Motor priming by action-related verbs

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There is increasing evidence in present research that reaction times in semantic decision tasks on action verbs are longer if the effector used to react to a given verb is the same as implicitly referred to by the action verb (e.g. Sato et al., 2008). Further investigations with structural and functional neuroimaging techniques suggest a central role of the primary motor cortex not only in planning and execution of movements but also in understanding and processing action-related language (e.g. Hauk et al., 2008).

These findings are in line with the theory of grounded cognition (e.g. Barsalou, 2008). However, there are also findings suggesting that word comprehension relies on amodal brain systems (Bedny & Caramazza, 2011).

In order to extend the findings described above a priming paradigm was applied in this study thus investigating a more automatic level of processing action-related language. Priming consists of the procedure of presenting a stimulus (e.g. a word) prior to another consciously perceived stimulus (e.g. a shape) whose processing is supposed to be influenced by the preceding prime. Based on grounded cognition theory and findings such as the ones described above we hypothesized differential effects of hand and foot verb primes depending on the response effector. In a discrimination task, 21 healthy subjects responded either with their right hand or foot to pointed or rounded shapes. The targets were preceded by three kinds of visually presented prime words: hand verbs (e.g. greifen, to grasp), foot verbs (e.g. springen, to jump), or non-body verbs (e.g. wünschen, to wish). The latter did not imply any body movement and served as fillers. Verbs were chosen according to a multidimensional rating procedure with 30 different participants amounting to a total of 48 verbs per category. The verbs were matched as closely as possible with respect to their familiarity, frequency and length and split into low and high levels of imageability and movement energy. Prime stimuli were presented for 300 ms, thus being supraliminal. After that a blank screen was shown for 100 ms, followed by the target which was displayed until response onset. Individual reaction times were analyzed excluding very slow responses above 1000 ms. Median reaction times entered a 4-way-ANOVA including within-subject factors imageability (low, high), movement energy (low, high), verb (hand, foot) and effector (hand, foot). We found a significant main effect for response effector with hand reactions being faster than foot reactions. No significant main effect was found for verb or movement energy. Imageability resulted in a trend for faster reactions following highly imageable words ($p = .072$). Instead of the hypothesized interaction between verb and response effector, we found a significant 3-way interaction between verb, response effector and movement energy. To resolve this interaction, separate 2-way ANOVAs with the factors verb and response effector were conducted for the high and low movement energy subconditions. The interaction of verb by response effector was significant only for the low movement energy verbs. Post-hoc tests revealed that

hand reactions following hand verbs were significantly faster ($p = .042$) than following foot verbs, while foot reactions following foot verbs were just numerically faster than following hand verbs ($p = .329$).

Confirming earlier studies, our results suggest a contribution of the primary motor cortex to action-language understanding. As in our task action verbs only appeared as primes and were not task-relevant, this contribution, furthermore, does not seem to hinge on an indepth semantic processing of action verbs that may arguably be induced by explicit lexical or semantic decisions on the action verbs themselves. Task and timing might additionally modulate the direction of the reported effect, because unlike other studies reporting interference effects, our results showed facilitation. Reactions were faster for verbs matching the executor of the response, but only for verbs describing actions with low movement energy. This may be interpreted in terms of differing activation of the motor cortex depending on movement content of the verbs. Hand verbs addressing the hand motor cortex but implying only little amount of movement may preactivate the motor cortex without posing too much demand on processing resources. Subsequent manual reactions therefore are faster than without preactivation.

High movement energy verbs may use motor cortical resources for language processing to a larger extent, extinguishing the aforementioned priming effect.

Taken together, our findings imply a motor cortical contribution to verbal processing that seems to depend on task and timing, but also on inherent properties of the verbal material like its amount of motion content.

Barsalou, L.W. (2008). Grounded cognition, Annu Rev Psychol vol. 59, pp. 617-645.

Bedny, M. & Caramazza, A. (2011). Perception, action and word meanings in the brain: the case from action verbs, Annals of the New York Academy of Sciences, vol. 1224, pp. 81-95.

Hauk, O., Shtyrov, Y. & Pulvermüller, F. (2008). The time course of action and action-word comprehension in the human brain as revealed by neurophysiology, Journal of Physiology-Paris, vol. 102, pp. 50-58.

Sato, M., Mengarelli, M., Riggio, L., Gallese, V. & Buccino, G. (2008). Task related modulation of the motor system during language processing, Brain and Language, vol. 105, pp. 83-90.