Putting an ‘end’ to the motor cortex representations of action words

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Probabilistic cues to grammatical class

Recent theories have proposed that encapsulation of conceptual information is achieved by ‘grounding’ representations of action word meanings in the motor systems responsible for performing those actions, reflecting an ‘embodied’ approach to language comprehension (e.g., Pulvermüller, 2005). Although this proposal is controversial, thus far the debate in the neuroimaging literature has been largely concerned with establishing whether the motor activity observed in conjunction with action word processing is necessary or context-dependent. That is, it has been framed exclusively in terms of semantic and syntactic information.

Similar motor responses have also been reported for nonword and action word stimuli, suggesting that the activity is not category-specific, that is, it cannot be attributed selectively to conceptual representations and/or their implicit motor simulation (Postle et al., 2008). To confirm this, we collated 53 activity peaks ascribed to premotor (PM) and primary motor (M1) regions from 15 neuroimaging studies. We next collated 49 peaks from 18 neuroimaging investigations of written and auditory nonword perception and nonword production conducted during a similar period. In addition, we verified the location of each peak within the cytoarchitectonically defined PM or M1 cortex maps by determining the probabilities of their respective coordinates, using a liberal 20% threshold for assignment (Eickhoff et al., 2007).

Embodied language researchers have also frequently contrasted manual action words (e.g., caress) with non-body-part-related nouns (e.g., cavern). However, there is a substantial body of psycholinguistic research involving large-scale corpus analyses and behavioural measurements demonstrating that verbs tend to show distinct, non-morphologically derived, orthographic and phonological (henceforth ortho-phonological) properties that are different from those exhibited by nouns (Arciuli & Cupples, 2006; Kemp et al., 2009). A demonstration that PM and M1 cortices are responsible for reading both action words and nonwords that contain probabilistic cues to grammatical category would point to an alternate mechanism for motor system activity elicited by the former stimuli.

Experimental design and analysis

Participants. 19 participants (9 male), mean age 25 years (range 21 to 35 years).

Materials and Procedure. A grammatical judgment task using 80 actional words and 80 nonactional words. Half of the words were transitive verbs denoting manual actions (e.g., carry) and the other half nouns denoting non-manipulable entities (e.g., cavern). Half of the nouns and verbs were randomly associated with verb status and the other half had endings associated with noun status. Following a motor localizer task (Postle et al., 2006; 20 movie clips), half with right-hand-movement instructions, the other half controlling left-hand movements randomly assigned to each participant in a 2 × 2 within-subjects factorial design. The motor task demarcated the ~1-s motor cortex baseline.

Imaging data: Images were acquired using a 3T Siemens Trio TIM with 12-channel head coil. BOLD images were acquired using a gradient-echo EPI sequence (36 slices, TR 2.5s, TE 36ms, 64 x 64 matrix, 3.3mm x 3.3mm in plane resolution, 3mm slice thickness with .3mm gap and flip angle 80°). A 3D T1-weighted structural image was also acquired (1 mm isotropic voxels).

3. Results

Figure 1. (From left to right) Renderings of the lateral and medial cortical surfaces of the left hemisphere with peak maxima from fMRI studies reporting motor cortex activity for action word meaning representations, colour-coded according to their respective body-part relations. Renderings illustrate peak depth in relation to the cytoarchitectonically-defined maximum probability maps of primary motor and premotor cortices (Eickhoff et al., 2007).

Remote experimental design

Results cont’d

Figure 2. (From left to right) Renderings of the lateral and medial cortical surfaces of the left hemisphere with peak maxima from fMRI studies reporting motor activity for non-manual phonological manipulations, colour-coded according to perception or production tasks. The renderings illustrate peak depth in relation to the cytoarchitectonically-defined maximum probability maps of primary motor and premotor cortices (Eickhoff et al., 2007).

Conclusions

Ortho-phonological processing is sufficient for eliciting activity along the motor strip. Our fMRI data shows that PM cortex is differentially sensitive to probabilistic ortho-phonological cues to grammatical class embedded in the endings of disyllabic nonwords, with verb-like stimuli resulting in significantly increased activity compared to noun-like stimuli. The regions of PM cortex demonstrating this sensitivity overlap with those showing increased activity for manual action verbs compared to non-body-part-related nouns. Thus, motor activity evoked during processing of action words cannot be attributed selectively to conceptual representations and/or their motor simulation.

References


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