Modulation of the mirror mechanism during observation of the consequences of possible and impossible human gestures.

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The discovery of the mirror mechanism for grasping actions highlights the relationship between the motor system and visual perception, where the observation of an action evokes in the 'observer a congruent motor cortical activation' (1; 2; for a review, see 3). The interpretation that has been given to this mechanism is that it plays a crucial role in understanding others: I understand the meaning of your behavior because my brain is activated as if I were also doing the same thing. Speaking of motor behavior, it is necessary to clarify its different levels of description. A movement is a motor behavior without a goal, for example, rotating the wrist or lifting a finger of the hand. In contrast, an action is composed of several coordinated movements and is characterized by having a goal whose consequence is tangible and unambiguous, like the action of grasping, in which the goal is to take possession of an object and the consequence is the hand holding it. Actions may be directed toward objects or toward one's own body. A gesture is an action whose goal is communicative and whose consequences are subject to the possibility of interpretation and as such are not univocal. Speaking, writing, expressing emotions with the body or the face, creating works of art or digital artifacts can all be considered gestures. He/she who performs the gesture has the goal of communicating a content that represents the consequence of his/her gesture, be it an emotion, a written or spoken word, or an artifact.

Streltsova and collaborators (4) have experimentally corroborated this categorization of different types of motor behaviors showing that the observation of movies displaying hands performing meaningless movements (https://www.youtube.com/watch?v=QeYQ23GaRw4), grasping actions (https://www.youtube.com/watch?v=zt7PbX3t39E) and communicative hand gestures (https://www.youtube.com/watch?v=UXZfYDrgdHw) evoke a different temporal distribution of sensorimotor cortical activation. The authors' interpretation of these results is that there are two different functional aspects related to the activation of the mirror mechanism during motor behavior observation in humans. The first one represents an automatic low-level motor resonance, starting as soon as the movement is observed: this resonance can be induced when a motor goal is not present as well. Action and gesture understanding is the second functional aspect related to the mirror mechanism. This implies that there is an activation of goal-related motor neurons in the brain of the observer (5; 6) that match the goal of the observed motor behavior of others.

In this paper I will illustrate two aspects underlying the mirror mechanism for gestures that are interrelated and represent the context within which my research project is developed. The first issue illustrates the role that the observer's motor repertoire plays in the modulation of the mirror mechanism; the second investigates how the observation of gestures modulates the mirror mechanism.

About the motor repertoire there is a crucial question to ask: is there a relationship between the the actual ability to perform the observed action and the motor resonance that the same action evokes in the observer? In other words: do we resonate more when we know how to do what we observe? The first study that investigated whether and to what extent the motor repertoire of the observer modulates the activation of the mirror mechanism used two categories of video stimuli showing a human, a monkey and a dog performing the action of biting food as well as communicative mouth gestures: human silent speech (https://www.youtube.com/watch?v=d-J-_QMsM4M), dog barking (https://www.youtube.com/watch?v=nJ3nGecvOt4), and monkey lip-smacking (https://www.youtube.com/watch?v=pqC2zjjnsBU) (7). The hypothesis was that observing the action of biting was not expected to evoke different cortical activations as the motor repertoire was shared between observers and displayed animal species. In contrast, the observation of communicative gestures was expected to be mapped differently in the brains of the beholders, in relation to the species observed. The results confirmed this hypothesis, showing that the observation of communicative gestures led to the activation of different cortical sites, depending on the observed species. These results indicate that communicative gestures made by others can be recognized through different mechanisms: actions belonging to the motor repertoire of the observer (e.g. speech reading) or very closely related to it (e.g. monkey's lip-smacking) are mapped on the observer's motor system. Actions that do not belong to the observer's repertoire (e.g., barking) are mapped and categorized based on their visual properties without the involvement of the motor system. Therefore, we can state that the observation of gestures pertaining to the viewer's motor repertoire is mapped onto the viewer's own motor representations of the gesture.

Subsequent EEG and fMRI studies have showed that humans simulate observed gestures in terms of their own motor representations of them, and not only in terms of shared visual experience. Calvo Merino and collaborators demonstrated that comparing the brain activity of expert dancers watching their own dance style versus another style resulted in differing activation of the observers' mirror mechanism. Specifically, it showed that expert dancers had greater sensorimotor cortex activation when viewing the dance style that they had been trained to perform compared to movements they had not (8). Another study highlighted the plasticity of the system, where learning a new dance style resulted in increased premotor activation when participants observed the new dance style but not when they observed a sequence of control movements (9).

I previously stated that gesture differs from action because although both motor behaviors have a goal, the goal that characterizes gesture is communication with other individuals, and the consequence of that gesture may be either material or abstract but still susceptible to subjective interpretation by the individuals who perceive it. An example of a gesture is writing, as it has a communicative goal and its consequences are tangible in the case of a letter or abstract in the case of a sentence. In this regard, a key EEG experiment was conducted by Heimann and collaborators (10) with the purpose of comparing the consequences of the gesture of writing (i.e. traces of handwriting), the consequences of which are letters and symbols, thus pertaining to a communicative goal, with the consequences of the action of scribbling, which has no communicative meaning. Right-handed participants were shown three categories of stimuli, all matched in size and stroke-number: Roman Letters, Chinese Characters, and Scribbles. The results showed that the cortical motor system was activated during perception of all three categories of stimuli in both hemispheres, with stronger effects in the left dominant hemisphere, as they were all recognized as visible traces of handwriting. But the most important result, in my opinion, was that, especially in the left hemisphere, there was greater cortical motor activation evoked by the observation of the Roman Letters and Chinese Characters with respect to that evoked by Scribbles. This indicates that the former two were "recognized" by readers' cortical motor system as consequences of communicative gestures, as "symbols", while the latter were mapped as mere consequences of hand actions and thus only as tracings without any intrinsic communicative content.

Are the consequences of a creative gesture performed by another individual mapped to the motor system of the perceiver? Following this question, we investigated, in two EEG experiments, sensorimotor cortical responses during observation of visual abstract artworks like the cuts on canvas by Lucio Fontana (11) and the brush strokes of Franz Kline (12). The results showed that when we observe the consequence of a creative gesture, a work of art, the motor system is activated, as if we were making it. The consequence of the artistic gesture, devoid of any univocal meaning, evokes in our brain the representation of the gesture that made it. It is particularly evident how in this case the meaning conveyed by the consequences of the artistic gesture, carried by the works of art, is prone to the subjective interpretation of observers.

Within the framework illustrated so far it is also possible to consider the visual forms of camera movement as being the consequences of the operator's gesture, where the communicative goal is intrinsic in the act of filming and the consequence is represented by the footage.

Specifically, two EEG studies have demonstrated for the first time how sensorimotor engagement in spectators is activated in response to camera movement. Heimann and colleagues (13) investigated the effect of the consequences of camera movement on motor cortex activation in viewers: the purpose of this experiment was to verify whether the observation of the same scene filmed with four different techniques: Still camera (https://www.youtube.com/watch?v=Ch4dZ_u_piI), Zoom (https://www.youtube.com/watch?v=o4Zkt3YElfU), Dolly (https://www.youtube.com/watch?v=NVRbCV-cHKw) and Steadicam (https://www.youtube.com/watch?v=-1jMqTvgx6o) would evoke a different response from the mirror mechanism of the observers. Three of the four categories of footage involved an approach to the filmed scene (zoom, dolly and Steadicam), but the only one required an actual gesture by the operator - the Steadicam. Shortening the distance between the participant and the scene by moving the camera closer to the actor/actress resulted in a stronger activation of the sensorimotor cortex, as mediated by the mirror mechanism. As was to be expected, the ERD (event-related desynchronization), expressing the intensity of the activation of observers' sensorimotor cortex, was significantly more intense when the scene was filmed moving the camera than when the still camera was used. Interestingly, among the three camera movement techniques, the Steadicam was most efficacious in evoking the activation of the sensorimotor cortex of the observers. The scenes filmed with the zoom evoked the least activation intensity. The results also showed that participants found that the Steadicam most closely reproduced the effect of someone really walking towards the scene. They also perceived the Steadicam movements as being the most natural and therefore having the highest potential of evoking the sensation of walking towards the scene. The congruence between the perception of the consequences of the Steadicam operator's gesture and the perception of real movement results in the maximum intensity of mirror mechanism activation. The strongest motor resonance measured in the Steadicam condition was driven by motor engagement with the 'trace' of the Steadicam's own movement across the scenic space. However, this experiment had the limitation of not being able to attribute the results to camera movements alone as the films showed an actor/actress performing a grasping action, and thus it was not possible to distinguish the effect of observing the action from that of camera movement. To this purpose, Heimann et al. (14) replicated the study by filming an empty room under three experimental conditions: Still camera (https://www.youtube.com/watch?v=4YcH5JuAgpc), zoom (https://www.youtube.com/watch?v=4p072Ay4Km0) and Stedicam (https://www.youtube.com/watch?v=QfMKqvlROtQ).

The Steadicam condition showed a significantly stronger ERD in observers' sensorimotor cortex than the Still and the Zoom conditions. No significant difference was found between Still and Zoom conditions. Taken together, this is evidence that the real camera movement (Steadicam) is most effective in activating the sensorimotor cortex. As no goal-related action was visible in the scene, the results are thus likely due to the activation of the mirror mechanism by the observation of the consequence of the filming gesture of the operator. Participants during interviews specifically referred to these videos as involving a "real" movement, as the involvement of a walking human holding the camera. Some of them also reported that this gave them the feeling of seeing through the eyes of someone in the scene or themselves walking towards the table in the scene.

All data illustrated so far indicate that to evoke the activation of the mirror mechanism during observation of the consequences of a gesture requires a shared motor repertoire between the observer and the observed individual. Now the question that arises is, how does the mirror mechanism respond if the consequences of an impossible gesture are shown? What happens in our brain when we observe the consequences of a gesture which we cannot perform, being outside of our natural motor skills?

To the purpose of answering this question we investigated the embodied nature of drone flight: to date no studies have investigated the effect of drone footage observation, with and without human presence, on spectators' cognitive behavioral mechanisms. In my talk, I will illustrate the results of a behavioral experiment in which we investigated whether the presence of a human subject, the movement of a camera-mounted drone, and the image speed modulate embodied elements of viewing experience. Specifically, perceived time, aesthetic appraisal, quantity of motion, and emotional and physical involvement were investigated.

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