



Short Communication

Does comprehension of symbolic gestures and corresponding-in-meaning words make use of motor simulation?



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HIGHLIGHTS

- We searched for the processes used to understand the meaning of emblems and words.
- TMS was applied to motor cortex during observation/listening of gestures and words.
- As controls meaningless gestures, pseudo-words and a still actor were presented.
- Motor cortex was activated by presentation of meaningless signals only.
- Understanding emblems and corresponding words probably use semantic circuits.

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ABSTRACT

The present study aimed at determining whether or not the comprehension of symbolic gestures, and corresponding-in-meaning words, makes use of cortical circuits involved in movement execution control. Participants were presented with videos of an actress producing meaningful or meaningless gestures, pronouncing corresponding-in-meaning words or pseudo-words; they were required to judge whether the signal was meaningful or meaningless. Single pulse TMS was applied to forearm primary motor cortex area 150–200 ms after the point when the stimulus meaning could be understood. MEPs were significantly greater when processing meaningless signals as compared to a baseline condition presenting a still-and-silent actress. In contrast, this was not the case for meaningful signals whose motor activation did not differ from that for the baseline stimulus. MEPs were significantly greater for meaningless than meaningful signals and no significant difference was found between gesture and speech. On the basis of these results, we hypothesized that the observation-of/listening-to meaningless signals recruits motor areas. In contrast, this did not occur when the signals were meaningful. Overall, the data suggest that the processes related to comprehension of symbolic gestures and communicative words do not involve primary motor area and probably use brain areas involved in semantics.

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Single-pulse TMS studies have demonstrated that the observation of hand/arm object-directed (i.e. transitive) actions induces an increase in MEPs (motor evoked potentials) recorded from hand muscles involved in the observed action [1,2]. Accordingly, brain imaging studies have shown that during the observation of transitive hand/arm actions, there is signal activation in the ventral premotor cortex and in the adjacent posterior pars opercularis of the inferior frontal gyrus (IFG) [3]. Ventral premotor cortex and posterior pars opercularis of IFG are also activated by execution

of object-directed hand/arm actions [4]. Thus, this circuit may be involved in understanding the meaning (aim) of the action by matching observation with action execution by means of motor simulation (mirror circuit) [3].

The present experiment firstly aimed to determine whether simulation is used even for understanding intransitive gestures. Intransitive gestures are communicative signals and can be emblematic, that is symbols or signs expressed by intentional bodily movements or request gestures which convey request to initiate, maintain, or terminate various types of interaction. Villarreal and colleagues [5] assessed cortical activity during recognition of communicative gestures containing symbolic connotations (e.g., victory, salute), transitive gestures (i.e., pantomimes of actions involving tool use) and meaningless control movements. A stronger

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activation for symbolic compared to transitive gestures was found in the pars opercularis and pars orbitalis of the left IFG (Inferior Frontal Gyrus) and in Dorsolateral Prefrontal Cortex (DPC), bilaterally. The authors argued that the greater engagement of left IFG as compared to other areas such as premotor areas reflected the symbolic/linguistic nature of intransitive gestures.

Up to now, TMS studies have not investigated the role of motor cortex in understanding intransitive gestures, i.e. whether M1 is necessary to retrieve the gesture meaning or, conversely, whether gesture observation without motor simulation is sufficient to access semantics.

The embodied theory of language assumes that language comprehension makes use of the neural system ordinarily recruited for action control [6]. Focusing on spoken language material related to concrete actions, recent neurophysiological studies have shown that premotor regions are involved in language processing [7]. Also, in keeping with the involvement of the motor system in processing action-related material, the results reported by Buccino et al. [8] in a single pulse TMS study, have shown that motor evoked potentials (MEPs) recorded from hand muscles are modulated during listening to hand-related action sentences. Regarding abstract words, the issue is much more debated [9]. Scorolli et al. [10] found M1 activation when TMS applied in an abstract verb condition was delayed (650 ms post-stimulus). In contrast, Innocenti et al. [11] found M1 activation 300 ms post stimulus in response to hand-action verbs and no activation 300 and 500 ms post-stimulus in response to abstract verbs. Consequently, it is possible to suppose that cognitive and neural organization of concrete and abstract concepts may be partially distinct.

There are two opposing views about the relationship between gesture and speech. The first posits that gesture and speech are two different communication systems [12]. The other view [13,14] posits that gesture and speech form a single system of communication, since they are linked to the same mental processes even if they differ in expression modalities. In line with the views of McNeill [13] and Kendon [14], we have hypothesized that manual gestures and speech share in-part the same control circuit [15,16]. This idea has been confirmed by behavioral [17] and r(repetitive) TMS data [18] in which the relations between emblems and the corresponding-in-meaning words were analyzed. Behavioral data [17] showed that when individuals performed symbolic gestures and simultaneously pronounced a corresponding-in-meaning word, the gesture kinematics and voice spectra of the word changed as compared to the sole gesture performance or word pronunciation. This effect was not observed after rTMS of Broca's area [18].

On the basis of the literature reported above, we reasoned that, if simulation processes are at the basis of understanding the meaning of visually presented transitive actions and acoustically presented action words, a motor representation of hand/arm movement may be activated in order to understand both the meaning of meaningful intransitive gestures and their corresponding-in-meaning words. Alternatively, if comprehension of these signals mainly relies on symbolic/linguistic processes, no motor simulation should be observed. Finally, if gestures and corresponding-in-meaning words are reciprocally related [15,16], the type of activation seen should not differ from each.

We addressed these issues in the present study. We applied single pulse TMS to forearm motor cortex when participants were presented with meaningful intransitive gestures, meaningless gestures, corresponding-in-meaning words, or pseudo-words. We expected either no activation or the same activation of arm M1 when presenting meaningful intransitive gestures and words. The same was expected even for meaningless gestures and pseudo-words. By comparison of these conditions with a baseline condition (still/silent actor) we verified the possible existence of a different M1 activation between meaningful and meaningless signals.

Moreover, we conducted a control experiment to compare the times of recognition of meaningful stimuli with those of meaningless stimuli.

Ten right-handed [19] Italian native, naïve volunteers (7 females and 3 males, age 21–28 years.), participated in the TMS experiment. All participants signed consent forms and were screened to rule out any history of neurological, psychiatric, or medical problems, and to check for possible contraindications to TMS [20]. The Ethics Committee of the Medical Faculty at the University of Parma approved the study, which was carried out according to the declaration of Helsinki.

Excitability of the forearm area of left M1 was evoked using single pulse TMS of the extensor carpi radialis (ECR) muscle area, and measured by evaluating the area of the resultant MEPs. Participants sat relaxed in a comfortable chair, while EMG activity of their right ECR muscle was recorded. Surface electrodes (Ag–AgCl, disposable, 7 mm × 4 mm) were attached, one on the belly of the ECR muscle (active electrode), and one on the elbow (reference electrode).

Muscle activity was amplified (1000×) and filtered (highpass 0.1 Hz, AC couple, 50 Hz notch, CED 1902, CED Ltd.). The signal was digitized at a sampling rate of 5 kHz (CED1401 interface, CED Ltd.). Visualization and later processing was done using Spike2 software (CED Ltd.). TMS was delivered using one module of a Bistim system (Magstim Co. Ltd.) and using a 70 mm figure-of-eight standard coil (Magstim Co. Ltd.). The coil was held tangential to the head. Once the site for stimulation of the ECR muscle was found, the participants' threshold was measured as the level of stimulation required to evoke at least 50 μ V MEP on 5 out of 10 stimulations. Stimulation during the task was set to be 120% of the threshold level.

The experiment took place in a soundproofed room where participants were seated on a comfortable armchair, with their elbow flexed at 90° and their hands prone in a relaxed position. Participants wore earphones (to listen to auditory stimuli, see below). By means of a PC monitor (19 inch) placed at a distance of 110 cm from the observer, five types of audio-visual video-clips (sampling rate: 25 frames per second, duration: 2 s) were presented to the participants (Fig. 1). In the videos, an actress executed a meaningful gesture (“ciao”, “no”, “okay” or “stop”: meaningful gesture condition), pronounced the corresponding-in-meaning words (/ciao/, /no/, /okay/or/stop/: word condition), executed meaningless gestures consisting of moving her arm up and down, from right and left, from right to left transversally, and from left to right (meaningless gesture condition), or pronounced pseudo-words (/ciar/, /nu/, /okoa/or/stor/: pseudo-word condition). Finally, in a baseline condition the actress was still and silent.

Video-clips were aligned in order that the TMS single pulse was delivered 200 ms after the critical point after which a meaning (if present) was accessible for videos showing movements (e.g. the hand waving beginning for gesture “ciao”), and 150 ms [21] after the isolation point (i.e. the point after which it was possible to discriminate if the string of letters, was meaningful or meaningless) for videos presenting spoken words and pseudo-words. This difference in time of stimulation was due to briefer acoustical perception of strings of letters [22]. Once the critical point time was determined for each signal, all videos were temporally shifted order to align stimulation and all times to critical point.

The participants were required to carefully observe or to observe-and-listen-to the video-clips. Three blocks of 20 trials were presented. Every communicative or meaningless stimulus was quasi-randomly presented once per block, whereas baseline videos were quasi-randomly presented four times. In four random trials per block (twelve in total) a question on the meaning of the last presented video-clip appeared at the end of the trial and participants were required to verbally respond ‘yes’ or ‘no’, to indicate whether the presented stimulus was a meaningful or meaningless

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