Reading Other's Intentions: An fMRI Study

Bruno G. Bara (bruno.bara@psych.unito.it)
Mauro Adenzato (adenzato@psych.unito.it)
Ivan Enrici (enrici@psych.unito.it)
Angela Ciaramidaro (angela.ciaramidaro@psych.unito.it)
Center for Cognitive Science, University of Turin
via Po 14 - 10123 Turin, Italy

Lorenzo Pia (l_pia@psych.unito.it)
Department of Psychology, University of Turin
via Po 14 -10123 Turin, Italy

Susanne Erk (s.erk@med.uni-frankfurt.de)
Henrik Walter (h.walter@med.uni-frankfurt.de)
Johann Wolfgang Goethe University
Heinrich-Hoffmann-Str. 10, D-60528 Frankfurt am Main, Germany

Abstract

Theory of Mind (ToM) is a neurocognitive mechanism developed by natural selection to bear social complexity. In literature there is an agreement on the existence of a widely distributed neural network underpinning ToM, including right and left posterior Superior Temporal Sulcus (right pSTS and left pSTS), Precuneus, and Medial Prefrontal Cortex (MPFC). Although the prevalent view is that the MPFC is the key brain area subserving ToM, recently it has been argued that the role of the right posterior STS is more specific than the role of the MPFC for the attribution of mental states. In order to contribute to the scientific debate regarding the key regions of the ToM network, here we introduce a new theoretical distinction among varieties of intentions able to detail the role of these brain regions.

Keywords: Theory of Mind; Intention; Goal; Sharedness; fMRI.

Varieties of Prior Intentions

In philosophy of mind there is a conceptual difference between prior intention and intention in action. Searle (1983) defines *prior intention* as an initial representation of the goal of an action prior to the initiation of the action; this kind of intention is formed in advance. In contrast, an *intention in action* is the proximal cause of the physiological chain leading to overt behaviour. In cognitive neuroscience, the term intention in action has been replaced by the term *motor intention* (Jeannerod, 1994; Becchio et al., 2006). Note that the causal order of prior and motor intentions from a first person perspective is reversed in typical ToM paradigms from a third person perspective. Whereas a prior intention logically and temporally precedes the motor intention in the first person perspective (e.g., in Dante's Inferno, Minos intends to send the damned to their place in Hell and hence girds himself with his tail), in the third person perspective prior intentions are inferred after the action has been observed (e.g., Dante, from the fact that Minos girds himself with his tail, infers that Minos intend to send the damned to their proper circle). The purpose of this work is to examine how human beings infer prior intentions after the observation of others' actions, and not to discuss how people read motor intention.

We propose a distinction between prior intentions along two dimensions: the kind of the *goal* (private or social), and the presence or absence of *sharedness* of the goal pursued by the agents. This means that, starting from a specific observation of an action, we can infer two kind of prior intentions: private intention and social intention. Social intention and private intention differ with respect to the nature of the inherent goal.

Private intentions (PInt) elicit the representation of a private goal. We define private goal as a goal in which no other but the actor is involved in the satisfaction of the goal.

Social intentions elicit the representation of a social goal. We define social goal as the goal of an actor (A) in which at least one other person (B) is implied for the satisfaction of the goal. Within social intentions we can distinguish between present interaction and prospective interaction. When A and B are currently interacting the social goal is shared. The prototypical example of this kind of social intention is *communicative intention* (CInt), i.e. the intention to communicate a meaning to someone else plus the intention that this intention should be recognized by the addressee (Bara, 2006; Grice, 1975). Social intentions elicit the representation of a social goal also when A and B are not currently interacting, but when B is part of A's goal. In this latter situation the social goal is not shared at the moment and the interaction is prospective in future. We shall use for this kind of social intention the label *prospective social intention* (PSInt).

Starting from these conceptual distinctions, we devised an experimental protocol able to clarify the role of each

brain region of the ToM network in understanding others' prior intentions.

Methods

Twelve right-handed volunteers (six female; age range = 19-27; *M* = 24.75; *SD* = 2.63) were recruited. A detailed description of our experimental design is given in Walter et al. (2004). In short, we presented cartoons involving a sequence of three pictures (story phase). The story phase was followed by a choice-phase during which three possible solutions were displayed simultaneously. The task of the participant was to select the logical story ending. For each of the four conditions (PInt, PSInt, CInt, and the control condition Physical Causality) eleven comic strips were presented, making up a total of 44 trials. fMRI data were acquired using a 1.5 Tesla Siemens Magnetom Symphony whole-body MRI-System.

Results

The signal time course revealed specific signal time patterns for each region and condition. In Precuneus there was a highly significantly BOLD increase in all three intentional conditions compared to the control condition. The same was true for right pSTS. The time course analysis of the aPCC showed a significant increasing BOLD response only to both social intentions (PSInt and CInt). No significant response was observed in the private intention condition, PInt. Comparing both hemispheres directly we found the right pSTS to be significantly more activated than the left pSTS in the PSInt and PInt conditions. In contrast, in the CInt condition both pSTS were activated in a similar way, i.e. showed no difference in activation strength.

Discussion

In this work we analyse the contribution of four key regions of the ToM network (aPCC, Precuneus, right pSTS, and left pSTS) in the comprehension of different kinds of prior intentions. Based on our results, we propose a neurocognitive framework for reading other's intentions. Our assumption is that this ability occurs in different modalities according both to the kind of goal involved (private or social) and to the presence or absence of sharedness of the goal pursued.

The main result we find is that the ToM network shows different activation patterns in relation to the nature of the intentions the participant must deal with. Only the comprehension of a social intention with a shared goal (CInt) recruits all the four main areas described above. Instead, the comprehension of a social intention without a shared goal (PSInt) recruits the right pSTS, Precuneus and the aPCC. Furthermore, the comprehension of a private intention (PInt) involved only the activation of the Precuneus and right pSTS. Finally, this network shows specific activation patterns that differentiate the role between the left and the right pSTS, respectively.

In literature two different key brain regions have been proposed at the core of the Theory of Mind competence: the aPCC, as part of the MPFC (Gallagher et al., 2002), and the right pSTS (Saxe & Wexler, 2005). Our results confirm the crucial role of both of these areas but suggest that they are differentially involved accordingly to the nature of the prior intention represented. Whereas the right pSTS with the Precuneus is necessary for all types of prior intentions, the aPCC and left pSTS are crucial for social and communicative intentions, respectively.

Introducing a theoretical distinction able to differentiate intentions according to the dimensions of private versus social, and shared versus not shared, we have demonstrated the progressive recruitment of the network along these dimensions. Our approach allows to re-interpret the seemingly contradictory findings in the literature within an integrative framework.

Acknowledgements

This work was supported by MIUR of Italy (cofin 2005, protocol n. 2005119758_004) and by Regione Piemonte (Bando regionale per la ricerca scientifica 2004, cod. A239).

References

Bara, B. G. (2006). *Cognitive Pragmatics*. Cambridge, MA: MIT Press.

Becchio, C., Adenzato, M., & Bara, B. G. (2006). How the brain understands intention: Different neural circuits identify the componential features of motor and prior intentions. *Consciousness and Cognition*, *15*, 64-74.

Gallagher, H. L., Jack, A. I., Roepstorff, A., & Frith, C. D. (2002). Imaging the intentional stance in a competitive game. *Neuroimage*, *16*, 814-821.

Grice, H. P. (1975). Logic and conversation. In P. Cole & J. L. Morgan (Eds.), *Syntax and Semantics. Speech Acts* (pp. 41-58). New York and London: Academic Press.

Jeannerod, M. (1994). The representing brain: Neural correlates of motor intention and imagery. *Behavioral and Brain Sciences*, *17*, 187-245.

Saxe, R., & Wexler, A. (2005). Making sense of another mind: the role of the right temporoparietal junction. *Neuropsychologia*, *43*, 1391-1399.

Searle, J. R. (1983). *Intentionality. An essay in the philosophy of mind*. Cambridge, MA: Cambridge University Press.

Walter, H., Adenzato, M., Ciaramidaro, A., Enrici, I., Pia, L., & Bara, B. G. (2004). Understanding intentions in social interaction: The role of the anterior paracingulate cortex. *Journal of Cognitive Neuroscience*, *16*, 1854-1863.