HAND-OBJECT INTERACTION IN PERSPECTIVE

*Angela Bruzzo,[1] Anna M. Borghi,[1] Stefano Ghirlanda[1]

In press in Neuroscience Letters, 2008.

* Angela Bruzzo

[1]Department of Psychology

University of Bologna

Viale Carlo Berti Pichat, 5

40127 Bologna, Italy

Phone: +39-051-2091838

Fax: +39-051-243086

E-mail angela.bruzzo@libero.it

Acknowledgements

Study supported by a grant from Italian MIUR. Thanks to Bernhard Hommel, Diane Pecher and an anonymous reviewer for useful comments.

Abstract

We investigated the effect of perspective on the recognition of actions, without using motor preparation. Photographs of a hand wearing a glove were presented as primes, followed by photographs of the same hand interacting with an object. Both primes and targets were shown in ego- or non-egocentric perspective. Participants had to decide whether or not the hand interacted with the object in a sensible way. In order to increase the similarity between the perceived and the enacted movement, half of the participants were required to wear a glove while responding. We found an advantage of the egocentric over the non-egocentric perspective for targets in the Glove condition. The advantage of the egocentric perspective was present for primes as well, even though the effect was limited to the No Glove condition. Results are discussed in the framework of the recent literature on mirror neurons and body schema.

Key words: Body schema; Mirror system; Motor preparation; Perspective; Theory of Event Coding (TEC); Action.

Manuscript

Introduction

To identify the movement of a specific body part, the brain constructs a representation of the general body structure. In doing this, the brain relies on the so-called body schema [12, 13], which encompasses the perceptions and dynamics of an individual's own body in relation to that of another [2]. Neuro-imaging evidence [1, 10] suggests that a multimodal representation of one's own body might be involved in the perception of other people's bodies [18, 23].

Studies on the mirror system (MS) show that, whenever we look at someone performing an action, there is, in addition to the activation of various visual areas, a concurrent activation of the motor circuits recruited when we ourselves perform that action [10, 15]. In other words, seeing an action is thought to activate a motor simulation [4, 17].

The brain imaging studies on the MS in humans are consistent with predictions advanced by common coding theories [14, 19], which focus on the link between perception and action. According to the Theory of Event Coding (TEC), perceived events (perceptions) and events to be produced (actions) are represented by the same integrated, task-tuned networks of feature codes in cognitive structures, called "event codes". One decisive feature of such representations is the commensurability of contents of perception and action intentions, ultimately stemming from the fact that both perception and action plans represent "events in the environment"[14]. This theory generates an important prediction: if perception and action draw on identical representational structures, the similarity between the seen stimuli and the performed actions facilitates processing of the seen stimuli.

In keeping with TEC, recent brain-imaging studies have demonstrated that the perspective through which we perceive others' actions influences performance [6,16] and that distinct areas of the posterior parietal cortex are specialized for egocentric and non-egocentric perspectives [24].

Along the same lines, behavioral studies have focused on the information elicited by a hand photograph presented in different orientations [e.g., 7]. In a study by [25], the authors manipulated the perspective in which the hand was presented. The hand could either match the end posture of the observer's own hand (egocentric perspective) or the end posture of that of another person (non-egocentric perspective). The authors [25] found a congruency effect for the egocentric perspective when a neutral hand stimulus was given as a preview and for the non-egocentric perspective when the prime stimulus was preceded by a fixation dot. They explained the non-egocentric advantage as a stimulus-driven visuo-motor effect, which rapidly encodes suddenly appearing conspecifics' hands. More importantly, the ego- perspective advantage can be interpreted as a planning-driven motor-visual priming effect that selectively enhances the visual processing of body parts. Even if the authors do not discuss this point, the reason for the advantage of the egocentric perspective could lie in the higher similarity between the perceived stimulus and the performed action.

Our study aims to verify whether the similarity between the execution modalities (*how*) of the perceived and the performed action can facilitate processing of motor information related to the seen stimulus. For this reason we manipulated both the perspective (egocentric and non-egocentric) of a visually presented hand and the morphological similarity between the seen hand and the responding hand.

Participants were presented with a prime consisting of a photograph of a human hand wearing a glove. The hand was presented alone, in four different postures. The hand-prime was followed by a target consisting of the photos of the hand either correctly grasping an object or performing an action that did not make sense in relation to the object. The task was to decide whether or not the illustrated action made sense by pressing the relevant key on the keyboard. For example, it makes sense to use a power grip to grasp an apple whereas a crossing finger action does not make sense in relation to an apple. Each photograph was presented in an egocentric and non-egocentric perspective. By egocentric perspective, we refer to the perspective consistent with looking at one's own hand, while by non-egocentric perspective we refer to the perspective consistent with looking at someone else's hand performing an action [22]. To manipulate the similarity between the observed stimulus and the performed action, half of the participants wore a glove while performing the experiment (Glove condition), while the other half did not (No Glove Condition).

Two main hypotheses derived from TEC were tested.

1. We predicted an advantage of the ego- over the non-egocentric perspective due to the increase in similarity between the perceived and the performed action. Also, we hypothesized a compatibility effect between the hand and the hand-object perspective. Hence, a hand in egocentric perspective followed by an egocentric hand-object interaction should elicit the fastest response.

2. The presence of the glove should improve performance due to the inferred visuotactile similarity between the seen stimulus (the hand wearing a glove) and our own body part (our own hand wearing a glove). In particular, we predicted that the best performance should be found when participants wore a glove and saw the hand interacting with the object in an egocentric perspective. In keeping with the TEC, this improvement might be due to the increase of overlap between the perceived and the acted "events".

Methods

Participants

Forty right-handed students from the University of Bologna, with normal or corrected-to-normal vision, participated in the experiment, which was carried out according to the ethical guidelines laid down by the Committee on Human Research of Bologna (Italy). All participants gave their written informed consent for their participation in the study, and were unaware of the purpose of the experiment.

Stimuli

Primes consisted of digital photos of a human hand wearing a glove. Presenting a hand wearing a glove could seem like an artificial step, but it was crucial in order to avoid the recognition of particular morphological features. We used gloves, in line with previous studies [e.g., 8], because other strategies, such as painting the seen hand, would have not impeded recognition of the morphological differences between the subject's own and the seen hand. The photos displayed four different hand postures as primes, two prehensile postures (a precision and a power grip) (e.g., for precision grip Fig.1 A, B), and two postures not related to a prehensile action (horns and a victory signal) (e.g., for horns Fig. 1 C, D). A hand with a lifted index finger worked as a catch trial. As targets, we selected sixteen photos of actions performed with everyday objects. Eight displayed a hand grasping an object with a precision grip (e.g., a tooth-brush) (Fig. 1 E, F) and eight with a power grip (e.g., an orange, Fig. 1 G, H). Besides the sixteen photos displaying a correct grasping action performed with the object (referred to from here onwards as sensible actions), we presented sixteen other photos displaying a hand action that did not make sense in relation to the object (Fig. 1Q, R, S, T). All photos were presented with the hand in both an egocentric and a non-egocentric perspective and were equated for luminance.

Thus, we had a total of 10 primes and 64 targets, 32 representing a sensible action and 32 displaying an action that did not make sense. Each target-stimulus was presented once with each different prime action.

Insert Figure 1

Procedure

The experiment was performed in a quiet, dimly-lit laboratory room. Each participant was randomly assigned to one of two different conditions. In the first condition (Glove condition), they were asked to wear two blue gloves in order to augment the similarity between the observed and the performed actions. Our interest was not the effect of the glove *per se*, but the effects of the increased similarity between the participant's effector and the perceived effector. In the other condition (No glove), participants simply had to perform the task. For both groups the instructions were the same. Participants were required to wear the gloves both during the initial training phase, in which participants familiarized themselves with a separate training set of items, and during the experiment, composed of two blocks, counterbalanced in order across participants. Half of the participants in each group were asked to respond "yes" with the right index in the first block and "no" in the second; the other half was asked to do the opposite. A chin rest was used in the trials, allowing the participants, in principle, to glimpse their own hand. However, they were invited to focus their attention on the center of the screen, where the visual stimuli appeared. Each trial began with the 250 ms display of a photo of a prime, followed by the photo of the target. Participants were instructed to refrain from responding when a photo of a hand with the lifted finger (catch-trial) appeared. Otherwise, they had to indicate by pressing a right or a left button on the keyboard whether or not the target represented an action that made sense. The photo displaying a hand-object interaction remained on the screen until participants responded, with a cut off at 2000 ms. We did not introduce any SOA between prime and target presentation. Participants received feedback when they provided a correct answer. Both reaction times and errors were recorded.

Data analysis

A mixed multifactorial ANOVA was performed on errors, with the factors of Prime Perspective (ego- *vs.* non-egocentric) and Target Perspective (ego- vs. non-egocentric) manipulated within participants, and Morphological Similarity manipulated between participants. No effect was significant. As seen in Table 1, the error pattern indicated an advantage of the egocentric over the non-egocentric perspective, more marked with Primes than with Targets. The error analysis revealed that there was no speed-accuracy trade off, so we focused on an analysis of reaction time. Reaction times more than 2 standard deviations from each participant average were discarded. No participant was excluded from the analysis. Correct RTs were entered into a mixed multifactorial ANOVA. The factors of Prime Perspective (ego- *vs.* non-egocentric) and Target Perspective (ego- *vs.* non-egocentric) were manipulated within participants, while Morphological Similarity (Glove vs. No Glove) was a between participants factor.

Results

Our analyses focused on sensible actions. We avoided analyzing non-sensible actions, because our stimuli were construed and our hypotheses were formulated referring to sensible actions, in analogy with the standard procedure of psycholinguistic and language grounding studies on action sentence sensibility [e.g., 11].

The Prime perspective was not significant, $F_{(1, 38)} = 0.03$, $MSe = 1497.31$, $p = .50$. However, we found a main effect of Target Perspective, $F_{(1, 38)} = 10.23$, $MSe = 3147.87$, $p < .01$, due to the fact that targets were processed faster in an egocentric (M=712.62 ms) than in a non-egocentric perspective (M = 732.68 ms). The main effect of Morphological Similarity ($F_{(1, 38)} = 6.92$, $MSe = 10892.2$, $p <. 0122$) might be due to the simple fact that wearing a glove slows down responses. However, the significant interactions between Morphological Similarity and Target Perspective, $F_{(1, 38)} = 6.92$, $MSe = 3147.87$, $p < .01$ and Similarity and Prime Perspective, $F_{(1, 38)} = 5.85$, $MSe = 1620.18$, $p < .05$ (see Fig. 2, panel A and B) are theoretically relevant.

Insert Figure 2

The first interaction was due to the advantage of the Egocentric Target over the Non-egocentric Target in the Glove condition (Newman-Keuls, $p < .001$), the second due to the advantage of the Egocentric Prime over the Non-egocentric Prime in the No Glove condition (Newman-Keuls, $p < .05$). Having obtained significant interactions between Morphological Similarity and Prime Perspective, and between Morphological Similarity and Target Perspective, we decided to perform two separate ANOVAs for the Glove and No Glove conditions to better understand the double interactions. The decision to perform separate ANOVAs was also due to the difference in RTs between the Glove and No Glove conditions. The factors of both ANOVAs, manipulated within participants, were Prime Perspective and Target Perspective. In the No Glove condition, the factor Prime Perspective reached significance due to the advantage of the ego-over the non-egocentric perspective, $F_{(1, 19)} = 4.33$, $MSe = 896.93$, $p = .05$. In the analysis of the Glove condition, Target Perspective was significant, as targets in the egocentric perspective produced faster RTs than targets in the non-egocentric perspective, $F_{(1, 19)} = 10.15$, $MSe = 2634.90$, $p < .01$. Therefore, our first hypothesis, that the egocentric perspective has an advantage over the non-egocentric perspective, was confirmed. Importantly, whereas the egocentric prime advantage was restricted to the No Glove condition, the egocentric target advantage was more pronounced in the Glove condition. This may be due to the fact that, if the similarity between the perceived and the performed action is increased, as was the case in the Glove condition, participants become more sensitive to the role played by the action goal, that is, by the Target. Interestingly, the predicted congruency effect between the perspective of Prime and Target almost reached significance, $F_{(1, 38)} = 3.64$, $MSe = 828.07$, $p < .06$ (Fig. 3).

Insert Figure 3

The results show both the advantage of the egocentric perspective with targets as well as a prime-target compatibility effect. Namely, faster RTs were obtained when an egocentric Prime was followed by egocentric Target (M=708.02 ms), whereas a non-egocentric prime followed by a non-egocentric target had an advantage of only 3 ms compared to pairs composed of a non-egocentric prime followed by an egocentric target.

In order to be sure that our effects were due to perspective and not to congruency, we analysed the results a second time removing any of the items that were palm up but could represent "canonical" views of one's own hand (horns and victory signals in both perspectives). Accordingly, a further ANOVA was performed with the factors of Prime Perspective (ego- *vs.* non-egocentric) and Target Perspective (ego- *vs.* non-egocentric) manipulated within participants, and Glove/No Glove condition manipulated between participants. The results we found matched the results found with all hand postures perfectly. Specifically, the difference between Target Egocentric and Non-egocentric Perspective was significant, $F_{(1, 38)} = 8.93$, $MSe = 2150.4$, $p < .01$. In addition, there was a significant interaction between Morphological Similarity and Target, $F_{(1, 38)} = 5.22$, $MSe = 2150.4$, $p < .05$, due to the fact that the egocentric Target was processed much faster than all other targets (Newman-Keuls, $p <.001$). Finally, the interaction between Morphological Similarity and Prime Perspective also reached significance, $F_{(1, 38)} = 5.9$, $MSe = 1497.3$, $p < .05$, due to the advantage of the No Glove over the Glove condition and to the fact that, in the No Glove condition, the Prime was processed slightly faster in the egocentric perspective than the non-egocentric Prime (Newman-Keuls, $p =.07$).

Discussion

Our results are clearly in keeping with the TEC theory, that is, with the idea that there is a common framework for the recognition and planning of motor actions.

First, we found a slight advantage in responding when targets were preceded by egocentric rather than by non-egocentric primes. The fact that this effect was confined to the No Glove condition could be due to the perceptual salience of the glove in particular for participants who did not wear a glove.

Second, and more crucially for our predictions, in the Glove condition egocentric Targets were processed faster than non-egocentric Targets. The results on Targets are particularly relevant because target pictures displayed hand-object interactions. The effect obtained in the Glove condition with targets and not with primes indicates that the advantage of the egocentric perspective occurred when the hand was presented together with the object, that is, when the goal of actions ("event in the environment") was displayed. We interpret this result as an indication of the synergic contribution of both object-related (canonical) and action-related (mirror) neurons during observation of actions directed towards graspable objects. It can be objected that the perspective effect should extend to the prime as well, particularly in the Glove condition. However, in our defense we could advance at least two arguments. The first is that we believe our results capture the main point of TEC. This theory concerns the planning of actions and claims that an event is more easily perceived in cases of correspondence between the planned action and the environment in which the action is executed. Regarding our stimuli, the event was displayed in the target, where the action was actually presented. The second argument is that we did find the predicted Prime-Target compatibility effect, even though this result did not reach full significance; participants performed particularly well when egocentric Targets followed egocentric Primes.

Our study has implications for research on perspective taking. Recent studies provide evidence of perspective effects. For example, in a fMRI study [16], participants either passively watched or imitated hand or foot actions depicted in video clips. The video clips depicted actions filmed either from an egocentric or a non-egocentric perspective. Latency for imitation was significantly shorter for the egocentric than for the non-egocentric perspective. Functional imaging results showed more activity in the left sensory motor cortex for the egocentric perspective, even during simple observation, and in the lingual gyrus for the non-egocentric perspective. Furthermore, neural evidence confirms our sensitivity to action perspective. For example, [6] have shown the existence of neurons in the superior temporal sulcus that differentiate self-produced actions from the actions of others. PET studies [21] have demonstrated that cortical activations in inferior parietal, precuneus and somatosensory differ when humans imagine actions in egocentric or non-egocentric person perspective. In addition, a number of neuropsychological studies on both normal subjects and patients have shown that shifts in perspective might lead to erroneous attributions of our own actions to others (e.g., 8). In these studies participants typically saw their own effectors acting according their own or the experimenter's perspective.

Our behavioral study both confirms such perspective effects and extends previous results. Namely, our findings suggest that visually displayed hands interacting with objects activate a sort of motor simulation, which is sensitive to perspective. Differently from previous studies, we found that even seeing static stimuli portraying the performance of an action is sufficient to activate a representation of our body schema and to induce a resonance effect. Importantly, the perspective effect driven by a motor simulation occurred even in the absence of a motor-preparation phase and without a task that strongly involves the motor system, such as a simple key pressure task.

References

[1] S.V. Astafiev, C.M. Stanley, G.L. Shulman, M Corbetta. Extrastriate body area in human occipital cortex responds to the performance of motor actions, Nature Neurosci 7 (2004) 542–548.

[2] G. Berlucchi & Aglioti S. The body in the brain: neural basis of corporeal awareness. Trends in Neurosciences 20 (1997) 560-564.

[3] A.M. Borghi, C. Bonfiglioli, L. Lugli, P. Ricciardelli, S. Rubichi, R. Nicoletti. Are visual stimuli sufficient to evoke motor information? Studies with hand primes, Neurosci. Lett. 411 (2007) 17-21.

[4] A. Bruzzo, B., Gesierich, A. Wohlschlaeger. Simulating biological and non biological motion. Brain and Cogn 66 (2008) 145-149.

[5] D.N. Bub, M.E.J. Masson, C.M. Bukach. Gesturing and naming: the use of functional knowledge in object identification, Psychol Sci 14 (2003) 467-472.

[6] D.P. Carey, D.I. Perrett, & M.W. Oram. Recognizing, understanding and reproducing action. In: Jeannerod, M., Grafman, J., (Eds). Handbook of Neuropsychology-Action and Cognition, 1997.

[7] L. Craighero, A. Bello, L. Fadiga, G. Rizzolatti. Hand action preparation influences the responses to hand pictures, Neuropsychologia 40 (2002) 492-502.

[8] E. Daprati , N.FranK, N.Georgieff, et al. Looking for the agent: an investigation into consciousness of action and self-consciousness in schizophrenic patients. Cognition 65 (1997) 71-86.

[9] G. di Pellegrino, L. Fadiga, L. Fogassi, V.Gallese, G. Rizzolatti. Understanding motor events: a neurophysiological study. Exp Brain Res 9 (1992) 176-180.

[10] P.E. Downing, Y. Jiang, M. Shuman, N. Kanwisher. A cortical area selective for visual processing of the human body, Science 293 (2001) 2470–2473.

[11] A. Glenberg & M.P. Kaschak, Grounding language in action. Psychonomic Bull & Rev 9 (2002) 558-565.

[12] P. Haggard, K. Kitadono, C. Press, M. Taylor-Clarke The brain's finger and hands. Exp Brain Res 172 (2006)94-102.

[13] H. Head, & H.G. Holmes Sensory disturbances from cerebral lesions. Brain 34 (1911) 102-254.

[14] B. Hommel, J. Musseler, G. Aschersleben, W. Prinz. The Theory of Event Coding (TEC): a framework for perception and action planning, Behav Brain Sci 24 (2001) 849-878.

[15] M. Iacoboni, & M. Dapretto. The mirror neuron system and the consequences of its dysfunction. Nature Review Neuroscience 7 (2006) 942-51.

[16] P.L. Jackson, A.N. Meltzoff, & J. Decety. Neural circuits involved in imitation and perspective taking, Neuroimage 31 (2006) 429-439.

[17] M. Jeannerod. Motor Cognition: What actions tell the self. Oxford University press (2007).

[18] D.T. Leube, G. Knoblich, M. Erb, W. Grodd, M. Bartels, T.T. Kircher. The neural correlates of perceiving one’s own movements, Neuroimage 20 (2003) 2084-2090.

[19] W. Prinz. Perception and action planning. Eur J Cogn Psychol 9 (1997) 129-154.

[20] C.L. Reed, & M.J.Farah. The psychological reality of the body schema: A test with normal participants, J Exp Psychol Hum Percept Perform 21 (1995) 334–343.

[21] R. Ruby, & J. Decety. Effect of subjective perspective taking during simulation of action: a PET investigation of agency, Nat. Neurosci 4 (2001) 546-550.

[22] R. Saxe, N. Jamal, & L. Powell. My Body or Yours? The effect of visual perspective on cortical body representations, Cereb. Cortex 6 (2006) 178-182.

[23] A.Tessari, & A.M. Borghi (2007). Body image and body schema: The shared representation of body image and the role of dynamic body schema in perspective and imitation. Commentary to the target-article 'Somatosensory processes subserving perception and action' by Dijkerman & de Haan. Behav Brain Sci. 30 (2007) 221-222.

[24] K. Vogely & G.R. Fink. Neural correlates of the first-person-perspective, Trends Cogn Sci. 7 (2003) 738-742.

[25] S. Vogt, P. Taylor, B. Hopkins. Visuo-motor priming by pictures of hand postures: perspective matters, Neuropsychologia 41 (2003) 941-951.

FIGURES LEGEND

Figure 1. **The stimuli**. The photos display: four different hand postures used as primes, in egocentric (A, C, E, G) or in non-egocentric perspective (B, D, F, H), a catch trial in both perspectives (I, L), and some targets. The targets display a precision grip in egocentric (fig. 1M: grasping a tooth-brush) and in non-egocentric perspective (fig. N), and a power grip, in egocentric (fig. O: grasping an orange) and non-egocentric perspective (fig.P). In fig Q, R, S, T non-sensible actions are displayed.

Figure 2. **The interactions. (A) Targets.** In the Glove condition, Targets in an egocentric perspective produced faster RTs than Targets in a non-egocentric perspective. **(B) Primes.** In the No Glove condition, Targets preceded by Primes in egocentric perspective were processed faster than Targets preceded by Primes in a non-egocentric perspective. Asterisks mark significant comparisons ($p < 0.01$). Bars show standard errors.

Figure 3. **The congruency effect between the perspective of Prime and Target.** The fastest RTs were obtained when an egocentric Target followed an egocentric Prime.

Table 1. **Error Analysis.** The values of accuracy are shown (%) for each condition.

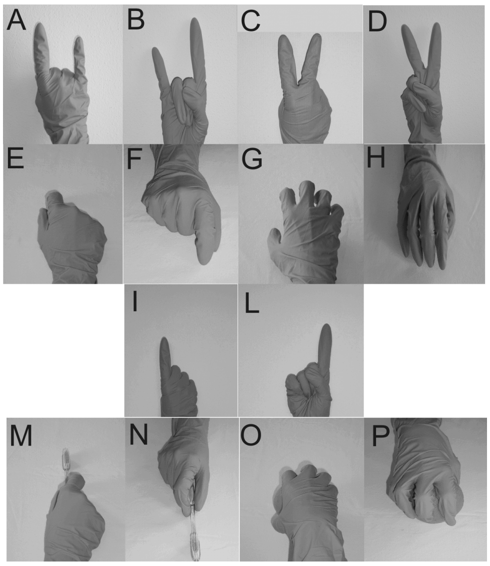
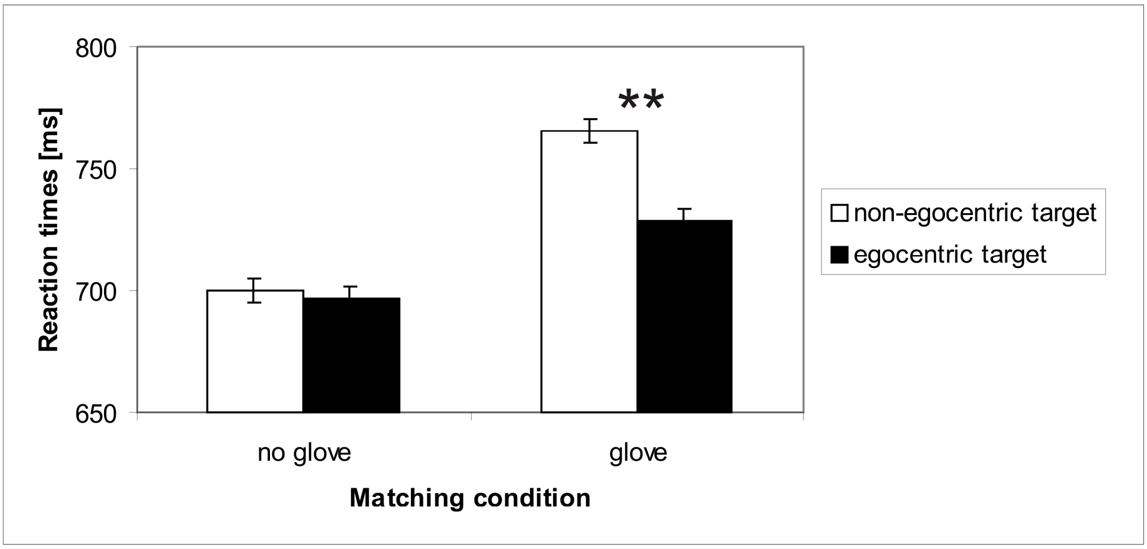
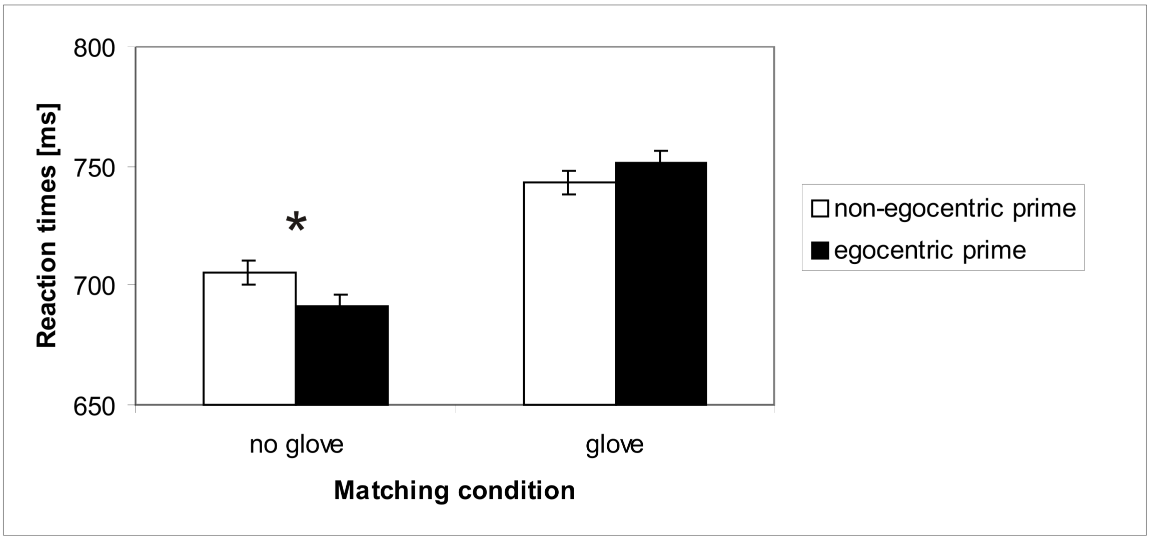

A
B
C
D
E
F
G
H
I
L
M
N
O
P

Fig.2

A


800
750
700
650
Reaction times [ms]
**
no glove
glove
Matching condition
non-egocentric target
egocentric target

B


800
750
700
650
Reaction times [ms]
*
no glove
glove
Matching condition
non-egocentric prime
egocentric prime

Tab.1

Reaction Times Means (ms)			Accuracy (%errors)	
	Glove	No glove	Glove	No glove
Allocentric Target allocentric	742.98	687.082	0.93	0.94
Allocentric Target egocentric	752.55	686.419	0.68	0.82
Egocentric Target allocentric	701.67	707.052	0.77	0.93
Egocentric Target egocentric	730.74	680.859	0.85	0.83