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Discussion forum

How does “mirroring” support joint action?

*Lincoln J. Colling, Günther Knoblich and Natalie Sebanz**

Central European University, Dept. of Cognitive Science, Budapest, Hungary

The discovery of mirror neurons (e.g., Gallese et al., 1996) has reignited interest in theories that postulate a tight functional link between perception and action. According to these theories, perception and action share a common representational code, with actions coded in terms of the distal perceptual effects that they produce (Prinz, 1997). Accordingly, action representations should be activated when perceiving actions or perceiving the perceptual effects generated by actions. Mirror neurons have been regarded as a neural substrate implementing this functional principle. Perhaps the most important implication of common coding is that it establishes a social link between actor and observer that supports action understanding (Rizzolatti and Sinigaglia, 2010) and/or prediction (Wilson and Knoblich, 2005). How might close perception–action links help people to perform actions together? In the sections that follow, we discuss three possible functions of mirroring for joint action: 1) supporting temporal coordination in real time, 2) enabling seamless integration of one's own and others' actions in joint action planning, and 3) enabling groups to imitate the coordinated actions of other groups.

Close perception–action links support temporal coordination by enabling predictions about others' actions without the need for a separate perceptual prediction mechanism. Emulator theories postulate that *forward models* in the motor system automatically generate continuous real-time predictions about the expected sensory consequences that will result from performing an action (Wolpert and Kawato, 1998). Combining this postulate with the assumption of an automatic perception action match leads to the hypothesis that the same forward models used in action execution can also be used to generate predictions about the future course of actions that others are currently performing (Csibra, 2008; Kilner et al., 2007; Knoblich and Flach, 2001; Wilson and Knoblich, 2005). Such a mechanism could be highly useful for achieving flexible coordination between different actors in real time (Sebanz and Knoblich, 2009). There is recent evidence that motor prediction takes place during joint action: In a study by Kourtis et al. (2013), EEG was measured while participants prepared to receive an object from a task partner. A slow rising motor component of the EEG (the late CNV) peaked exactly at the moment in time when the participant's partner started to initiate her giving action, even though this component normally peaks at the onset of one's own actions. This suggests that partners in joint action engage in predictive motor planning of each other's actions. Results from a study investigating coordination of ballistic movements (jumping) provide further support for the role of motor prediction in joint action (Vesper et al., 2013). Participants succeeded in temporally coordinating landing times with an invisible partner even when their jumping distances differed considerably. Jump height and jump time scaled with the partner's jump and closely matched individual bipedal jumping, supporting the conclusion that internal forward models helped participants to coordinate with their invisible partners.

However, motor prediction alone cannot explain how participants coordinate the landing time of their jumps. It is also necessary for them to relate their actions to each other through a joint plan that specifies not only their own but also their partner's part. Such integrated planning of own and others' actions is likely enabled by the representational equivalence between self-produced actions and other-produced actions. This assumption is supported by the finding that people have a tendency to represent distributed tasks as joint ones even if it would be more effective for them to only represent their own part (Sebanz et al., 2005). In an EEG study that directly compared individual and joint planning, a

* *Corresponding author*. Central European University, Department of Cognitive Science, Frankel Leo utca 30-34, 1024 Budapest, Hungary.
E-mail addresses: n.sebanz@donders.ru.nl, sebanzn@ceu.hu (N. Sebanz).

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larger medial P3 amplitude was observed during preparation for joint action. The higher amplitude likely reflects the generation of a joint task representation that includes the other's part (Kourtis et al., 2013). Such joint task representations may assist agents in executing complementary actions, as in the jumping study discussed above. They may also modulate the motor response to observed actions. For instance, Sartori et al. (in press) found that when participants observed action sequences, motor representations congruent with the observed actions were activated only during the individual part of the sequence. When the observed agent made a social request – gesturing as if to pour coffee into a cup placed "in front" of the participants – motor representations for the complementary action of picking up the cup became active. Joint task representations may thus structure the representation of one's own and others' actions.

A further function of joint task representations is that they enable perception–action matching between groups of individuals. Typically, perception–action matching is considered as a phenomenon that occurs between two individuals and explains why observing an action creates a tendency to perform this action (Brass et al., 2001). However, if people acting together form joint action plans that specify the relation between their actions in terms of perceptual outcomes, then observing others producing joint actions should trigger a tendency to perform these joint actions. In support of this hypothesis Tsai et al. (2011) found that when participants were engaged in a task with another person, observing actions facilitated action production specifically when the observed actions were produced by two people engaged in a joint action. There was no such facilitation when the two participants observed a single person performing the very same actions. This finding has two important implications. First, joint action plans seem to have the power to override individual perception–action matching in favour of perception–action matching at the group level. Second, this provides a mechanism for the cultural transmission of joint skills through imitation of joint action.

To conclude, tight links between perception and action can support joint action because they permit actors to plan joint actions using the same type of representations for self and other. Joint action plans, in turn, can facilitate real-time prediction by allowing the same predictive mechanisms in action execution to serve as predictors for one's own and others' individual parts in a joint action. Finally, perception action matching can be scaled up to the group level so that it becomes a candidate mechanism for imitation of coordinated group action.

REFERENCES

Brass M, Bekkering H, and Prinz W. Movement observation affects movement execution in a simple response task. *Acta Psychologica*, 106: 3–22, 2001.

Csibra G. Action mirroring and action understanding: An alternative account. In Haggard P, Rossetti Y, and Kawato M (Eds), *Sensorimotor Foundations of Higher Cognition*. New York: Oxford University Press, 2008: 435–459.

Gallese V, Fadiga L, Fogassi L, and Rizzolatti G. Action recognition in the premotor cortex. *Brain*, 119: 593–609, 1996.

Kilner JM, Friston KJ, and Frith CD. Predictive coding: An account of the mirror neuron system. *Cognitive Processing*, 8: 159–166, 2007.

Knoblich G and Flach R. Predicting the effects of actions: Interactions of perception and action. *Psychological Science*, 12: 467–472, 2001.

Kourtis D, Sebanz N, and Knoblich G. Predictive representation of other people's actions in joint action planning: An EEG study. *Social Neuroscience*, 8: 31–42, 2013.

Prinz W. Perception and action planning. *European Journal of Cognitive Psychology*, 9: 129–154, 1997.

Rizzolatti G and Sinigaglia C. The functional role of the parietofrontal mirror circuit: Interpretations and misinterpretations. *Nature Reviews Neuroscience*, 11(4): 264–274, 2010.

Sartori L, Bucchioni G, and Castiello U. When emulation becomes reciprocity. *Social Cognitive & Affective Neuroscience*, in press. Advance Access published April 8, 2012, http://dx.doi.org/10.1093/scan/nss044.

Sebanz N and Knoblich G. Prediction in joint action: What, when, and where. *Topics in Cognitive Science*, 1: 353–367, 2009.

Sebanz N, Knoblich G, and Prinz W. How two share a task: Corepresenting stimulus-response mappings. *Journal of Experimental Psychology: Human Perception and Performance*, 31: 1234–1246, 2005.

Tsai JC-C, Sebanz N, and Knoblich G. The GROOP effect: Groups mimic group actions. *Cognition*, 118: 135–140, 2011.

Vesper C, Van der Wel RPRD, Knoblich G, and Sebanz N. Are you ready to jump? Predictive mechanisms in interpersonal coordination. *Journal of Experimental Psychology: Human Perception and Performance*, 39: 48–61, 2013.

Wilson M and Knoblich G. The case for motor involvement in perceiving conspecifics. *Psychological Bulletin*, 131: 460–473, 2005.

Wolpert DM and Kawato M. Multiple paired forward and inverse models for motor control. *Neural Networks*, 11: 1317–1329, 1998.

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