Grasping ideas with your hands: Neuromechanical assessment of the relation between cognitive processing and motor performance

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Summary

Is it your mind or your hand that grasps an idea? Neural and behavioural evidence from the cognitive sciences suggests it may be both due to a theorized bidirectional relationship between cognitive processes and motor control. Yet, this hypothesis has not been approached from a neuromechanical perspective. We aim to test this claim with detailed analyses of semantic and mechanical features of action-related words. Our results suggest a close relationship between semantic and motor representations of action, supporting the idea of shared neural substrates between cognitive and motor systems.

Introduction

Characterizing the involvement of the sensorimotor system in cognitive processes is a crucial step in developing a theoretical framework for the enhancement of both cognition and movement for rehabilitation, learning, and robotics. While grasping an idea and grasping an object have traditionally been thought to be separate processes, there is evidence suggesting that the control of movement may be fundamentally linked to cognitive processes [1]. For example, movement can affect comprehension of words semantically related to the performed movement [2], while simply reading certain action words can influence the speed and acceleration of related movements [3]. Typical analyses in this area, however, conflate incompatible movement language while limiting behavioral analyses to biomechanically simplistic measures [4]. The degree to which detailed sensorimotor information is incorporated into cognitive representations of action remains unclear. Our aim is to quantify and characterize the relationship between semantic understanding of action-related words and motor performance of those actions.

Methods

We conducted two separate experiments to assess cognitive and motor representations of action-related words. 32 healthy, native English speakers provided written informed consent prior to participating in this institutionally approved study.

To quantify cognitive representations of action-related words, 28 subjects were shown 195 words referring to physical (e.g., “pinch”) or abstract (e.g., “admire”) actions. They then used their initial impressions to rate the degree to which they would use various body segments to perform the actions from 1 (not used) to 5 (mostly used). Surveys were administered online via Qualtrics and analysed using custom code (Matlab).

To quantify motor representations of action-related words, a subset of action words was chosen based on the survey results to ensure a wide coverage of movements, with 2 verbs representing each of four categories: finger, whole-arm, leg, and abstract. Four male subjects were instructed to pantomime performing the action they associate with that word. Actions were repeated 5 times in random order. Electromyography (EMG) of 6 upper extremity muscles (first dorsal interosseus, extensor and flexor carpi ulnaris, biceps brachii, triceps lateral head, anterior deltoid) were recorded via surface electrodes (Motion Labs Systems, Baton Rouge, LA). Full-body kinematics (Vicon, Centennial, CO) and kinetics (AMTI force plates, Watertown, MA) data were simultaneously collected. We collected the rectified, MVC-normalized integrated EMG (iEMG) over each 8-second movement trial.

Results and Discussion

Cognitive representations of upper extremity words were rated higher for arm involvement (4.66±0.40) than leg (2.23±0.23) or abstract (0.25±0.51) words. Motor representations reflected these results, as iEMG of upper extremity muscles was higher for upper extremity words vs. abstract or leg words. Cognitive representations rated hand/finger use as important or neutral for all upper extremity words (2.14±1.09) while the upper arm was not rated as important (≥3) for any word. 67.9% of total iEMG came from forearm and hand muscles for finger-related words. Arm muscles accounted for 64.7% of iEMG for arm words (Fig. 1). Kinematics data also reflected these trends.

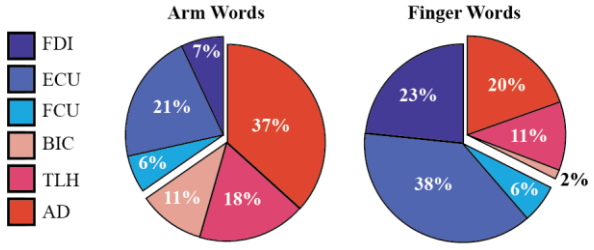

Figure 1: Relative iEMG for muscles of the arm (red hues) and hand/finger (blue hues) performing actions semantically correlated to arm (“punch”, “slash”) and finger (“pinch”, “flick”) words.

Conclusions

Our results suggest that cognitive representations of action words underestimate the importance of the upper arm but are generally correlated with muscular activity during motor performance. The close relationship between cognitive and motor representations of action supports the hypothesis of shared neural substrates between cognitive and motor systems.

References

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