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Title

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Permalink

<https://escholarship.org/uc/item/44p1s4zq>

Journal

Proceedings of the Annual Meeting of the Cognitive Science Society, 27(27)

ISSN

1069-7977

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Publication Date

2005

Peer reviewed

Neural Correlates Underlying Action-intention and Aim-intention

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Abstract

In this paper we present a theoretical analysis of recent neuroscientific evidence for different neural activations underlying “action-intention” and “aim-intention”. As regards action-intention, it is shown that recognizing the action-intentions of others is based, at least in part, on the same mechanisms that underlie one’s own action-intention. In contrast, a specific area of activation was found to correlate with social aim-intention, a special case of aim-intention related to acting together. This result suggests that the distinction between I-mode (viz. “private” mode) and we-mode (viz. “group” mode) intention is relevant also at the neuroscientific level of analysis.

Intentional Action, Action-intention, Aim-intention

People normally distinguish between “intentional” and “unintentional” behavior, and this distinction applies not only to self-initiated actions, but also to other people’s actions. By observing people acting, we can usually say *what* they doing and what their *goals* are (Baldwin & Baird, 2001). We can frequently even imagine *why* they are acting.

If agents have this capacity, it must supervene on their brain activities. Thus, the question is to know which specific neural processes enable it. The topic of this paper is the investigation of the neural processes underlying one’s own intentional action and the observation of others’ action. How do we understand other people’s intentional actions? What is the relation, in neural terms, between action and intention and what is the neural basis of intention? How do we impute intention on the basis of action?

In order to address these questions we need first to introduce some relevant conceptual distinctions.

We assume that an action is a behavior undertaken with a goal in view and partly because of this goal. Action depends for its intentionality on a relevant intention of the agent. Following Tuomela (in press), this intention can be either an “action-intention” or an “aim-intention”.

Action-intention. If the intention concerns the direct performance of an action (e.g., when an agent intends to open the window), we speak of an action-intention. In this case, the agent is assumed at least to lack the belief that it is impossible for him to perform the action. This kind of intention is (direct) action-intention. At in least in this paper, action-intention will be identified with the intention to perform an action directed to a *proximate goal* (e.g., reaching and grasping an object).

Aim-intention. An action-intention contrasts with an aim-intention. Whereas action-intention is necessarily related to one’s own actions, aim-intention does not require a control condition, e.g. that the agent believes that he can alone bring about or see to it that the action comes about. An aim-intention can in typical cases be rendered as “the agent intends, by his actions, to bring about a state or event E”, where E can in principle be any kind of state.

An aim-intention can be either I-mode or we-mode. Intending in the I-mode just means intending purely personally (or as a private person), the relevant intention expression here being “I intend to do X”, while intending in the we-mode means intending as a group member, the relevant intention-expression here being “we together intend to do X” (where X can be done together or separately by us).

The Action System

Empirical evidence suggests that recognizing the action-intentions of others is based, at least in part, on the same mechanisms that underlie one’s own action-intention.

The discovery made approximately ten years ago of a particular class of motor neurons in a sector of the ventral premotor cortex of monkeys, called F5, provided the first convincing physiological evidence for a direct match between action execution and action perception (Gallese *et al.*, 1996; Rizzolatti *et al.*, 1996). In fact, quite unexpectedly, the study of motor functions showed that not only are pure motor neurons found in the F5 area, but also

that are neurons that fire when a recorded monkey observes another monkey, or even an experimenter, performing a similar action.

Subsequent experiments showed that these neurons, designated as “mirror neurons”, are not restricted to the premotor cortex, but are also found in other areas of the monkey brain, notably, in the posterior parietal cortex (Gallese *et al.* 2002), and in homologous areas in the human brain (Fadiga *et al.*, 2002; Grezes *et al.*, 2003; Hamzei *et al.*, 2003).

As Jackson and Decety (2004) note, the existence of a system matching executed and perceived actions offers a parsimonious explanation of how we recognize other people’s intended actions - i.e., by a direct mapping of the visual representation of the observed action onto our own motor representation of the same action. The same motor representation is used for intending actions as well as recognizing other people’s action-intentions (Garbarini & Adenzato, 2004).

The Necessity of a “Who?” System

The existence of shared neural representations enables us to settle the question of what the agent is doing, but it poses the problem of action/intention attribution (Becchio & Bertone, 2004): if the same areas are activated while representing one’s own action and during the observation of another person’s action, how do we in neural terms distinguish between ourselves and others? The activation of shared neural representations allows us to identify the action-intention (e.g., to discriminate between the intention of grasping an object and the intention of touching it), but it seems not to be *per se* sufficient to attribute the intention to an agent.

The Agent System

At the level of the mirror neuron system, the agent parameter is still not articulated as a component of the representation of the action. As Dokic and Pacherie (2004) note, the agential understanding of action is something different. It involves understanding the more complex relationship between an agent with a goal, the instrumental means, and the effects produced. In fact it involves agent-intentionality. Various neural mechanisms have been proposed as possible candidates for the “Who” system (Georgieff & Jeannerod, 1998), specifically dedicated to action attribution. One hypothesized mechanism is the monitoring of signals arising from body movements, i.e. comparison between the control signals that contribute to generating a movement and signals arising out of its execution. There is good evidence that the inferior parietal cortex and the insula are crucial components of this mechanism, which is specifically involved in perceiving the *spatial* features of movements (Decety *et al.* 2002; Chaminade & Decety, 2002; Farrer *et al.*, 2003; for a review see also Jackson & Decety, 2004). A recent study by Leube *et al.* (2003) found that right posterior superior sulcus activation positively correlates with a *temporal* delay introduced on-line between an action and its visual feedback.

The spatio-temporal congruence of the features of a movement certainly represents a strong cue for determining the experience of agency. This mechanism, however, does not account for the frequent instances in which an intention is generated but the corresponding action is not executed. A paradigmatic situation where this occurs is motor imagery (i.e., imagining the performance of an action), in which there are no reafferent signals and no proprioceptive signals. Yet, attribution of action is clearly made (Jeannerod, 2003).

Jeannerod (2003) hypothesizes that in situations such as these, correct attribution depends on the existence of non-overlapping areas that are specifically activated for the self and others. The diagram in Figure 1 is a tentative illustration of this process. It represents a motor cognitive situation involving two people. Agent A generates a representation of a self-generated action, i.e., a motor intention. If it is then executed, it will become a signal for agent B, such that agent B will form a representation of the action she sees. Agent B will make an estimate of the social consequences of the action she sees and will possibly change her beliefs about agent A. The interaction of the two agents should depend on the interaction of the representations of the observed and executed actions within each of the two brains. In fact with an individual, the two representations are closely situated and partially overlap. Determining who is acting - the other or the self - should be based on the non-overlapping part.

Motor imagery studies provide a crucial opportunity to test these hypotheses. In a PET experiment, Ruby and Decety (2001) asked participants to imagine actions from different perspectives. In the first-person perspective, participants were told to imagine that they are executing a given action. In the third-person perspective, the instruction was to imagine that they were watching somebody else doing that same action. In the first-person perspective, specific activation was observed in the inferior parietal lobule in the left hemisphere. By contrast, activation was found in a symmetrical area of the right hemisphere for the third-person perspective. Other areas were activated in both conditions.

It is interesting to note that in both experimental conditions, participants were required to imagine an action. The representations activated in both situations were thus activated from within. The fact that a difference in activation was nevertheless observed in the right inferior parietal lobe shows that the inferior parietal lobe is not simply involved in associating actions and their sensory consequences (Farrer *et al.*, 2003), but also in distinguishing the self from others. In a subsequent PET study, Ruby and Decety (2003) investigated the neural correlates of the self/other distinction at the conceptual level by comparing the neural networks involved in answering the same set of questions from either a first- or a third-person perspective. Participants were selected from a group of medical students and were presented with written sentences related to the health sciences. They were then instructed to make truthful judgments about the statements, according either to their own perspective or according to what they thought a layman might think. Variations in rCBF between the two conditions demonstrated that the brain areas distinguishing the cerebral

correlates of first- and third-person perspective-taking at the conceptual level are similar to those already detected at the motor level, i.e. the right inferior parietal lobe and the frontopolar and somatosensory cortices.

Furthermore, the role of the inferior parietal lobe in first-person/third-person perspective distinction is confirmed by neuropsychological and psychopathological evidence. Mesulam (1981) reported the case of a patient with an abscess of the right parieto-occipital region who suffered

from delusion of external control. Schizophrenic patients experiencing passivity phenomena believe their thoughts and actions to be those of external, or alien, entities. Using a PET methodology on such patients, Spence *et al.* (1997) found hyperactivation of the right inferior parietal cortex, and experience passivity as compared to healthy subjects during the performance of freely selected movements.

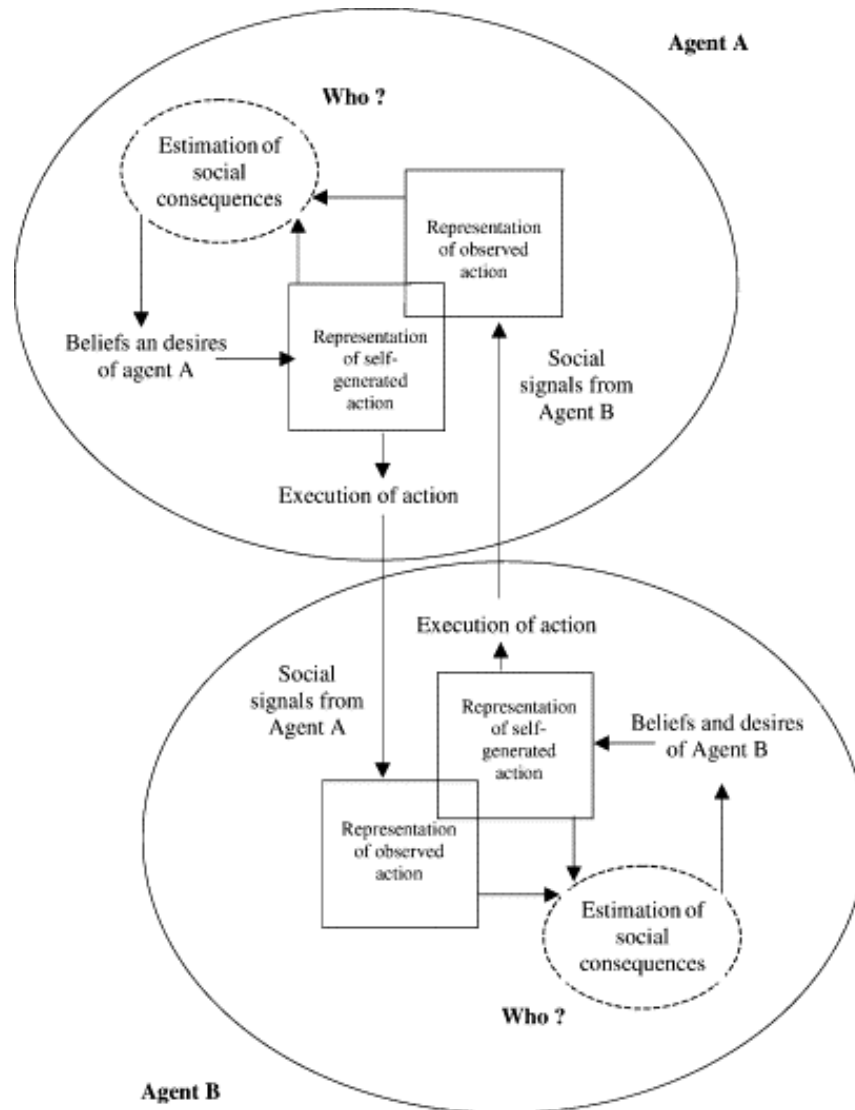


Figure 1: The diagram depicts the interactions of two agents (A and B) observing each other. Each agent builds a representation of his or her own intentions/actions and of the intentions/actions of the other agent. Representations of self-generated actions and observed actions tend to overlap. From Jeannerod (2003).

The Aim System

The processes described thus far concern the recognition of an action-intention and its attribution. As we have seen, a further aspect to be considered concern aim-intention. The same behavior, performed by the same agent can be initiated for different aims: enlarging the temporal horizon allows us to focus on what the agent aims at by its action. As said above, an aim-intention can be either in the I-mode or in the we-mode (Tuomela, 2002). Consider the case of an agent, John, lighting a candle. John may light a candle because the electricity has gone out, and he wants to read a book. This is an I-mode case. As to we-mode intention, suppose John and Mary have both formed the (we-) intention to have lunch together, their we-intention (amounting to a joint intention when considered collectively) is a we-mode aim-intention. I-mode means acting and having an attitude privately, as a private person, whereas we-mode means having it as a group member.

Walter *et al.* (2004) have launched a new series of brain mapping experiments, with the objective of distinguishing between merely private aim-intention and social aim-intention. In a first fMRI experiment, participants were asked to read short comic strips that depicted an unfolding story plot. The participants' task was to choose the most logical story ending from three pictures representing answers. The story content was either physical, i.e., unintentional (a ball blown by the wind breaking several bottles) or intentional. In turn, the intentional strip contents pertained to three conceptual categories, depicting either the intentional, I-mode action of a single agent (changing a broken bulb in order to read a book) or of two agents acting independently in the I-mode (an agent building a doghouse while another agent sets up a tent for camping), or social interaction between two people communicating through gestures (requesting another person to pass a bottle by pointing at it).

The most interesting result was a significant increase in activation associated with the social interaction condition. Seeing two agents communicating resulted in significant activation in the medial prefrontal cortex, especially in the anterior paracingulate cortex. The fact that Walter *et al.* (2004) found no activation during the reading of comic strips depicting either one agent acting or two agents acting independently of each other suggested that the observed activation was not due simply to the intentional content or to the number of agents represented in stories. Indeed, the activation of the anterior paracingulate cortex required two agents socially interacting.

A somewhat controversial issue is whether cooperation requires that agents, beyond having a shared social aim, also actually overtly interact (for a discussion of this point see Tuomela (2000), chapter 3). In the first experiment the critical activation was always associated with actual interaction. Of course, the interacting agents also had a social aim but the experimental design did not allow differentiating between the effect of interaction and the effect of social aim.

Would we still find an activation within the anterior paracingulate cortex when eliminating actual interaction?

The question is in part addressed by the second experiment designed by Walter *et al.* (2004). This experiment substituted the condition involving actual interaction for a new conceptual category: prospective social intentionality, which the authors referred to as the intention of a single agent whose private action is oriented towards subsequent, social interaction (e.g., John preparing a romantic evening with Mary). This condition involves a social aim but without actual interaction. The reasoning underlying the experiment was that if anterior paracingulate cortex activation was due to the presence of two agents actually interacting, no activation should be observed in the prospective social intentionality condition. Conversely, if the activation depended on the social nature of the aim an agent pursued, anterior paracingulate cortex activation should still be observed.

The results confirmed this second prediction: a pattern of activation similar to that observed in the social interaction condition was also found in the prospective social intentionality condition. As expected, based on the results from the previous experiment, no activation was detected in the intentional conditions that presented either a single agent or two agents acting independently in the I-mode.

The experiment shows that the activation of the anterior paracingulate cortex modulates with respect to the nature of the aim (social vs. non-social). Observing an agent acting on a social aim results in the same activation associated with the observation of two agents socially inter-acting.

A question still to be investigated is whether a social aim in this kind of context has to be thought as representing, in all cases, a foreseen social interaction in order to result in the expected pattern of activation. At least the majority of the examples of prospective social condition used by Walter *et al.* (2004) implied in fact the representation of a future interaction). As a consequence, even if the second experiment allows us to exclude that an actual interaction is a necessary condition, it does not rule out the possibility that foreseen interaction plays a role in such activation.

Conclusions

In this paper we presented a theoretical analysis of recent neuroscientific evidence for different neural activations underlying action-intention and aim-intention (as defined in the paper and also in Tuomela, 2002). As regards action-intention, it is shown that recognizing the action-intentions of others is based, at least in part, on the same mechanisms that underlie one's own action-intention. In contrast, a specific area of activation was found to correlate with social aim-intention, a special case of aim-intention related to acting together (Walter *et al.*, 2004). This result suggests that the distinction between I-mode (viz. "private" mode) and we-mode (viz. "group" mode)

intention might be relevant also at the neuroscientific level of analysis.

Acknowledgements

This work was supported by MIUR of Italy (cofin 2003, protocol n. 2003119330_008).

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