The motion component is preserved in metaphorical sentences. A TMS study.

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Abstract

We used Transcranial magnetic stimulation (TMS) to assess whether reading literal and non-literal (i.e., fictive, metaphorical, idiomatic) motion sentences modulates the activity of the motor system. In Experiment 1, TMS was delivered immediately after the verb when participants were not yet aware of the literal or figurative nature of the conveyed motion. These sentence fragments elicited a significant change in the MEPs area only when the agent was animate. In Experiment 2, TMS was delivered at the end of the sentence. The MEP response was larger when participants were presented with metaphorical than with idiomatic or fictive motion sentences. These results suggest that the excitability of the motor system is modulated by: a) the animate vs. inanimate nature of the sentential subject, and b) the motor component of the verb that is preserved in metaphorical motion sentences. We showed that the activation of motor representations is influenced by the linguistic context and only appears when the use of the verb preserves the basic semantic components of the verb meaning.

1 Introduction

In recent years, the hypothesis that the neural circuitries associated with action are recruited when processing action-related words and sentences has opposed traditional *amodal/disembodied* models of conceptual knowledge to *embodied* models. The first models posit that conceptual knowledge is fundamentally amodal and abstract and represented separately from modality-specific systems recruited for perception and actions. In contrast, *embodied* models of cognition posit that sensory-motor processes are a fundamental part of the mental representation of abstract and concrete concepts. The neural architecture of language-induced *motor resonance* would therefore comprise regions encoding information that is not purely linguistic or conceptual but reflects the sensory-motor properties associated with the underlying concept.

2. Aim of the study

The relationships between language and action has been investigated by an impressive amount of studies employing behavioral, neuropsychological and neuroscientific methodologies (for overviews, see Fischer & Zwaan, 2008; Glenberg et al., 2008; Vigliocco et al., 2004). Notwithstanding, important problems remain (Mahon & Caramazza, 2008). One of them concerns the extent to which motor areas are activated during figurative sentence processing. When someone says *The road turned left suddenly*, it is evident that she or he does not refer to a physical entity moving (this expresses a *fictive motion*, Talmy 2000, see below). These properties are instead implied in literal sentences as *The man turned left suddenly*. But what happens when the verb *turn* is used in a metaphorical context as *The lady turned her thought away from sorrow*? We hypothesized that the activation of the motor system reflects how much the motion component of the verb meaning is preserved. Following the claim of a behavioral study on metaphorical verb meaning (Torreano et al.,

2005), we hypothesized that metaphorical sentences might preserve the motion component. Specifically, we assumed that in metaphorical sentences the semantic component of a verb is abstracted out and employed to predicate a type of movement of whatever subject can change direction, regardless from its literal or figurative nature. We verified this claim in two experiments that employed a Transcranial Magnetic Stimulation (TMS) protocol with literal and figurative sentences that differed in the extent to which the motion component of the verb was preserved.

3. Method

Participants. Eight and twelve right-handed Italian participants were enrolled in the first and second experiment, respectively**.**
Materials. We selected twenty-seven common Italian verbs expressing a movement that involved the legs (e.g., *follow*, *cross*, *run*) and created four types of sentence for each verb: 1. Literal sentences (e.g., *The policeman follows the thief*); 2. Metaphorical sentences (e.g., *The girl follows her instinct always*); 3. Idiomatic sentences (e.g., *Giuseppe follows the footsteps of his father*); 4. Fictive motion sentences (e.g., *The railway follows the stream of the river*). Twenty-seven sentences of similar length and syntactic structure containing a mental verb were created as control sentences (e.g., *Cristina considers the idea very interesting*).
Procedure. We recorded motor evoked potentials (MEPs) from right inferior limb muscles while delivering single-pulse TMS on the left primary motor cortex. Variations of the motor cortex excitability indexed by MEPs provided a measure of the involvement of the motor system. The sentences were divided into three segments (the noun phrase, the verb and the final part of the sentence) presented on the screen one at a time. The participants' task was to read for comprehension. In the first experiment, the TMS pulse was delivered immediately after the verb (*The policeman follows*, *The railway follows*) namely when participants were not yet aware of the literal or figurative nature of the full sentence. The rationale was to verify whether the mere presence of a motion verb activated motion areas, regardless of the animate or inanimate nature of the agent. In the second experiment, TMS was delivered at the end of the full sentence. Readers were presented with figurative motion sentences (idiomatic and metaphoric), fictive motion and mental (control) sentences. We did not include literal sentences since it was clear from the results of the first experiment and from previous studies (e.g., Oliveri et al., 2004; Buccino et al., 2005) that literal motion sentences indeed activated the motor cortex. In both experiments, the effect of the sentence types on motor cortical excitability was evaluated by means of MEP changes expressed in terms of the ratio (Δ) between motion and mental sentences.

4. Results

Motion sentence fragments significantly modulated the MEPs evoked in the GCM muscle but only when the sentential subject was animate (Experiment 1) [animate motion fragments vs. inanimate motion fragments: $t(7) = -2.76$; $p = .03$]. When idiomatic, metaphorical, fictive motion sentences and mental sentences were presented in their full form (Experiment 2), the highest motor cortical excitability occurred in metaphorical motion sentences [Sentence Type factor: $F(2, 18) = 3.92$, $p < .04$; pairwise comparisons: metaphorical vs. idiomatic motion sentences $p < .036$; idiomatic vs. fictive motion sentences and fictive vs. metaphorical sentences: n.s.]. Fictive motion sentences triggered very low motor excitability, and even less so idiomatic sentences. In sum, we found that language-induced motor resonance was largest in metaphorical motion sentences than in fictive and idiomatic motion sentences.

5. Conclusion

The aim of this study was to determine the impact of literal and non-literal motion sentences on motor excitability as reflected by MEP changes during TMS stimulation. The high motor excitability induced by

metaphorical sentences is consistent with the behavioral claim that the metaphorical use of a verb preserves the basic semantic components of the verb meaning. The difference between metaphorical and literal motion sentences lies in the fact that in the metaphorical sentence the motion verb did not take its default arguments, for instance a physical entity. The level of abstractness of the motion component conveyed by literal and metaphorical sentences differs since in metaphorical sentences the motion verb is used at higher level of abstraction to refer to any instance of goal-driven conjoint motion.

Differently from metaphorical motion sentences, our results showed that the motion component of the verb was almost lost when it was embedded in idiomatic sentences. Why metaphor and idiom differ in the extent to which their meaning can resonate with the motor system? We believe that this is due to the different structure of these figurative expressions: in fact the relationship between an idiom's constituent words and the idiomatic meaning generally is arbitrary and learned and the idiomatic meaning overlearned (Azizh-Zadeh et al., 2006; Boulenger et al., 2009). Idioms typically convey abstract meanings and not concrete motor acts. Even though many idioms originate from metaphors, this origin can be totally unperceived by readers. Lastly, it should be mentioned that the absence of activity of the motor system in fictive sentences contrasts with what was found in some previous studies (e.g., Wallentin et al., 2005). However, we believe that this lack of modulation might depend on the inanimate nature of the agent typical of fictive motion sentences. In fact, as the results of Experiment 1 showed, the motor system did not activate when the action agent was inanimate as in *The railway follows the stream of the river*, for instance.

In sum, our findings indicate that the semantic representations grounded in the sensory-motor system indeed play a role in processing sentential meaning. However, the activation of motor representations is strongly influenced by the linguistic context and only appears when the verb preserves its basic semantic components, as in literal and metaphorical sentences.

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