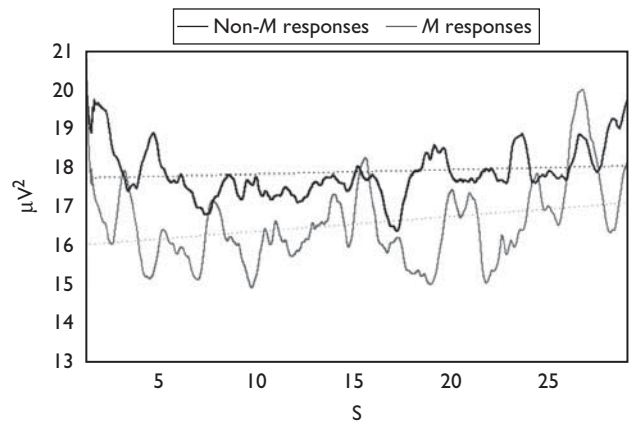
If μ suppression was evoked by the subsequent focusing on ‘selected’ responses and not by processes underlying M responses, one should expect the difference between μ power during non- M and M responses to increase with the time. In fact, the Spearman correlation between time (measured by 2 ms points) and μ power differences (non-

Fig. 1



Mean μ suppression at central sites during the identification of human M responses (black bars) and other non- M responses (gray bars) to the Rorschach cards. Mu suppression is calculated as the mean log ratio of power in the μ frequency (8–13 Hz) during experimental conditions over the power in the baseline condition. Error bars represent the standard error of the mean.

Fig. 2



Event-related desynchronization in the μ power for movement (M) and nonmovement (non- M) responses. The black line shows ERD of μ power at central sites (C3, Cz, and C4) during non- M responses; the gray line represents ERD of μ power at central sites (C3, Cz, and C4) during M responses. Linear interpolation lines are presented as well.

M μ power minus M μ power) is significant in the opposite direction, $\rho = -0.19$, P value of less than 0.001. This result suggests that μ suppression tends to be even stronger at the beginning of the exposure time than at the end.

Discussion

This study extends our earlier findings [10] in which a small subset of Rorschach inkblot cards that typically elicit movement responses (M responses) was associated with μ suppression. Using the standard 10 inkblot set, we found that μ suppression at central sites was greater during the observation of static, ambiguous stimuli that evoked human beings in action (M responses) compared with identification of static or nonhuman objects (non- M responses). This 8–13 Hz frequency band suppression was specific to central sites, supporting to the hypothesis that internal representation of the ‘feeling of movement’ elicited by these inkblot stimuli may be sufficient to trigger MNS-related activity even when no external explicit cues are present. The conclusions were made more robust by controlling for limitations that characterized the earlier study (e.g. no control for the participants’ attention during the short baseline period and the use of a small pool of selected Rorschach stimuli). This study used a larger sample (24 vs. 15 participants) and a much longer baseline period for EEG recording (90 vs. 25 s) than the earlier study [10]. In addition, a continuous performance task minimized baseline attentional variation. More importantly, using 10 rather than four Rorschach cards provided a much longer EEG recording for data acquisition (600 vs. 200 s). Furthermore, the Rorschach administration more closely resembled the real-world application of the test, increasing the ecological validity of our findings. The total number of Rorschach responses ($R = 20$) and M responses (mean = 4.3, SD = 2.2,

range = 1–9) in our study are similar to values in the RCS normative database (mean $R = 23.4$, $SD = 5.7$; mean $M = 4.8$, $SD = 2.2$, range = 0–12) [12]. Furthermore, more data allowed greater discrimination and presumably helped to eliminate occipital effects. It is possible that the observed effects at occipital sites in our first study were due to the visual differences between the inkblots used for the two conditions (M and non- M). With better controls, the effect size in this study was almost three times ($\eta^2 = 0.17$) that of the first study ($\eta^2 = 0.06$) falling in the large range of suggested benchmarks (small = 0.01; medium = 0.06; large = 0.14) [15]. To determine whether μ suppression occurred at the early exposure to the stimuli, during the response process versus later thinking about the previously ‘selected’ response, ERD analyses were undertaken. Results indicated that μ suppression at the beginning occurred at an even greater intensity than at the end.

It has been argued that actions, emotions, and sensations seen in others activate our own internal representations of the body states associated with these social stimuli, as if we were experiencing a similar set of actions, emotions, and sensations, a mechanism referred to as ‘embodied simulation’ [16]. The human MNS is thought to be an underlying neurological correlate of these experiences. Accordingly, given the absence of explicit perceptual cues depicted in the Rorschach stimuli, our study supports the idea that the internal sense of identification with a living, moving human being might play a central role in embodied simulation, even when identification relies exclusively on internally generated representations. In the extant literature, human movement responses to the Rorschach have been repeatedly associated with psychological factors that are consistent with the MNS-based mechanisms of social cognition and empathy [12,17]. Our findings give some support to this association.

Nonetheless, even if μ suppression is hypothesized to be a valid index of mirror neurons activity [18], the low spatial resolution of the EEG does not allow differentiation between the premotor MNS and other regions that are part of a larger action observation/execution network [5]. A study involving a higher spatial-resolution technique such as functional magnetic resonance imaging is currently being investigated to address this limitation.

Conclusion

This study found that EEG μ rhythms can be activated by static, ambiguous stimuli such as the Rorschach inkblot

cards. This finding is consistent with the embodied simulation hypothesis [16] and our earlier results [10] and supports the hypothesis that strong internal representation of the ‘feeling of movement’ may be sufficient to trigger MNS-related activity even when minimal external cues are present. Furthermore, this study suggests that M response in the Rorschach test may involve mirroring activity in the brain, thus supporting its traditional interpretation as an index of empathy and social cognition.

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References

- Rizzolatti G, Craighero L. The mirror neuron system. *Ann Rev Neurosci* 2004; **27**:169–192.
- Rizzolatti G, Fabbri-Destro M, Cattaneo L. Mirror neurons and their clinical relevance. *Nat Clin Pract Neurol* 2009; **5**:24–34.
- Keysers C, Kaas JH, Gazzola V. Somatosensation in social perception. *Nat Rev Neurosci* 2010; **11**:417–428.
- Decety J, Ickes W, editors. *The social neuroscience of empathy*. Cambridge, MA: MIT Press; 2009.
- Muthukumaraswamy SD, Johnson BW, McNair NA. Mu rhythm modulation during observation of an object-directed grasp. *Cogn Brain Res* 2004; **19**:195–201.
- Woodruff CC, Maaske S. Action execution engages human mirror neuron system more than action observation. *Neuroreport* 2010; **21**:432–435.
- Lepage JF, Tremblay S, Nguyen DK, Champoux F, Lassonde M, Théoret H. Action related sounds induce early and late modulations of motor cortex activity. *Neuroreport* 2010; **21**:250–253.
- Keuken MC, Hardie A, Dorn BT, Dev S, Paulus MP, Jonas KJ, et al. The role of the left inferior frontal gyrus in social perception: an rTMS Study. *Brain Research* (in press).
- Perry A, Bentin S. Does focusing on hand-grasping intentions modulate electroencephalogram μ and α suppressions? *Neuroreport* 2010; **21**:1050–1054.
- Giromini L, Porcelli P, Viglione DJ, Parolin L, Pineda JA. The feeling of movement: EEG evidence for mirroring activity during the observations of static, ambiguous stimuli in the Rorschach cards. *Biol Psychol* 2010; **85**:233–241.
- Exner JE. *The Rorschach: a comprehensive system. Vol. 1. Basic foundations and principles of interpretation*. 4th ed. New York: Wiley; 2003.
- Exner JE, Erdberg P. *The Rorschach: a comprehensive system. Vol. 2. Advanced interpretation*. 3rd ed. New York: Wiley; 2005.
- Ulloa ER, Pineda JA. Recognition of point-light biological motion: mu rhythms and mirror neuron activity. *Behav Brain Res* 2007; **183**:188–194.
- Pineda JA, Hecht E. Mirroring and mu rhythm involvement in social cognition: are there dissociable subcomponents of theory of mind? *Biol Psychol* 2009; **80**:306–314.
- Kittler JE, Menard W, Phillips KA. Weight concerns in individuals with body dysmorphic disorder. *Eating Behav* 2007; **8**:115–120.
- Gallese V. The roots of empathy: the shared manifold hypothesis and the neural basis of intersubjectivity. *Psychopathology* 2003; **36**:171–180.
- Weiner IB. *Principles of Rorschach interpretation*. 2nd ed. Mahmah, NJ: Lawrence Erlbaum; 2003.
- Pineda JA. The functional significance of mu rhythms: translating ‘seeing’ and ‘hearing’ into ‘doing’. *Brain Res Rev* 2005; **50**:57–68.