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Body-specific representations of action word meanings

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Running head: Body-specific word meanings

Body-specific representations of action word meanings

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A human mirror neuron system, responsible in part for both the perception and performance of actions, has been posited to subserve the meanings of action words. Processing words for actions performed with the legs (e.g., *kick*) or the hands (e.g., *pick*) produces somatotopic activation in sensorimotor cortices (Aziz-Zadeh, Wilson, Rizzolatti, & Iacoboni, 2006; Hauk, Johnsrude, & Pulvermuller, 2004; Tettamanti, et al., 2005), and modulates motor-evoked potentials recorded from associated effector muscles (Buccino, et al., 2005). The present study used the processing of manual action words in right and left handers as a testbed for the *Body-Specificity Hypothesis*: if concepts and word meanings are constituted, in part, by mental simulations of our own perceptions and actions, then their neurocognitive representations should differ for people with different kinds of bodies, who perceive and act upon the environment in systematically different ways.

Mirror neurons appear to be distributed bilaterally; viewing a right or left hand in action tends to elicit activity in motor areas contralateral to that hand (Aziz-Zadeh, et al., 2006). Yet across studies, activity in sensorimotor cortex associated with words for manual actions has been consistently lateralized to the left hemisphere. This lateralization could be due to the general left-hemisphere dominance for language. Alternatively, it could be a consequence of testing only right-handed participants. For stimulus words that name actions performed with the dominant hand (i.e., the right hand), the finding of left-lateralized motor activity suggests that understanding manual action words involves mentally simulating actions, using mirror neurons contralateral to the hand that usually executes them. This mental simulation claim would be challenged if the meanings of manual action words were found to be lateralized to the left-hemisphere in left handers as well as right handers. By contrast, the simulation claim would be strongly supported if the motoric components of action word meanings were found to be lateralized differently in right vs. left handers, despite the fact that language function, overall, is left-lateralized in the majority of both right and left handers (Goodglass & Quadfasel, 1954).

Methods

Sixteen right handers and sixteen left handers, according to the Edinburgh inventory (Oldfield, 1971), were recruited from Stanford University's introductory psychology class and were videotaped while performing a speeded 'motor-meaning congruity' task, followed by a surprise recognition memory test. 96 single words appeared in the center of a computer screen, one at a time for 2 seconds each. Half were verbs naming manual actions (e.g., *paint*, *chop*, *draw*) that raters indicated they typically perform with their dominant hands, and the other half were verbs naming non-manual actions (e.g., *sigh*, *peek*, *giggle*) matched for length, frequency, and number of phonemes. Half of the words appeared in red letters and the other half in blue letters. A red box was placed on the left of the screen and a blue box on the right (or vice versa), and a white box filled with hundreds of clear glass marbles was placed above the screen, in the middle. As soon as each word appeared, participants moved one marble into the box that matched the color of the letters. For one block of 48 words participants used their left hand, and for the other block their right hand. Each block contained equal numbers of red and blue words and equal numbers of manual and non-manual action words, randomly intermixed. The assignment of colors to words, the positions of the red and blue boxes, and the sequence of the left and right hand blocks were counterbalanced across subjects. After completing the marble moving task, participants performed an old/new recognition memory test in which all of the words presented previously in red or blue were shown again in black letters, randomly intermixed with an equal number of matched new words.

Participants were not instructed to imagine the actions that stimuli named, or even to read the words, but it was expected that they would read and understand the words incidentally. If the meanings of action words are constituted, in part, by mental simulations of perceptuo-motor experiences, then: (a) there should be effects of congruity between manual motor actions and the meanings of manual action verbs (but not non-manual action verbs), and (b) right and left handed participants should show opposite effects of using their right and left hands to move marbles during incidental processing of manual action verbs.

Results

Right handers were dramatically faster to initiate marble movements to the correctly colored boxes when using their right hands, and left handers when using their left hands, but only for manual action verbs (fig 1a-b). 2-way mixed ANOVA showed a significant interaction of Handedness (left-hander, right-hander) and Response Hand (left hand, right hand), with no main effects ($F1(1,30)=320.12$, $p=.0001$; $F2(1,94)=310.38$, $p=.0001$). By contrast, no effects of handedness or response hand were found for non-manual action verbs ($F1(1,30)<1$; $F2(1,94)<1$). The 3-way interaction of Handedness, Response Hand,

and Verb Type (manual, non-manual) confirmed that the advantage of using the dominant hand to move marbles was found selectively for manual action verbs ($F1(1,30)=320.63$, $p=.0001$; $F2(1,94)=306.01$, $p=.0001$).

The magnitude of the response time congruity effect depended on participants' degree of handedness. The absolute value of participants' laterality quotients (Oldfield, 1971) correlated reliably with their response time advantage (RT non-dominant hand – RT dominant hand) for manual action words ($r^2=.36$, $t(30)=4.11$, $p=.0002$), but not for non-manual action words ($r^2=.07$, $t(30)=1.48$, *ns*).

Right handers were also much more likely to correctly recognize manual action verbs that appeared while they were using their right hands, and left handers while they were using their left hands ($F1(1,30)=35.42$, $p=.0001$; $F2(1,94)=52.92$, $p=.0001$), but no interaction of handedness and response hand was found for non-manual action verbs ($F1(1,30)<1$; $F2(1,94)<1$; fig 1c-d). The 3-way interaction of Handedness, Response Hand, and Verb Type confirmed that the advantage for recognizing words incidentally encoded while using the dominant hand was found selectively for manual action verbs ($F1(1,30)=27.74$, $p=.0001$; $F2(1,94)=76.52$, $p=.0001$).

Conclusions

These double dissociations, one in action execution and the other in recognition memory, provide initial evidence for the Body-Specificity Hypothesis. Right and left handers, who perform actions differently with their hands, also instantiate the meanings of manual action words differently in the brain and mind.

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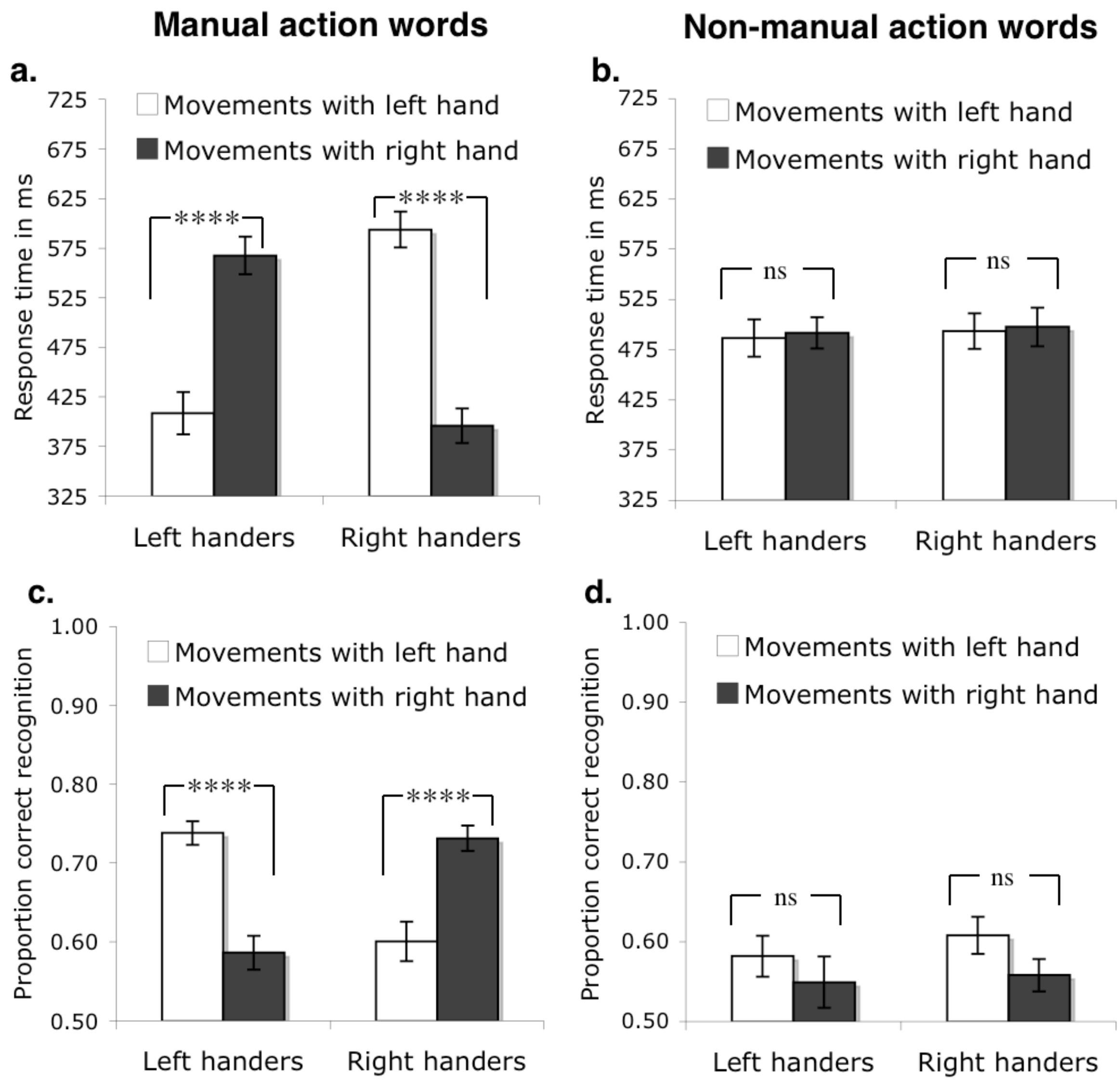

Figure 1. Top: Mean response times in ms (± s.e.m.) to initiate marble movements for manual action words (1a, left) and non-manual action words (1b, right). Response times indicate the latency from the onset of a stimulus word to the initiation of the marble movement. Bottom: Proportion correct recognition (± s.e.m.) for incidentally encoded manual action words (1c, left) and non-manual action words (1d, right). **** indicates p<.0001, *ns* indicates p>.05, 2-tailed.

a. **b.**

Supplementary Figure 1. The experimental apparatus was constructed from five empty Xerox paper boxes and colored paper. Trays holding the marbles were inverted box lids. Stimuli were presented on an iMac computer, using Psyscope software (Cohen, MacWhinney, Flatt, & Provost, 1993). Participants used their left hand to move marbles for one block of trials (1a, left) and their right hand for the other block of trials (1b, right). The sequence of blocks was counterbalanced across subjects.

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