



## A FUNCTIONAL ROLE FOR THE MOTOR SYSTEM IN LANGUAGE UNDERSTANDING: EVIDENCE FROM RTMS

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Does the sensorimotor system contribute to language comprehension? According to theories of embodied cognition, the meanings of action words are constituted in part by activity in brain areas involved in perceiving and performing actions. While fMRI studies have demonstrated activation of sensorimotor cortex during action language understanding, it has remained unclear whether this activation is functionally relevant for comprehension, or only a by-product of meaning construction (Mahon & Caramazza, 2008).

Here we used repetitive transcranial magnetic stimulation (rTMS) to investigate a causal relationship between activity in premotor cortex and action language processing. We applied theta-burst rTMS over the hand area of left premotor cortex in one experimental session and over right premotor hand area in another session. Theta-burst rTMS modulates excitability of the stimulated region up to an hour after application, allowing for measurement of behaviour such as reaction times. After stimulation, 12 healthy right-handed participants performed lexical decisions on verbs naming manual actions that people typically perform with their dominant hand (e.g., to throw, to write) and on non-manual verbs (e.g., to wander, to earn).

In right-handers, manual action verbs preferentially activate the premotor hand area in the left hemisphere, which mainly controls actions performed by the right hand (Willems, Hagoort, & Casasanto, 2010). Therefore, we predicted that (a.) rTMS applied over hand areas would modulate reaction times more strongly for manual action verbs than for non-manual verbs, and that (b.) the strength of this effect would depend on whether rTMS was applied over the left or right premotor cortex.

Results showed the predicted HEMISPHERE x VERB interaction ( $F(1,11)=6.18, p=0.03$ ). Responses to manual verbs were faster after stimulation of left premotor cortex than after stimulation of the right premotor cortex ( $t(11)=2.13, p=0.03$ ). This effect was not observed for the non-manual verbs ( $t < 1$ ). Response times for the pseudowords showed no main effects or interactions, attesting to the specificity of the observed effects for action verbs.

This rTMS study provides a more direct test of the motor system's contributions to language understanding than previous single-pulse TMS studies, which have used motor evoked potentials in limbs as a dependent measure (Papeo, et al., 2009). Muscle contractions in the limbs are most easily interpreted as effects of language comprehension, not as constituents of language processing, per se. Lexical decision is a classic index of semantic processing; not a TMS-induced response in hand or foot muscles that occurs downstream of language processing.

These results corroborate fMRI data showing that left premotor cortex is activated preferentially when right-handers read verbs for actions they perform with their dominant hand. Beyond showing a brain-behaviour correlation, the present data show that changing premotor activity causes a corresponding change in action language processing. These data challenge the skeptical view that premotor activity cued by action words is an epiphenomenon or a downstream consequence of lexical processing, and suggest a functional role for premotor cortex in action language understanding.

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