The influence of hand or foot responses on response times in investigating action sentence processing

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Abstract

In a response time experiment dealing with action language comprehension, we investigated the question of whether the execution of a hand-response would interfere with or facilitate hand-related action sentence processing. We analyzed response times on concrete action, abstract action, and abstract control stimuli, given by hand or with the foot respectively. Beside the well-known concreteness effect, we found that responses by hand on concrete action sentences were relatively prolonged in relation to responses with the foot. Thus, there is a decisive interdependency between the effector-reference of the action verb and the effector used for response detection. We suggest that this has to be taken into account when analyzing action language comprehension and that response effectors should be chosen in accordance with the action language stimuli used.

Keywords: action verb, abstract and concrete language, motor interference and facilitation, embodiment, response times

Introduction

The activation of sensory-motor areas during language processing is an effect that has frequently been replicated in numerous studies (e.g. Aziz-Zadeh et al., 2006; Desai et al., 2010; Hauk, Johnsrude, & Pulvermüller, 2004; Hauk & Pulvermüller, 2004; Moreno, de Vega, & León, 2013; Pulvermüller, Härle, & Hummel, 2001; Pulvermüller, Shtyrov, & Ilmoniemi, 2005; Tettamanti et al., 2005; van Elk et al., 2010). Against the background of these findings, compatibility and interference effects between action language processing and motor performance have been one of the topics focused in related research projects. As early as in 1989, Klatzky et al. described facilitation of a sensibility decision if a congruous movement was primed before the judgment. In each trial, they primed the representation of a previously trained hand shape before participants were asked whether a subsequently presented object-action target phrase referring to respective hand and finger movements was sensible. In a series of four experiments, Klatzky et al. (1989) reported that any handshape regardless of its precise structure facilitated comprehension of the target phrase in comparison to a neutral priming condition. This result gives rise to the assumption that – as long as the same effector is involved – the detailed representation of a motor action is indecisive for its priming effect. Glenberg and Kaschak (2002) summarized their results of related experiments in defining the action-sentence compatibility effect (ACE). It describes that congruency between a direction implied in a sentence and the direction in which the response was to be done lead to shorter response times (RTs) than in incongruent trials. In their stimuli, participants acted as first-person referents. Bergen and Wheeler (2005) were able to replicate the ACE for third-person referents and additionally claimed that action execution is primed by action language processing at a detailed motor level. Responses on sentences expressing open palm vs. closed fist actions were faster if participants responded with an open palm movement and vice versa. This contradicts the findings by Klatzky et al. (1989) but was further confirmed by an EEG-study conducted by Aravena et al. (2010), in which a more negative N400-component was found for incompatible compared to compatible trials in an ACE-paradigm.

In contrast to these observations of compatibility, matching action and language targets might also yield interference effects. Bergen, Narayan, and Feldman (2003) visually presented comic-like line drawings of motor-actions prior to an action verb. The verb either matched the action that was depicted in the picture or did not match. If it did not match, it either referred to an action done with the same or with a different effector. Participants were asked to decide whether pictures matched the verb or not. The authors report a significant difference in RTs between the *match* vs. the *non-matching same effector* condition. They give the explanation that there might be a circumscribed group of mirror neurons coding a very specific gesture. If a participant was confronted with a gesture, then mirror circuits encoding very similar gestures would be inhibited, which would lead to interference effects when rejecting compatibility of picture and verb in the *same effector* condition (Bergen et al., 2003). Narayan, Bergen, and Weinberg (2004) replicated the effect for verb – verb instead of picture – verb combinations.

Reporting the results of these and other studies, Bergen (2007) concluded that compatibility effects could be observed whenever two matching motor or perception processes do not occur simultaneously and the verbal stimulus precedes the image. Interference, in contrast, would arise whenever the two matching processes occur simultaneously or the verbal stimulus follows the image. However, the argument of the sequence of events as being decisive is rather weak, since in the studies cited in Bergen (2007) interference effects have been shown for both the sequence image – verb and verb – image.

To our knowledge, none of the studies investigating compatibility vs. interference effects by means of behavioral measures took into account the circumstance that most of the time RTs are indicated by hand, which requires an arm/hand/finger movement. Although the processing of hand action words or movements in a certain direction might prime the actual execution of a respective motor program, the required finger movement might still positively or negatively influence RTs. After all, results concerning the need for detailed vs. undetailed motor representations in order to obtain a priming effect are controversial (Bergen & Wheeler, 2005; Klatzky et al., 1989). This might be a minor question if stimuli address only one effector but it becomes a major question if more than one effector is addressed and RTs are compared between the different modalities. In a combined behavioral and EEG study, Pulvermüller et al. (2001) presented arm-, face-, and leg-related action verbs in a lexical decision task. They aimed at investigating RTs in order to see whether wider cortical networks (as for leg-related verbs) would lead to longer RTs than more narrow networks (as for face-related verbs). They found that responses on face-related verbs were significantly shorter than on arm-related verbs and those on arm-related verbs were significantly shorter than on leg-related verbs. However, the RT difference between face- and arm-related verbs was only about 10 ms. If one takes into account that there might have been interference effects between the processing of arm-related verbs and the hand response, RTs might have been the same for face- and arm-related verbs. Romero Lauro et al. (2013) conducted an fMRI study to investigate the activation of sensory-motor areas during literal, fictive, metaphorical, and idiomatic action sentences. Action verbs were either hand- or foot-related. The task for participants was to decide whether a specific task sentence was congruent or incongruent to its preceding target sentence and to respond by a button-press. The authors report that the interaction between sentence type and effector approached significance. However, if an interference effect occurred for hand-related action sentences because of these stimuli being judged by a button-press, RTs in these cases might actually have been faster and the interaction might have come out significant, which could have indicated some interesting impact of effector on sentence type.

The current study addressed this issue in order to avoid mistakes concerning significant RT differences in future studies investigating questions of action language processing. We specifically addressed the following questions: Will RTs on hand-related action sentences differ if they are measured by means of a hand vs. a foot response? Will there be any interference effect at all, since the hand response does not share a detailed motor representation with the action described by the verb? Our hypotheses were that if general movements of the hand (mouse-click) influence RTs on hand-related action verbs, then we should detect differences between RTs measured by hand vs. with the foot. Instead, no difference in RTs would suggest that unrelated movements – no matter if executed by the same or a different effector – do not have any influence on RTs. A further question in the current study was whether similar effects could be found for abstract action sentences, which is why we included these stimuli in the analysis.

Material and Method

We subsequently conducted two experiments with equal stimuli and very similar procedures. That is why in the *Participants*, the *Procedure*, and the *Results* section we report experiment 1 and 2 partially separate, while in the *Stimuli* section, we do not differentiate between the two groups.

Written informed consent was obtained from all participants for publication of this study. All subjects declared that they were neither under strong medication nor did they suffer from auditory or motor diseases or other restrictions that might have had an influence on RTs.

Participants

Experiment 1 Participants of the first experiment will be referred to as group H (hand response). 22 monolingual German students (13 females) of Bielefeld University aged 21 – 32 years ($M = 24.9$, $SD = 2.8$) participated in the first RT-experiment. Subjects were right-handed with a mean lateralization quotient of 92 ($SD = 10.6$) according to a modified version of the Edinburgh Handedness Inventory (Oldfield, 1971).

Experiment 2 Participants of the second experiment will be referred to as group F (foot response). 16 different monolingual German students (8 females) of Bielefeld University aged 20 – 36 years ($M = 25$, $SD = 4.6$) participated in the second RT-experiment. Subjects were right-handed with a mean lateralization quotient of 93 ($SD = 10.9$) according to a modified version of the Edinburgh Handedness Inventory (Oldfield, 1971). About 85 % of participants had a preference for the right foot as well.

Stimuli

197 sentences were used as stimuli, 50 of which were nonsense fillers. In a preparatory test, 27 different subjects rated the stimuli on a scale ranging from 1 (nonsense) to 5 (sensible). A two-tailed independent samples t-test corrected for inhomogenity of variances revealed that sensible stimuli were rated significantly more plausible ($M = 4.39$, $SD = 0.45$) than nonsense stimuli ($M = 1.29$, $SD = 0.28$), $t(74.25) = 42.26$, $p = .000$. 147 sentences were crucial and originated from the three categories *concrete action* (CA), *abstract action* (AA) and *abstract* (A). Stimuli were set up as triplets with one sentence out of each category. The category CA contained sentences like "Ich habe die Handbremse gezogen" (*"I have pulled the hand break"*), in which an arm-/hand-related action verb was embedded in a literal

context. In the AA category, the action verb was presented in an abstract context, like in "Ich habe die Konsequenz gezogen" (*"I have drawn the consequence"*). The third category (A) contained abstract control sentences, like "Ich habe die Konsequenz gefordert" (*"I have demanded the consequence"*). Sentence structure was the same for every item so that the target verb was always positioned at the end.

The mean length of verbs was 734.9 ms (SD = 129.2 ms). In the preparatory test, subjects not only rated the stimuli as sensible or nonsense but also rated sensible stimuli as concrete or abstract on a scale ranging from 1 (abstract) to 5 (concrete). A repeated measures ANOVA showed a significant influence of the type of sentence on rating values, $F(2, 52) = 196.59$, $p = .000$. Pairwise comparisons revealed that sentences in category CA were rated significantly more concrete ($M = 4.62$, $SD = 0.32$) than sentences in the categories AA ($M = 2.38$, $SD = 0.50$) and A ($M = 2.51$, $SD = 0.55$). There was no significant difference between the two categories containing abstract sentences. Stimuli of each triplet were matched according to gender of nouns, number of noun-syllables and number of verb-syllables. Stimuli of each category were matched according to word frequency of nouns and verbs and co-occurrence of nouns with verbs.

Sentences were recorded with a semi-professional speaker in a sound-attenuated booth.

Procedure

Experiment 1 After instruction, participants of group H were seated in an upright position one meter in front of a computer screen in a sound-attenuated booth. A computer mouse used for response detection was placed to their right on a small platform at about the height of the subjects' knees so that it was easy to reach.

The experiment was presented via a customized presentation software running under Ubuntu (vers. 8.04.2) detecting responses with an accuracy of about 3 ms. A picture of the mouse used for response detection signaled the beginning of a new trial to participants. It stayed on the screen for 1.5 s and then disappeared shortly before the sentence started. Sentences were presented auditorily. Subjects were asked to do a sensibility judgment in a Go-/No-Go-paradigm, so that they would only have to respond if the sentence made sense. They were instructed to respond as fast and as accurate as possible as soon as they understood the sentence's meaning. Responses were given with the forefinger of the right hand. Stimuli were fully randomized for each subject.

Experiment 2 The procedure was very similar to the one in experiment 1, with the exception that participants in group F responded by stepping on a foot-pedal with their big toe of the right foot. They were asked to take off their shoe before starting the experiment. Applying this method, accidental responses due to the weight of the foot could be avoided. The pedal was placed in front of subjects' right foot. They were asked to adjust its position themselves so that they would feel comfortable during the experimental session and would not suffer from any hardening in foot muscles or joints.

Due to other research questions, we presented a picture of a person sitting still on a chair as an alertness signal in this experiment. It stayed on the screen for the whole length of the subsequent stimulus. The method of presentation, the presentation soft- and hardware and the task were the same as for group H.

Results

The statistical analyses were conducted via SPSS 22 on Mac OS X (vers. 10.8.5). RTs were measured from verb onset. We corrected for outliers by means of boxplot analyses for each sentence type in both groups.

Experiment 1 Mean accuracy for the semantic judgment was 93.2 %. Three single responses were excluded due to the outcomes of the boxplot analyses, which was about 0.1 % of all valid responses on sensible stimuli. However, 12 items had to be removed due to their error rates exceeding the mean error rate by two standard deviations. A repeated measures ANOVA with the within-subject factor *sentence type* revealed a significant effect, $F(2, 42) = 51.62$, $p = .000$. Responses on all three sentence types differed significantly, with subjects responding faster on CA than on AA and A sentences and on AA sentences than on A items (see figure 1a).

Experiment 2 Mean accuracy for the semantic judgment was 93.4 %. Four single responses were excluded as outliers, which was about 0.2 % of all valid responses on sensible stimuli. The same 12 items as in experiment 1 had to be removed. The repeated measures ANOVA revealed a significant effect. As Mauchly's test indicated a violation of the assumption of sphericity ($\chi^2(2) = 11.21$, $p = .004$), degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .65$). The effect of *sentence type* then was $F(2, 30) = 29.02$, $p = .000$. As for group H, responses on all three stimulus types differed significantly (see figure 1b).

Comparison Data of the two experiments were analyzed in a repeated measures ANOVA with the within-subject factor *sentence type* (CA, AA, A) and the between-subject factor *effector* (hand vs. foot). Mauchly's test indicated a violation of the assumption of sphericity, $\chi^2(2) = 10.22$, $p = .006$. Degrees of freedom were therefore corrected using Huynh-Feldt estimates of sphericity ($\varepsilon = .80$). Results show a significant main effect of *sentence type*, $F(1.71, 61.37) = 76.01$, $p = .000$, but no significant interaction between *sentence type* and *effector*, $F(1.71, 61.37) = 2.03$, $p = .147$. Univariate pairwise comparisons of the between-subject factor revealed a marginally significant effect of *effector*, $F(1, 36) = 3.97$, $p = .054$, with participants responding faster by hand (M = 946.9 ms) than by foot (M = 1057.5 ms).

To further compare the relation of RTs on the different sentence stimuli between the two groups, we calculated mean difference values (DVs) for each category. As a basis for the mean DVs, we subtracted the mean RT given by hand (RT_{hand}) from the mean RT given with the foot (RT_{foot}) for every single item resulting in a DV for every item. The mean DVs for the conditions CA, AA, and A were then analyzed in a one-way between-subjects ANOVA to compare the effect of *sentence type* on DVs in the two groups. Abstract sentences did not contain an action verb and therefore served as the reference category. Since the assumption of homogenity of variance was violated, the Welch F-ratio is reported. There was a significant effect of *sentence type* on DVs, $F(2, 86.20) = 6.70$, $p = .002$. Games-Howell post-hoc comparisons revealed significant differences between DVs on CA in comparison to AA and A stimuli, but no significant difference between AA and A items. Results are displayed in figure 1c.

Discussion

The aim of the current project was to find possible compatibility or interference effects between hand-related action sentence processing and a hand response. Participants listened to sentences containing hand-related action verbs and were asked to do a sensibility judgment. Responses were given by hand in group H and with the foot in group F.

Overall, participants were slower to respond with the foot than by hand. This effect was marginally significant and can simply be explained by the greater distance motor potentials have to cover when spreading to foot in comparison to hand muscles. Further, in everyday life, much more actions are performed with the hand than with the foot, which makes it much easier to respond with the hand. We also found a concreteness effect in both group H and F. Participants responded significantly faster on CA sentences than on AA stimuli and on AA stimuli than on A items in both conditions. This is a well-known effect and is thought to go back on the activation of a larger neural network in concrete language processing. Accordant evidence has been found in EEG studies, in which higher coherence effects between electrodes for concrete than for abstract words could be observed (Weiss & Müller, 2003; Weiss & Müller, 2013; Weiss & Rappelsberger, 1998). Further, fMRI studies support the assumption of stronger visual imagery processes and demands on more different domains (visual, auditory, tactile, etc.) to occur during concrete than during abstract language processing (Ghio & Tettamanti, 2010; Jessen et al. 2000; Weiss et al., 2011). The difference between the AA and the non-action A stimuli indicate a processing advantage for the abstract stimuli containing a motion verb. Since both sentence types only differed with regard to the action verb, this effect has to go back on processing differences induced by that verb. Consequently, we suggest an activation of motor areas during action verb processing in both concrete and abstract contexts, which support the process of meaning constitution.

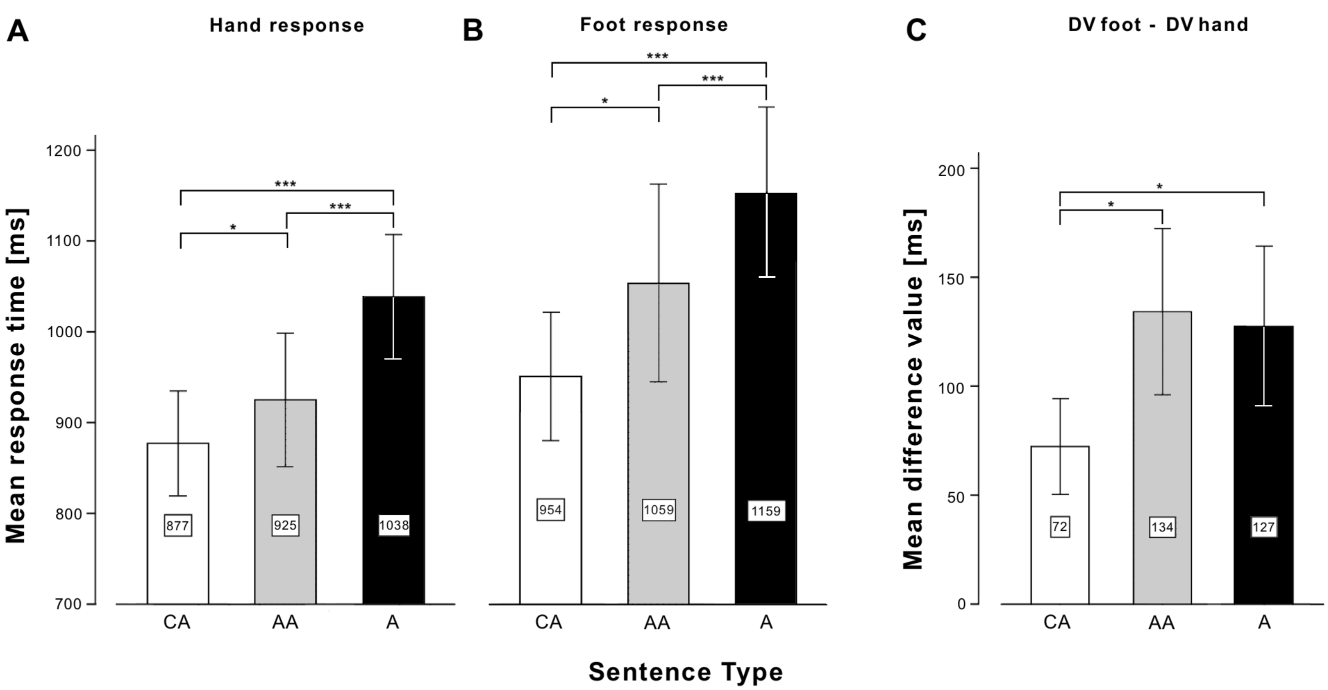

Figure 1: Mean response times in ms for **A** the hand and **B** the foot condition. Figure **C** displays the mean difference values in ms defined as $DV_{foot} - DV_{hand}$. Significant differences are marked by asterisks with * = $p \leq .05$ and *** = $p \leq .001$. CA = concrete action, AA = abstract action, A = abstract control

The repeated measures ANOVA conducted in order to find a possible interaction between effector and sentence type did not reveal any effects. However, calculating mean DVs for RTs in each condition and testing those on significant differences between the three sentence types in groups H and F showed that RTs on CA stimuli in group H were prolonged relative to RTs in group F. Abstract control sentences served as a baseline. Here, RTs should not be influenced by the type of effector since these sentences did not contain any action verbs. The mean DV for control sentences was 127 ms. If there was no influence of type of effector on the other two sentence types, then their mean DVs should not differ significantly from the control condition. We found that this was true for the AA items but not for the CA stimuli. The mean DV for concrete sentences containing a hand-related action verb was significantly lower than for the two abstract sentence types. This might be either due to RTs on concrete sentences being shorter in the F group or to RTs on concrete sentences being longer in the H group. The distance between the RTs for the different sentence types in the two groups suggests that the latter is the case. In group F, participants responded 100 ms faster on the AA than on the A stimuli. This is comparable to the relation in group H, in which participants responded 113 ms faster on the AA than the A sentences. The distance between RTs on CA and AA stimuli in group F was 105 ms. In group H, this distance was as low as 48 ms. It thus becomes clear that the low mean DV for the CA stimuli is due to RTs being prolonged when the response is measured by hand. This finding leads us to conclude that the hand movement executed as a response to hand-related action sentences interferes with processing the hand-related action verb. We observed this effect for the CA stimuli only. Thus, although there might be processing advantages for abstract sentences containing an action verb due to an involvement of motor cortices, this involvement might not be as strong and not as definite as in concrete action language (Schaller, Weiss, & Müller, in prep.).

On a neurobiological level, findings of both compatibility and interference can be explained by the activation of motor areas during action language processing. Hauk et al. (2004) presented results of an fMRI study, showing the activation of motor and premotor areas for both the execution of face, arm, and legmovements and respective action word processing. Crucially, arm words activated premotor areas in the middle frontal gyrus bilaterally and in the motor cortex of the left hemisphere, whereas leg-related words elicited activation in left and midline areas of pre- and postcentral gyri as well as dorsal midline premotor cortex (Hauk et al., 2004). Quite similar findings were reported by Hauk and Pulvermüller (2004). For action sentence processing these results were replicated by Tettamanti et al. (2005) and Desai et al. (2010). According to these outcomes, a pre-activation of motor areas induced by a language stimulus might lead to facilitation effects when a subsequent motor command has to be executed and vice versa. However, as Bergen et al. (2003) claimed, this will only be the case if the motor representation activated by the first stimulus and that needed for processing the second stimulus are the same. The activation of neurons responsible for coding a certain motor representation is thought to inhibit motor representations which are very similar. According to this view, a stimulus which is only similar but not equal to a second stimulus will lead to its inhibition (Bergen et al., 2003). This might be the case whenever interference effects can be observed. In studies reporting an ACE, the motor representation evoked by the sentence (e.g. movement away from the body) was the same as the motor representation needed to accurately solve the task demands (movement away from the body). Interference effects have been reported if the two stimuli were only similar but not equal, e.g. sharing the same effector.

The results of our study support these assumptions. We primed a certain hand movement, which is done with the same effector as the hand movement needed for the response but the actual motor representation is not equal. This evoked an interference effect. The button-press itself is a motor response that may facilitate comprehension if there are sentences about button-presses but it may also interfere with comprehension processes concerning every other hand-related action verb. We did not observe an interference effect if participants responded with the foot because the hand-related action verb and the foot response do not share many neuronal resources.

Conclusion

We suggest that the level of similarity between a language and a motor action is decisive for whether the parallel processing of two respective stimuli yields facilitation or interference effects. If the two actions are the same, that is, referring to the same semantic content, then compatibility occurs and the ACE can be observed. If, instead, the two actions do not share the same semantic content but only the same effector, interference occurs due to inhibition processes as suggested by Bergen et al. (2003).

This has important implications for research in the action language domain since in behavioral studies, RTs are most of the time measured by a hand response. However, a button-press might itself interfere with hand-/arm-related action language, which might pose a problem whenever different effectors are compared. Therefore, when analyzing effector-specific action language, a response method unrelated to the effector-reference needs to be used. Alternatively or additionally, RTs should be analyzed against a non-motor baseline, so as to adjust for interference effects elicited by the response method.

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References

Aravena, P., Hurtado, E., Riveros, R., Cardona, J. F., Manes, F., & Ibáñez, A. (2010). Applauding with closed hands: Neural signature of action-sentence compatibility effects. *PLoS ONE*, *5*, e11751.

Aziz-Zadeh, L., Wilson, S. M., Rizzolatti, G., & Iacoboni, M. (2006). Congruent embodied representations for visually presented actions and linguistic phrases describing actions. *Current Biology*, *16*, 1818-1823.

Bergen, B. (2007). Experimental methods for simulation semantics. In M. Gonzalez-Marquez, I. Mittelberg, S. Coulson, & M. Spivey (Eds.), *Methods in Cognitive Linguistics*. Amsterdam: John Benjamins.

Bergen, B., Narayan, S., & Feldman, J. (2003). Embodied verbal semantics: Evidence from an image-verb matching task. *Proceedings of the Twenty-Fifth Annual Conference of the Cognitive Science Society*. Mahwah, NJ: Lawrence Erlbaum.

Bergen, B., & Wheeler, K. (2005). Sentence understanding engages motor processes. *Proceedings of the Twenty-Seventh Annual Conference of the Cognitive Science Society*. Mahwah, NJ: Lawrence Erlbaum.

Desai, R. H., Binder, J. R., Conant, L. L., & Seidenberg, M. S. (2010). Activation of sensory-motor areas in sentence comprehension. *Cerebral Cortex*, *20*, 468-478.

Ghio, M., & Tettamanti, M. (2010). Semantic domain-specific functional integration for action-related vs. abstract concepts. *Brain and Language*, *112*, 223-232.

Glenberg, A. M., & Kaschak, M. P. (2002). Grounding language in action. *Psychonomic Bulletin & Review*, *9*, 558-565.

Hauk, O., Johnsrude, I., & Pulvermüller, F. (2004). Somatotopic representation of action words in human motor and premotor cortex. *Neuron*, *41*, 301-307.

Hauk, O., & Pulvermüller, F. (2004). Neurophysiological distinction of action words in the fronto-central cortex. *Human Brain Mapping*, *21*, 191-201.

Jessen, F., Heun, R., Erb, M., Granath, D.-O., Klose, U., Papassotiropoulos, A., & Grodd, W. (2000). The concreteness effect: Evidence for dual coding and context availability. *Brain and Language*, *74*, 103-112.

Klatzky, R. L., Pellegrino, J. W., McCloskey, B. P., & Doherty, S. (1989). Can you squeeze a tomato? The role of motor representations in semantic sensibility judgments. *Journal of Memory and Language*, *28*, 56-77.

Moreno, I., de Vega, M., & León, I. (2013). Understanding action language modulates oscillatory mu and beta rhythms in the same way as observing actions. *Brain and Cognition*, *82*, 236-242.

Narayan, S., Bergen, B., & Weinberg, Z. (2004). Embodied verbal semantics: Evidence from a lexical matching task. *Proceedings of the 30th Annual Meeting of the Berkeley Linguistics Society*. Berkeley: Berkeley Linguistics Society.

Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh Inventory. *Neuropsychologia*, *9*, 97-113.

Pulvermüller, F., Härle, M., & Hummel, F. (2001). Walking or talking?: Behavioral and neurophysiological correlates of action verb processing. *Brain and Language*, *78*, 143-168.

Pulvermüller, F., Shtyrov, Y., & Ilmoniemi, R. (2005). Brain signatures of meaning access in action word recognition. *Journal of Cognitive Neuroscience*, *17*, 884-892.

Romero Lauro, L. J., Mattavelli, G., Papagno, C., & Tettamanti, M. (2013). She runs, the road runs, my mind runs, bad blood runs between us: Literal and figurative motion verbs: An fMRI study. *NeuroImage*, *83*, 361-371.

Schaller, F., Weiss, S., & Müller, H. M. (in prep.). Embodiment of action verbs in abstract contexts. Results of a motor-priming study.

Tettamanti, M., Buccino, G., Saccuman, M. C., Gallese, V., Danna, M., Scifo, P., Fazio, F., Rizzolatti, G., Cappa, S., & Perani, D. (2005). Listening to action-related sentences activates fronto-parietal motor circuits. *Journal of Cognitive Neuroscience*, *17*, 273-281.

Van Elk, M., van Schie, H. T., Zwaan, R. A., & Bekkering, H. (2010). The functional role of motor activation in language processing: Motor cortical oscillations support lexical-semantic retrieval. *NeuroImage*, *50*, 665-677.

Weiss, S., & Müller, H. M. (2003). The contribution of EEG coherence to the investigation of language. *Brain and Language*, *85*, 325-343.

Weiss, S., & Müller, H. M. (2013). The non-stop road from concrete to abstract: High concreteness causes the activation of long-range networks. *Frontiers in Human Neuroscience*, *7*, 1-13.

Weiss, S., Müller, H. M., Mertens, M., & Woermann, F. G. (2011). "Tooth and truth": Brain activation during passive listening to concrete and abstract nouns. *The Open Behavioral Science Journal*, *5*, 37-47.

Weiss, S., & Rappelsberger, P. (1998). Left frontal EEG coherence reflects modality independent language processes. *Brain Topography*, *11*, 33-42.