Moving hands, moving entities.

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Abstracts. In this study we investigated with a priming paradigm whether uni and bimanual actions presented as primes differently affected language processing. Animals' (self-moving entities) and plants' (not selfmoving entities) names were used as targets. As prime we used grasping hands, presented both as static images and videos. The results showed an interference effect with unimanual action primes (both static and moving) with plants' names. No modulation of responses for animals' names was found. We argue that in the present task plants elicit information on unimanual grasping actions they support, while the lack of effect for animals could be due to them being better characterized as active agents.

What happens in the mind when one sees someone grasping an animate or an inanimate object such as a hen or a melon? Does our brain “resonate” as if we were performing the action in question? More importantly, does motor resonance take into account that animate entities might move or try to escape while inanimate entities can not? Does language processing reflect this ‘resonance’? The present paper aims to investigate these issues, using a priming paradigm in which a hand-prime was followed by words referring to either animate or inanimate entities.

A number of studies have shown that seeing an effector (e.g., hand) performing an action evokes a resonance mechanism. The neural underpinning of this echoing mechanism is known as the mirror neuron system (MNS). Research has shown that the MNS is activated when the subject performs a purposeful movement toward an object and when the same movement, executed by someone else, is observed (for a review, see Rizzolatti & Craighero, 2004). Behavioral studies with visuomotor priming paradigms provide evidence of this motor resonance mechanism. In particular, congruency effects have been found between the position and perspective of a given hand prime and the grasping hand final position, or the position and perspective of the hand target (Bruzzo, Borghi & Ghirlanda, 2008; Craighero, Bello, Fadiga & Rizzolatti, 2002; Vogt, Taylor & Hopkins, 2003).

Further behavioural studies manipulate not only the type of hand prime, but also the pragmatic characteristics of the target-object being compatible or incompatible with the action depicted in the prime (e.g. Yoon & Humphreys, 2005). Overall, the mentioned studies do not allow determining whether a static image prime depicting a moving action is sufficient to evoke motor resonance, or whether a motor training is necessary. For example, in a categorization task Borghi, Bonfiglioli, Lugli, Ricciardelli, Rubichi & Nicoletti (2007) observed a congruency effect between the prime hand posture (power, precision) and the object size (large, small), but this occurred provided that participants received motor training, which required them to imitate the gestures displayed in the hand-pictures (see also Bazzarin, Borghi, Tessari & Nicoletti, 2007). The training might be necessary for participants to allow them to capture the static hand posture as a 'snapshot' of a moving grasping action, i.e. to enhance the implied motion evoked by the hand. Vainio, Symes, Ellis, Tucker & Ottoboni (2008) found similar congruency effects between a hand prime and a target object, but they presented videos instead of static images of the grasping hand. Fischer, Prinz and Lotz (2008) found that seeing different hand postures automatically directs attention towards congruent target objects, but they used hand postures the position of which varied dynamically over time. Whether or not the observation of a static depiction of a manual action is sufficient to activate the MNS remains unclear. Studies on implied motion have focused on the differences between observation of static or moving actions showing that static photographs characterised by implied motion (Freyd, 1983) activate brain regions involved in visual motion processing (Kourtzi & Kanwisher, 2000). In a recent fMRI study by Nelissen, Luppino, Vanduffel, Rizzolatti, & Orban (2005) monkeys viewed videos displaying human hands performing an action with or without an object. Videos with actions and motion of the object were compared with static photographs. Static images of mimicked actions did not show much activation on the mirror neurons areas or on Brodmann area 45, where information on objects and on action converges. However, activation did occur when videos were used. In contrast, in another fMRI study with humans Johnson-Frey, Maloof, Newman-Norlund, Farrer, Inati and Grafton (2003) showed that observing static pictures of the same objects being grasped or touched is sufficient to selectively activate the frontal mirror region. In a Transcranial Magnetic Resonance (TMS) study Urgesi, Moro, Candidi, Aglioti (2006) presented participants with static pictures of either a resting hand, a grasping hand in (implied) motion, or a hand adopting a final precision grip posture (always without objects). They found TMS gating effects over the primary motor area for the implied motion picture, but not for the start or end postures.

To summarise, the reported behavioural studies leave the question unanswered, of whether the presentation of a static hand image is sufficient to activate motor resonance, or whether some kind of motor training or dynamic presentation of the hand is required. Similarly, but at a different level, the neural studies described above do not provide definitive clarification on whether the movement of an observed action is necessary to activate the mirror neuron system or whether implied motion in an image is sufficient

At the same time, while a great deal of research has been dedicated to motor programs associated with different kinds of postures (e.g., precision vs. power grip), the difference between unimanual and bimanual grasping and its effect on target processing has not been investigated. However, this difference seems relevant on an ecological ground, as different kinds of objects are intuitively preferably associated with different actions, i.e. monomanual and bimanual. In particular moving entities, such as animals, are more associated with bimanual actions, i.e. one is more likely to grab a dog or a hen with two rather than one hand. Conversely unimanual actions seem to be more associated with static entities, e.g. vegetables and fruit (within the natural kinds).

One of the aims of our study is to clarify the differences between the role played by dynamic and static hand primes and to investigate the different effects of unimanual and bimanual postures on processing of word targets. In line with the studies reviewed above we chose a priming paradigm with hand-primes and animate and inanimate entity names as targets. The primes were characterised by one or two hands either (1) moving with a grasping action, or (2) depicting a grasping action with implied motion, or (3) moving in a downward direction without performing an action. With this selection we aimed to assess whether a prime depicting a moving action is more effective than a static image or whether the implied motion (action) is sufficient to evoke motor resonance. The prime depicting only the motion (not the action) would constitute a baseline relative to the primes depicting an action. This would be used in order to assess the motor resonance induced by seeing the action.

The second aim of our study is to investigate the effects of hand primes on word targets referring to animate and not inanimate entities. Up to now only a few studies have focused on action priming on word processing. For example, Lindemann, Stenneken, van Schie and Bekkering (2006) have shown in a go/no go task that preparing to execute an action (e.g. drinking from a cup) primes the processing of a related word (e.g. mouth) but not of an unrelated one (e.g. eye). In this study participants were asked to perform (or not to perform) the action depending on the characteristics of the target word (e.g. lexically correct word or 'non word'). The performed action could be compatible with the final objective (endpoint) of the action (e.g. drinking – mouth /eye). Response times were faster in the compatible condition. However, in this study participants performed an action. It is not clear to what extent the observation of an action (not performing it) would also interacts with word processing (see also Zwaan & Taylor, 2006 on motor resonance in sentence processing). Besides some recent studies in our laboratory, to our knowledge the effects of hand priming on word processing have not yet been investigated. Borghi, Bonfiglioli, Lugli, Ricciardelli, Rubichi & Nicoletti (2005) used hand primes displaying either a precision or a power posture followed by words referring to objects graspable with a precision or a power grip. Borghi, Zotti and Oggianu (under review) presented static and dynamic primes that were objects, hands, or hands interacting with objects followed by target verbs. Participants were required to press a key if they thought the target-verb was concrete. The interaction prime was the fastest. In addition, when a video instead of a still hand image was displayed, RTs with the hand action were faster than with the object prime.

Even if they do not use priming paradigms, several behavioral studies support the hypothesis that motor resonance occurs automatically during exposure to action-related words (nouns, verbs, adjectives) (for a review, see Barsalou, 2008). In addition, studies on language grounding have revealed sensitivity to motion information. Previous studies with recognition paradigms have shown that we mentally simulate the motion of an object implied by a verbal description, for example the motion implied by sentences such as “The car approached you” (Kaschak, Madden, Therriault, Yaxley, Aveyard, & Zwaan, 2004). However, as far as we know no research has explored the possibility that objects characterised by autonomous movement could activate different actions from objects characterised by non autonomous movement.

If seeing a hand-prime evokes motor resonance, and if words activate information on their referents’ motion, we predict a different effect of uni- and bimanual primes on animate and inanimate entities. Namely, unimanual hand primes should affect processing of inanimate entities: these entities do not need to be grasped with both hands, because they do not move. On the contrary, bimanual primes should primarily influence processing of animate entities, provided that these entities elicit motor resonance related to action.

Method

Participants

49 undergraduate students from the University of Bologna volunteered for this experiment without pay. All participants reported normal or corrected-to-normal vision and their first language was Italian. They were all right handed by self-report.

Stimuli and Materials

Stimuli consisted of 8 primes coupled with 32 targets. The primes were moving or static images, the targets were words, i.e. concept nouns. Four primes displayed one arm and hand either moving or static (unimanual primes), 4 other primes displayed two arms and hands either moving or static (bimanual primes). The primes were the following: unimanual 'Action+Motion' (video illustrating one arm moving downwards while the hand is performing a grasp); unimanual 'Motion only' (video illustrating one arm moving downwards while the hand is closed in a fist); unimanual 'Action only' (static image representing one arm with the hand in grasp position); unimanual 'Catch trial' (video representing the 'Action+Motion' condition played in reverse); bimanual 'Action+Motion' (video representing two arms moving downwards while the hands are performing a grasp); bimanual 'Motion only' (video representing two arms moving downwards while the hands are closed in a fist); bimanual 'Action only' (static image representing two arms with the hand in grasp position); bimanual 'Catch trial' (video representing the 'Action+Motion' condition played in reverse).

All videos were recorded with a female actress moving the arm(s) on a blue background, with natural lighting. The upper arm (shoulders excluded), the lower arm(s) and hand(s) were at the centre of the display. The videos were recorded with a JVC high band digital video camera and edited with the software Adobe Premiere® in order to equate the duration (500 ms).

The static stimuli were obtained by extracting a frame from the 'Action+Motion' videos (either unimanual or bimanual) with the software Adobe Premiere®. The frame displaying the central part of the action, when the grasp was clearly recognisable, was chosen as static stimulus.

Target words consisted of 16 names of plants (e.g. apple) and 16 names of animals (e.g. rabbit). The words in both categories (plants and animals) were taken from the Lotto, Dell'Acqua, Job (2001) database of Italian nouns and they were balanced regarding the number of syllables (t_{items}= 0.8, n.s.), frequency (t_{items} = 0.9, n.s.) and familiarity (t_{items} = 0.13, n.s.).

All targets referred to relatively small size objects that can be grasped.

Design

The experiment was based on a mixed design with the Type of Prime (unimanual or bimanual) as between participants variables, Condition ('Action+Motion'; 'Motion only'; 'Action only'; 'Catch trial') and Type of Target (plants or animals) as within participants variables. The 8 types of primes were paired with the 32 targets (16 plants and 16 animals) leading to 256 prime-target couples (128 unimanual and 128 bimanual).

Two different groups of participants took part in the experiment so that each participant saw only 128 items (32 targets x 4 primes -either unimanual or bimanual-). Thirty two prime-target couples (2 plants and 2 animals x 8 conditions) were built for the training phase. In one set primes were unimanual, in the other they were bimanual.

Procedure

Participants were first seated in front of a computer screen at a distance of approximatly 57 cm. They were informed that they would see an image followed by a word. They were asked to press a key on the keyboard with their right hand if the target word referred to an entity that moves by itself. Another key was pressed with the left hand by participants if the target word referred to an entity that is moved by others and does not moved independently. The correspondence between the key and kind of response (animate/inanimate) was counterbalanced. Participants were also required to refrain from responding if the target word was preceded by one (or two) arm(s) moving from the bottom of the screen towards the top (Catch Trial). A training phase (16 prime-target pairs in each group) preceded the test phase in order to familiarize participants with the task. Each item was composed by a fixation cross (700ms) followed by the prime (500ms) and by the target (displayed until a response was provided – timeout 700ms) (Figure 2). Feedback was provided after each response indicating whether the response was correct or incorrect along with the RT. Half of the participants was presented with uni-manual primes and the other half with bi-manual primes.

Insert Figure 1 about here

Results

Participants with an error rate higher than 15% were eliminated (3 participants).

In order to account for anticipatory or unusually slow response times, response times (RTs) +/- 2.5 standard deviations from the grand mean were removed from each participant’s data set. This resulted in a removal of 4% of the data. Subsequently

RTs of the correct (i.e. hit) trials only and errors were analysed. A 2 x 3 x 2 Analysis of Variance (ANOVA) was run on the RTs and errors with Type of Prime (uni- and bi-manual) as between participants' factors and Condition and Type of Target as within participant factors. The analysis on RTs showed a significant interaction of the 3 factors [$F_{(2,88)} = 5.15$, MSe = 1823, $p < 0.01$] as well as significant interactions between Type of Prime x Condition [$F_{(2,88)} = 4.97$, MSe = 3678, $p < 0.01$] and Condition x Type of Target [$F_{(2,88)} = 6.72$, MSe = 12262, $p < 0.01$]. We will discuss only the three way interaction as it's the most relevant on both statistical and theoretical grounds.

A Post Hoc Newman-Keuls ($p < 0.05$) analysis was run on the Type of Prime x Condition x Type of Target interaction showing that, with a unimanual prime, plant targets were processed more slowly when preceded by a 'Action+Motion' prime relative to a 'Motion only' prime (*M* = 725ms; *M* = 690ms respectively) and in trend 'Action only' prime (*M* = 681ms, *p* = 0.059). Plants targets paired with an 'Action+Motion' prime were also processed more slowly than animal targets paired with an 'Action only' prime (*M* = 677ms).

Insert Table 1 about here

Considering the bimanual primes, targets referring to animals were processed faster when preceded by an 'Action+Motion' and a 'Motion only' prime (*M* = 644ms; *M* = 663ms) than when preceded by an 'Action only' prime (*M* = 704ms). No effect was found for plants with bi-manual primes.

The analysis on errors (ANOVA with Type of Prime as between participants factor and Condition and Type of Target as within participants factors) also showed a three way significant interaction between the three factors [$F(2,88) = 3.95$, MSe = 0.688, $p < 0.05$]. The interactions between Type of Prime and Condition [$F(2,88)$ = 10.03, $MSe = 8.16$, $p < 0.001$], Condition x Type of Target [$F(2,88) = 11.86$, MSe = 8.16, $p < 0.001$] and Type of Prime x Type of Target [$F(1,44) = 27.5$, $MSe = 17.75$, $p <$ 0.001] were also significant. A Post Hoc Newman-Keuls ($p < 0.05$) analysis was run on the Type of Prime x Condition x Type of Target interaction showing that targets referring to plants paired with a 'Action only' unimanual primes and targets referring to animals paired with the 'Action+Motion' bimanual primes lead to the highest number of errors and differed from all other conditions, while not differing from each other ($M = 1.95$; $M = 1.78$, respectively).

Comparing the results on RTs and accuracy for animal targets with bi-manual primes, a speed-accuracy trade-off appeared as animal targets paired with bimanual 'Action+Motion' primes were responded to faster leading to a higher number of errors than in the other conditions. Therefore, a further analysis taking into account the speed-accuracy trade-off was deemed necessary.

Response times were divided by the proportion of correct responses (Chan, Merrifield, & Spence, 2005; Townsend, & Ashby, 1978) and entered in an ANOVA with Type of Prime as a between participants factor and Condition and Type of Target as within participants factors (same as above). As in the previous analyses the three way interaction was significant [$F(2,88) = 9.84$, $MSE = 1.17$, $p < 0.001$]. The interactions between Type of Prime x Type of Target [$F(1,44) = 4.98$, $MSe = 1.49$, $p <$ 0.05] and Type of Target x Condition [$F(2,88) = 3.87$, $MSe = 4.62$, $p < 0.05$] were also significant. As above we will discuss only the three way interaction.

The Post Hoc Newman-Keuls ($p < 0.05$) analysis ran on the Type of Prime x Condition x Type of Target interaction showed a significant difference between RTs for targets referring to plants when preceded both by ‘Motion+Action’ and ‘Action only’ primes compared to the ‘Motion only’ condition. Plants in the unimanual ‘Motion+Action’ and ‘Action only’ condition also differed from animal targets in the unimanual ‘Action only’ condition. No significant difference was found when primes were bimanual. Figure 2 illustrates the normalised response times in both unimanual and bimanual conditions.

Insert Figure 2 about here

To summarise, once speed of processing and accuracy are taken into account in the analysis, only unimanual primes displaied a significantly affected target processing. Regarding the type of target, only information elicited by plants was significantly modulated by the prime.

Primes representing an action, either static (‘Action only’) or dynamic (‘Action+Motion’) affected participants responses by increasing RTs to targets referring to plants relative to primes representing a movement non involving action, i.e. with the hand forming a fist (‘Motion only’ condition).

Discussion

In the present study we aimed to clarify two issues: (a) assessing whether uni- and bi-manual actions presented as primes would have a different impact on target processing. We used grasping hands, presented both with static images and videos. (b) We aimed to verify whether the different actions activated by the uni-manual or bimanual hand prime were modulated by the kind of entity presented as a target, particularly to its degree of animacy/self motion.

A number of studies show that objects elicit affordances on the kind of manual action they support (e.g. Tucker & Ellis, 1998). However, to our knowledge no study has been dedicated to the difference between one or two hands. We also reasoned that the ‘motor resonance’ elicited by uni- and bi-manual primes should have been tuned to the kind of objects presented as targets. Plant names should be more associated with unimanual grasping while animal names with bimanual grasping.

As predicted, the kind of object modulates the effect of the hand prime. Both a video showing a grasping action and a static image depicting the central static frame of that action affected participants’ performance. The motor resonance led to an interference effect. The response to plants was slower when the prime depicted a unimanual action (either moving or static/implied), while no effect of prime was found for animals names.

It is worth noting that our task does not allow deciding whether the activation of motor information is automatic or not. It is possible that words activate motor information but not necessarily automatically, given that our task explicitly required activating knowledge on the actions that people can perform on the objects in order to decide whether the objects/entities moved by themselves or should be moved by others.

We argue that the slower RTs in the ‘Action only’ and ‘Action+Motion’ condition are due to an interference effect taking place between the action depicted by the target and the action/motor plan elicited by the target. This could be due to the use of words as target stimuli. Studies providing evidence for facilitation with linguistic stimuli are typically limited to cases in which participants are required to provide motor responses that require a movement rather than a simple key pressure response (e.g., Glenberg & Kaschak, 2002; Tucker & Ellis, 2004). Facilitation was also found when the target is a picture (e.g., Zwaan, Stanfield, & Yaxley, 2003). Otherwise, interference effects are typically reported, across different paradigms (e.g. Buccino et al., 2005; Kaschak et al., 2005). Kaschak et al. (2005) claim that interference might be due to two causes: the difficulty in integrating perceptual information into the linguistic simulation, and the temporal overlap between the two sources of information. In our study, we favour the first explanation: the interference might be due to the difficulty in integrating the perceptual and action information elicited by the prime with the specific motor program linked with animate and inanimate objects. Namely, in our task participants are not required to perform a specific action of grasping to respond, thus the interference occurs between a generic grasping action displayed in the prime and the knowledge on actions plants are acted upon. Considering that a quite large variety of manipulable objects (see Appendix) has been used in the experiment we can assume that different motor plans, i.e. different object-specific grasping movement, are activated through the linguistic input (see embodied theories of cognition). Accordingly interference could be due to the mismatch between a generic grasping and a specific motor plan.

An alternative explanation could be that the interference is due to the activation of the same neural circuitry by the prime and the target which would lead to a surcharge of the system. However we do not favour this idea because prime and target are presented sequentially and not simultaneously. A way of testing this hypothesis in further research would be to present the action and the word simultaneously (for further discussion on this issue, see Borreggine & Kaschak, 2006; De Vega, Robertson, Glenberg, Kaschak & Rinck, 2004).

The responses to animal targets were not modulated by the type of prime. We argue that this is due to the fact that animals are characterised by self-motion rather than the action one could perform on them. Even if animals can be grasped, (for example many have experienced grabbing a cat and taking it into his/her arms), they are mainly associated with their ability to move by themselves. Interestingly some brain regions responding to intentional actions (STS) (Saxe, Xiao, Perrett & Kanwisher, 2004) are also involved in perceiving objects as animate or inanimate (Schultz, Friston, O'Doherty, Wolpert, & Frith, 2005). In this line we argue that animals could be perceived more as acting agents than 'passive' objects of action.

One could argue that the interference occurs due to a mismatch between the motion displayed in the prime and a word referring to a stationary object. However if this was the case one would expect a different interference effect from static and moving action primes, which does not occur. One would also expect an effect of facilitation on response times from moving primes (Motion only and Action+Motion) on 'moving' (animate) targets because they are characterised by motion, not such an effect has been found.

In sum, the present study shows that (unimanual) grasping actions produced an interference effect on response to plant names. At a neural level, one could speculate that this interference effect could correspond to interactions in common cerebral circuitry, i.e. the mirror neuron system.

Our results have different theoretical implications. First, in keeping with simulation theories of language comprehension they indicate that during word processing we are sensitive to the degree of animacy / self motion evoked by natural entities, i.e. plants and animals. To our knowledge, this is the first study that reveals that the simulation activated by words can be sensitive to this dimension. As animate (animals) and inanimate (plants) targets were balanced on the main linguistic variables, we argue that the effect found for plants and the lack of effect found for animals tap into differences in their embodied simulation.

Second, our study complements previous studies indicating that, while observing a hand prime, motor resonance is activated. More specifically, our study shows that we are sensitive to fine-grained differences in the motor program activated by the prime. To our knowledge, this is the first study showing a modulation due to the unimanual vs. bimanual character of the prime. As predicted, unimanual primes had an impact only on entities which are typically grasped with one hand, such as plants. At present we can conclude that our study revealed that uni-manual actions evoke motor resonance for inanimate entities, i.e. plants. Differently inanimate entities could be better characterised as agents than objects of actions.

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		Action+Motion		Motion only		Action only	
		Plants' names	**Animals' names**	**Plants' names**	**Animals' names**	**Plants' names**	**Animals' names**
UNIM.	**RTs (ms)**	725(39)	703(33)	681(27)	710(29)	690(27)	677(27)
	Errors	0.78(0.22)	0.73(0.18)	0.52(0.18)	0.69(0.18)	1.96(0.2)	0.56(0.17)
BIM.	**RTs (ms)**	680(22)	644(20)	667(23)	663(22)	672(25)	704(34)
	Errors	0.65(0.17)	1.78(0.23)	0.6(0.18)	1.04(0.25)	0.48(0.12)	0.69(0.2)

Table 1. Response times not normalised and errors. Standard errors are in brackets.

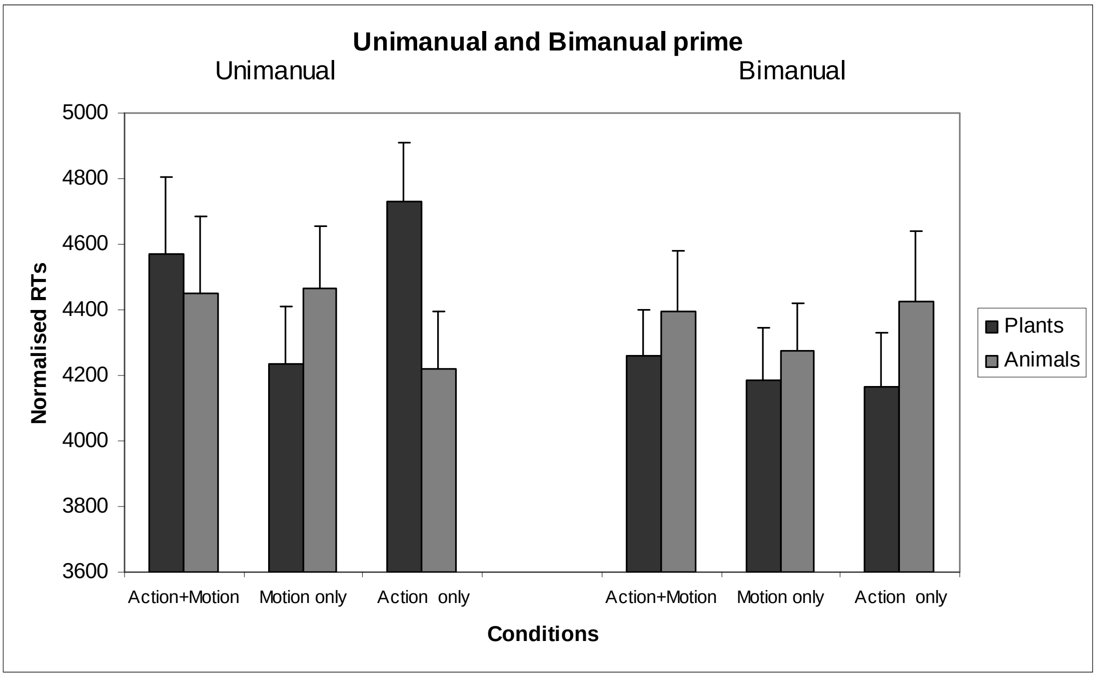

Figure 1. Normalised response times for plant and animal nouns, error bars represent the standard error of the mean. While with unimanual primes plants are responded to faster when no action is displayed in the prime, no effect for either plants or animals was registered with bimanual primes.