Intentions in the brain

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Cognitive neuroscientists are beginning to clarify the neural structures and circuits involved in intention recognition. The purpose of this paper is to offer a selective overview on the recent research in social neuroscience dealing with the neural mechanisms supporting the comprehension of others' intentions. In addition, we present data from our group (Ciaramidaro et al. 2007; Walter et al. 2004; 2009) and we propose a new theoretical framework on how people read intentions. We introduce a novel theoretical distinction among varieties of intention, which differ by the nature of the private's pursued goal (private again or social) and by the temporal dimension of the social interaction (present or future). We regard our experimentation with normal and with pathological subjects as converging evidence supporting our theoretical claims.*

Keywords: cognitive pragmatics, social neuroscience, neuropragmatics, intentions, communicative intention, social intention

1. Introduction

The present study about intentions falls within the scope of neuropragmatics in two respects. First of all, neuropragmatics covers the relation between mental states and their neural underpinnings. In particular neuropragmatics deals with how communicative agents brains represent and share intentions, belief and contexts, in order to infer speaker's meaning and to achieve successful communication (Bambini & Bara *forthcoming*). In our case, we investigate with the neural correlates of different types of intention, which we investigate through neuroimaging methods. Secondly, neuropragmatics is concerned with the dysfunction of the mental processes usually investigated by classical pragmatics. In our case, we explore how schizophrenics comprehend intentions with respect to the normal population.

In Philosophy of Mind and in Cognitive Pragmatics communication is defined as an agent's intentional action overtly aimed at the modification of the mental states of a partner (Austin 1962; Searle 1969). In particular, successful communication is defined in terms of the partner's recognition of a particular set of mental states of the

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speaker, among which there is the intention to achieve an effect on the partner (Grice 1989). We consider communication as an activity consisting of a combined effort of actor and partner, who consciously and intentionally cooperate to construct together the meaning of their interaction (Bara 2010). Communicative intention is defined as the intention to communicate a meaning to someone else, together with the intention that such intention is recognized by the addressee (Grice 1975). Therefore, it is not possible for an agent A to communicate something to another agent B, if B has no intention to communicate with A. Furthermore, if A intends to communicate something to B, A must be aware of the fact: while unconscious intentions may exist, unconscious communicative intentions do not. We do not consider the presence of two people a sufficient condition for to be communication. A further set of conditions must also be stipulated. The first assumption is that the global meaning of the interaction is *agreed on* by the participants, irrespective of whether they take the role of speaker or of hearer. In other words, a mental representation must be constructed of the event that is taking place which is shared by both interlocutors: if there is no partner to receive the message, then the communication remains private, a bridge that will never reach the other side of the river (Bara 2010).

2. Intentions in social neuroscience

Social cognitive neuroscience is an emerging discipline whose aim is the empirical investigation of the neural mechanisms underlying social behaviour, i.e., the ability to generate and recognize socially relevant information useful to handle human interactions (Adolph 2003; Blakemore et al. 2004). Successful interactions depend upon our capacity to experience other people as goal-directed, intentional agents.

Action recognition plays a special role within social behaviour, because it involves the recognition of the goal and the corresponding agent's intention. Intentions and goal are two different concepts: Intentions are representations of possible actions the system may take to achieve its goal (Cohen & Levesque 1990). If we observe someone grasping a glass of water we can infer his/her intention to drink, and observing the movement we can also infer the goal of the action (e.g., to quench one's thirst). We note that intentions have features in common with goals, but intentionality is more general and has also been applied to the evaluation of unpredicted actions (Pelphrey et al. 2004; Saxe et al. 2004) or actions in context (Iacoboni et al. 2005). We are able to differentiate an intentional action from an accidental action, and we can also recognize whether an action achieves the pursued goal. Even more important, detecting other people's intentions allows us to plan and anticipate reciprocal future actions. Observing a person filling a glass from a bottle with wine, we attribute him or her the intention to drink. If the same person offers us a glass of wine, we assume that he/she is inviting us to drink with him/her. We can accordingly accept or refuse the glass of wine.

Social skills emerge during early infancy: recent studies (for a review see Johnson 2003) suggest that around 12 months of age infants are able to attribute agency. Georgieff & Jeannerod (1998) proposed the "Who" system, specifically dedicated to action attribution, and Becchio et al. (2006) clarify how the "Who" system allow children to attribute actions to social agents, a prerequisite to become able to reason about the goal an agent is pursuing through a specific action. In fact by 9-12 months of age infants understand the fundamental features of goal directed actions: they know that agents monitor their actions in order to pursue a goal, and recognize when this goal is achieved (Tomasello et al. 2005). By around 4-5 years of age, children develop a "Theory of Mind" (**ToM**), i.e., the capacity to attribute to others independent mental states such as beliefs, desires, emotions and intentions (for a review see Frith & Frith 2003).

3. The Theory of Mind network

ToM is a neurocognitive mechanism developed by natural selection to sustain social complexity (Dunbar 1998). In the past decade, neurophysiologic research has provided evidence of a brain system that decodes conspecifics' actions and may contribute to the understanding of other people's intentions. Functional imaging studies of ToM have used different experimental paradigms like stories (Saxe & Kanwisher 2003; Vogeley et al. 2001), cartoons or comic-strips (Fletcher et al. 1995; Gallagher et al. 2000; Brunet et al. 2000), videos (Zacks et al. 2001) and also interactive games and animations (Castelli et al. 2000; Gallagher et al. 2002). In particular studies that have used active on-line tasks in which participants are directly involved in social interaction (Gallagher et al. 2002; McCabe et al. 2001) found activation in the medial prefrontal cortex (**MPFC**) confirming the crucial role of this brain area in social interaction. Amodio & Frith (2006) analyzed the anatomical and functional characteristics of medial frontal cortex, and proposed a model of MPFC functions, relevant to different aspects of social cognitive processing. These authors divided the MPFC in three sub-areas with different roles: a) The posterior region of the MPFC has been implicated in the continuous internal monitoring of action and in representing and continuously updating the value of possible future actions in order to regulate behaviour; b) the more caudal region of the MPFC is associated with three different categories: self-knowledge, person knowledge and mentalizing; c) the more orbital region seems to be involved in representing and updating the value of possible future outcomes.

Other research groups used film clips or stories of everyday activities performed by a single actor and pointed out that posterior brain areas are also involved in ToM tasks. For example, Zacks et al. (2001) used film clips with human actors engaged in structured goal-directed actions and observed activity in the right tempo-parietal junction (**TPJ**) and the precuneus. Furthermore, Saxe et al. (2004) reported right TPJ activation in response to an intentional action during which a person was shown walking across a scene and passing behind a large bookcase. Recent neuroimaging and lesion ToM studies suggest that the bilateral TPJ plays a prominent role in the comprehension of other peoples' intentional action (Castelli et al. 2000; Zack et al. 2001). A new perspective has come from a study by Saxe & Wexler (2005) focusing on the role of the four brain regions examined herein. The authors suggest that only the right TPJ is selectively recruited for the attribution of mental states. In this paper, the authors speculate about the functional lateralization in TPJ, suggesting that the left TPJ plays a broader role in the attribution of socially relevant traits, while the right TPJ is restricted to the attribution of relatively transient mental states.

Taken together, these results show that, although there is widespread agreement on the existence of a widely distributed neural network underpinning ToM, the contribution of each of the four brain regions (MPFC, right and left TPJ, precuneus) described above remains unclear. In the next paragraph we introduce a novel theoretical distinction among varieties of intention, a distinction that contributes to identify more clearly the role of each of the four brain regions involved in intention recognition.

4. Varieties of intentions: A neurocognitive framework for the human ability to read other peoples' intentions

Social interaction involves attributing mental states and predicting intentions. If we observe someone grasping a glass of water we assume his intention to drink it, and we can also infer the goal of his action (e.g., to quench one's thirst: a private intention). But there is also a second major type of intentions, namely those that involve a second agent to be fulfilled (social intentions, e.g., playing tennis with a friend). A special kind of social intention, for its recursive nature, is communicative intention. Communicative intention is the intention to communicate something, plus the intention that that intention to communicate that particular something be recognized as such (Bara 2010). The necessary condition for real communication to take place is that such information is intentionally and explicitly proposed to the interlocutor. For example, by wearing a Cambridge University tie, Wittgenstein makes the fact that he belongs to Cambridge University shared, but it cannot be assumed that he have communicated this particular fact. In order to be communicated, he had to openly declared: *I teach at Cambridge University*. In this case listeners would have gained awareness not only of the specific fact, but also of his open desire that they become aware of that fact.

In collaboration with Henrik Walter's research group in Berlin, we started a systematic examination of how human beings infer intentions after the observation of others' actions. The idea is to separate different kind of intention recognition. We introduced a taxonomy of intentions based on philosophy of mind (Searle 1983) and cognitive pragmatics (Bara 2010). The first OR-branch of the taxonomy distinguishes between private (preparing oneself a meal) or social intention (ordering a pizza). This distinction is crucial if we are interested to detail the neural correlates involved in the ToM mechanism and if we want to explore the implications of ToM dysfunction in disorders such as schizophrenia. We therefore implemented a new experimental protocol with the aim to specify the functions of the main brain areas involved in the ToM network (for more details see Ciaramidaro et al. 2007; Walter et al. 2004).

Our theoretical framework for reading intentions distinguishes intentions along two dimensions: the kind of *goal* (private or social), and the presence or absence of *sharedness* of the goal pursued by the agents (see Fig. 1). This means that, from the observation of a specific action, we can infer two kinds of intentions: private intention and social intention. Social intention and private intention differ with respect to the nature of the inherent goal. Furthermore within social intentions we can distinguish between present interaction (communicative intention) and prospective interaction (prospective social intention). We offer a detailed description of these three intention types (see Fig. 1 and Fig. 2):

Private intention (**PInt**) elicits the representation of a private goal. A goal is private when no one but the actor is involved in its satisfaction.

Communicative intention (**CInt**): This is the prototypical example of a social intention, both in the present and recursive, i.e., the intention to share something with someone else plus the intention that the first intention be recognized as such by the addressee (Bara 2010; Grice 1975).

Prospective social intention (**PSInt**): This is the second kind of social intention, as social intentions elicit the representation of a social goal also when agent A and agent B are not currently interacting, but when the interaction will happen in the future. In this kind of intention the social goal is not shared at the moment, because the interaction is prospective in the future.

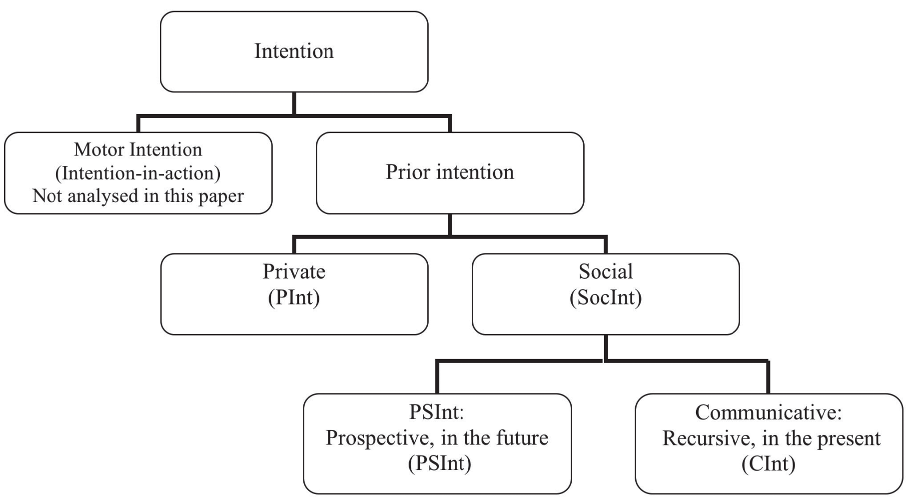

Figure 1. Varieties of intentions. Starting from the observation of an action, we can infer two kinds of prior intentions: private intentions (PInt) and social intentions. These two kinds of intentions differ with respect to the nature of the inherent goal: private goal and social goal. Within social intentions we can distinguish between present interaction (CInt) and prospective interaction (PSInt).

Based on these conceptual distinctions, we implemented an experimental protocol using cartoons that was designed to investigate the role of each area of the ToM network in understanding other people's intentions. In our experiment (Walter et al. 2004; Ciaramidaro et al. 2007), participants were asked to read short comic strips and then choose a picture that showed the only logical ending to the story, a procedure that induced participants to take the third-person perspective.

In order to detect the correct ending of the story, subjects had to read the mind of characters in the mentalizing task. As a control condition we used physical stories depicting non-intentional physical causality (**PhC**). The manipulation of social interaction in a mentalizing context was achieved by constructing stories involving individual intentions directed at objects without any social interaction (PInt), prospective intentions that were directed at future social interactions (PSInt), and communicative intentions (CInt), that is intentions in presently occurring interactions that involve communication (see Fig. 2).

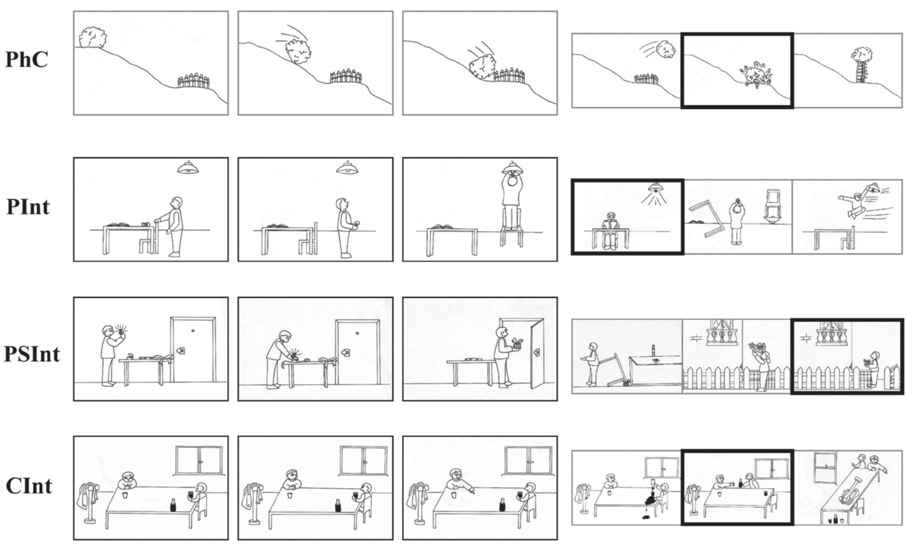

Figure 2. The four experimental conditions depicting different cartoon stories. The task was to pick the correct ending of the story (dark frame): PhC = physical causality (the example is showing a boulder rolls down a slope and breaks a wooden fence); PInt = private intention (the example is showing an agent changing a broken bulb in order to read a book); PSInt = social intention without a shared goal (the example is showing a young man wrapping an engagement ring); CInt = social intention with a shared goal (the example is showing two persons interacting, where an agent is pointing to a bottle to request it).

The most important result was that the ToM network showed different activation patterns in relation to the nature of the intentions participants were dealing with (see Fig. 3). The results underlying the comprehension of private intentions (PInt) showed that only the right TPJ and the precuneus were recruited (see Fig. 3). This result can explain why previous fMRI studies using film clips of everyday activities performed by a single actor reported activation of these areas. For example, Zacks et al. (2001) used film clips with human actors engaged in structured goal-directed actions and observed activity in the right TPJ and the precuneus but not in the left TPJ or the MPFC. The kind of stimuli employed in these studies fully corresponds with those probed by our PInt condition. The stimuli used in their study correspond to the intention type with those included in our PInt category: making a bed, washing dishes, fertilizing a houseplant, and ironing a shirt. Furthermore, Saxe et al. (2004) reported exclusively right TPJ activation in response to an intentional action during which a person was showed walking across a scene and passing behind a large bookcase. Once again, the type of intention involved in their study was conceptually equivalent to the PInt condition.

By contrast, comprehension of a potentially shared-in-the-future social intention (PSInt, i.e., prospective social intention) recruited the right TPJ, the precuneus and the MPFC (see Fig. 3). Recruitment of the MPFC (in particular the anterior paracingulate cortex, a region located in the anterior region of the rostral medial frontal cortex described in Amodio & Frith 2006) may relate to processing the inherent social goal of the PSInt condition, as we defined PSInt as a social intention wherein B is part of A's goal, even though B is not yet present. We propose that the MPFC activation is specifically linked to the social nature of the goal an actor is pursuing and not to the mere presence of two agents actually interacting. Indeed, participants in the PSInt condition were called upon to represent the mental state of an agent preparing to interact, i.e., when social interaction was not actually shown but implied (e.g., a young man wrapping an engagement ring).

Finally, only the comprehension of a shared-in-the-present social intention (CInt, i.e., communicative intention) recruited all of the four areas described above. Communication is an activity that calls for the initiative to be alternated between the actors involved, and responsibility for the interaction itself is constantly being shared by the actors (Bara 2010). In accordance with these considerations, we observed recruitment of the entire neural system underlying ToM (MPFC, precuneus, right TPJ, and left TPJ) only when participants

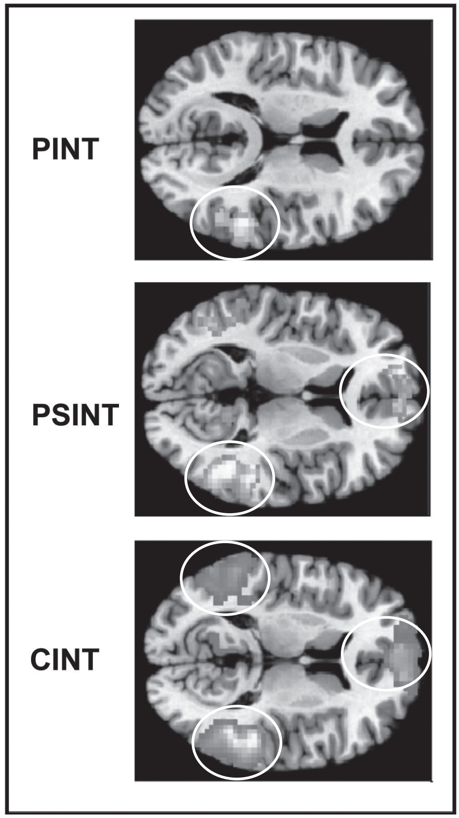

Figure 3. The intentional network for private intention (PInt), prospective social intention (PSInt), communicative intention (CInt).

were dealing with a shared-in the-present social intention, i.e., with communicative intention (CInt), and this activation of the left TPJ was rather exclusive for CInt (see Fig. 3). The left TPJ therefore appears to be particularly responsive in the understanding of communicative intention.

In summary, our results suggest that the standard definition of ToM in neuroimaging studies – i.e., ToM as the ability to attribute mental states to self and to others – is not specific enough, for addressing the question of the specific function of each brain area involved. We suggest that it would be more appropriate to consider that distinct areas of the ToM neural network may be specialized in processing different classes of social stimuli. This might help researchers and clinicians to better understand ToM disorders in both neuropsychological and psychiatric patients. In the next section, using the same approach, we will present data of a group of subjects with schizophrenia, and we will demonstrate how such distinction and theoretical framework is useful also to investigate the dysfunction in ToM task in patients with paranoid schizophrenia.

5. Schizophrenia and the deficit of Theory of Mind

ToM deficits are prominent in autism (Baron-Cohen 1995) but have also been found in patients with schizophrenia (Brüne 2005). Frith (1992) proposed that certain psychotic symptoms associated with schizophrenia reflect a deficit in the ability of mentalizing and claimed that this is the result of patients' failure to monitor their own and others' mental states and behaviour. It has been argued that paranoid patients may be characterized by hyperintentionality. Abu-Akel & Bailey (2000) speak about "hyper ToM": whereas healthy persons are able to reflect on the appropriateness and correctness of these more or less automatic attributions, patients with paranoid schizophrenia might over-attribute significance and intentions to events, person and objects. To date, only few studies have investigated ToM tasks in patients with schizophrenia using cartoons (Brunet et al. 2003; Brüne et al. 2008), and empathy and forgiveness judgments (Lee et al. 2006). These studies yielded inconsistent results with hypo- (Brunet et al. 2003; Lee et al. 2006) as well as hyperactivation (Brüne et al. 2008) of nodes of the ToM network, in particular in the MPFC.

We investigated brain activation in a homogeneous group with paranoid schizophrenia using the same paradigm described in the previous section using the three different types of intention (private intentions, prospective social intention, communicative intentions) and a physical causation control condition. Thanks to these data we wanted to approach the question of a mentalizing deficit in patients with paranoid schizophrenia. The assumption that these patients show ToM deficits because of their incapacity to monitor other people's intentions, lead us to claim that the experimental protocol that we described in the previous section would be adequate to study the specific maladaptive intentional attribution process in these patients. We hypothesized to find a dysfunction in the network underlying ToM in terms of reduced brain activations in the intentional conditions, in particular for communicative intentions (CInt), because these patients' attitude of 'over-attributing' intentions seems to be related to violations of pragmatic rules in their use of language and incorrect inferences of communicative intentions (Brüne 2005). Although there is clear evidence for behavioural deficits in ToM tasks in schizophrenia, the direct evidence for a neural dysfunction of the structures underlying ToM capacity in schizophrenia is rather sparse. Moreover, the existing studies do not distinguish between different types of mental states or intentions attributed.

Therefore we planed a second fMRI study using the same task described in the previous section employing our model about intention reading (PInt, PSInt and CInt) in order to investigate the maladaptive attribution of intention in paranoid patients. This study permits us to examine if the dysfunctional activation within the intentional network depended on the kind of intention involved (private or social).

Comparing groups directly significant differences in activation patterns were found in the right and left TPJ region and in the region of the MPFC (see Walter et al. 2009). Our main result, in line with our hypothesis, was that the neural dysfunction of the intentional network is modulated by type of intention. In particular for the PInt conditions, we found no group differences. So we assumed, that patients with schizophrenia present no neural dysfunction for this type of intention. Instead, for the PSInt condition we found significant group differences in the right TPJ and the MPFC. Although both intentions (PInt and PSInt) share a common element, namely, one agent acting in isolation (see Fig. 2), only PSInt requires the representation of a social goal. Also for the CInt comparison there was additionally a group difference in activation in the left TPJ (together with the right TPJ and the MPFC).

Furthermore, we are also interested to investigate if paranoid patients over-attribute intentions, leading them not to deactivate their intention detector when they are comprehending stories involving physical causality. For this reason we analyzed the beta parameters (see Fig. 4), enlightening that the lack of activation in the MPFC and left TPJ is not only due to decreased activation in these regions but also to increased beta values in the PhC condition. In fact observing the dashed circles (which indicate the beta parameters for the control condition or PhC in both groups) we note that the patient group (in light grey) shows more activation than the beta parameters of the control group (in dark grey).

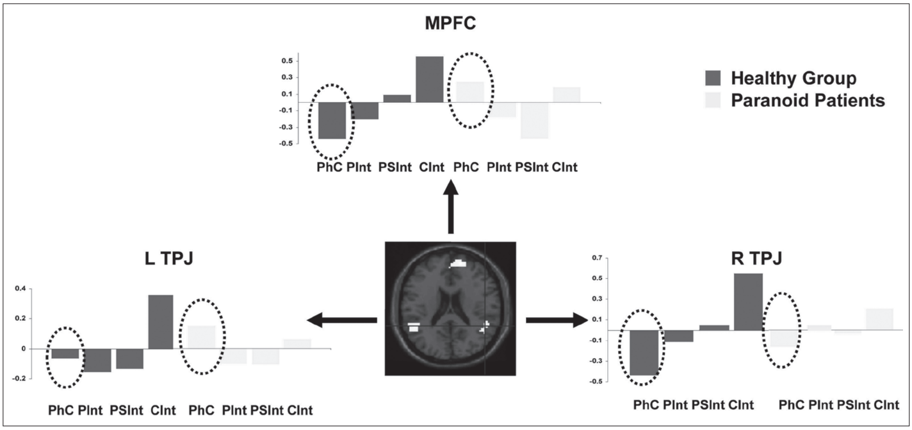

Figure 4. Mean activation effects (estimated beta parameters, 95% confidence interval) of the contrast communicative intention (CInt) vs. physical causality (PhC) for right tempo-parietal junction (R TPJ), medial prefrontal cortex (MPFC) and left tempo-parietal junction (L TPJ). Dashed circles indicate the beta parameters for the control condition (PhC). Figure adapted from Walter et al. 2009.

In accordance with the above mentioned hypothesis that paranoid schizophrenic patients may have a hyperactive intention detector, we can explain our results as follows: paranoid patients do not deactivate their intention detector when they are comprehending stories involving physical causality, but these patients are always in an 'online' modus of ToM. This would also be the case in contexts without intentional agents, where no ToM is required. Blakemore et al. (2003) report that patients with delusions of persecution attributed intentional behaviour to moving shapes in conditions where controls saw no intentionality. These authors propose that patients with schizophrenia perceive agency where others see none. The same process took place when our patient group observed PhC stories. An exaggerated sense of agency seems to characterize patients with delusions of persecution, and this tendency to perceive agency where there is none may be a more general feature of schizophrenia (Frith 2005). These results demonstrate that findings of dysfunctional activation within the ToM network can only be interpreted if the type of mental state (or intention), which is used to solve the task, is differentiated.

Furthermore, these results provide evidence that the debate concerning the 'key region' for the ToM network might be a misnomer: different structures might be relevant for different types of intentional states. Regarding the social and communicative aspects of ToM tasks, we provide evidence that the MPFC and the left TPJ play the most important roles. This might stimulate research in different ways. First, it would be valuable to separate private and communicative intentions and study subtypes of schizophrenia, e.g., disorganized versus negative symptoms versus positive symptoms. Second, these results point to the necessity to look also at the control condition, especially in patients with positive symptoms who might have a hyperactive intention detector already for physical events. Third, it would be very interesting to compare patients with autism and patients with schizophrenia with a paradigm similar to the one we used: one would expect both type of patients to show reduced differential activations when comparing ToM stories with communicative intentions with physical causality stories, but for different reasons: whereas for schizophrenic patients we would predict a high signal in the ToM-network for physical causality and ToM stories, for patients with autism we would predict a low signal in the ToM-network for both conditions. The idea is that both pathologies are characterized by ToM deficits, but patients with schizophrenia may be labeled as 'hyper-intentional' (they tend to treat objects as intentional agents), and patients with autism 'hypo-intentional' (they tend to treat persons like objects).

6. Conclusions

Human beings perceive conspecifics as social agents. This attitude implies that they constantly explain and predict others' intentions. Without this competence, other people's behaviour would be meaningless from a third person perspective, in that only behaviour – not action – would be observed. Philosophers of mind have postulated different types of intention. We empirically tested three types of intentions, first according to the private/social dichotomy, and then according to the present/future dichotomy. These two conceptual distinctions remain neglected, although they are quite elementary for philosophers, and although a growing number of experimental studies on the subject of intention processing are being produced in social neuroscience. In fact, paradigms that include these two categories within the same experimental condition are often reported in the literature; moreover, ToM neuroimaging studies have not yet distinguished between communicative and private intention, often grouping them into the same theoretical category. One exception is a recent study specifically centered on communicative intention (Kampe et al. 2003); this kind of intention, however, was not compared with private intention. Our experiments contribute to clarify the picture, as they show that the Intentionality network is progressively recruited in order to distinguish private intentions from social ones, and then future social intentions from present ones. Moreover, our results show that the dysfunctions in the ToM network showed by paranoid patients are modulated by different kind of intentions.

Both for linguistics and for pragmatics a specific type of intention is especially relevant, namely communicative intention: on this research topic we would like to focus now. Communicative intention possesses an intrinsic recursive nature that makes it almost unique. In the last version of Chomsky's theory of language evolution (Hauser et al. 2002), the authors distinguish a uniquely human "narrow" faculty of language from the "broad" faculty of language, which consists of adaptations for communication that have analogies or homologies in other animal species. They further claim that recursion is the core (and perhaps the only) component of the so defined narrow faculty of language. Recursivity may be domain dependent, and therefore one should expect to find different neural networks able to implement it. The one we are postulating for communicative intention would be one of these recursive networks. The other option is that recursivity is domain independent, and in this case our intentionality full network ought to be always active when intentions, syntax or calculus is involved. In our experiment we have *not* isolated such a recursive component. What we did was to empirically prove that communicative intention, that possesses such recursive feature, is sustained by a specific brain circuit. Although further investigation is needed, our prediction is that the neural basis of recursion, the key feature of the human ability for social interaction, has to be looked for in the distributed intentionality neural network just shown.

In such vein, the next question to be answered about communicative intention should be the following: is the intentionality network independent from the expressive mean of communication used? We used gestures as stimuli; but would there be a difference if language had been involved? Is recursion a single mechanism, common to language and gestures? Enrici et al. (*submitted*) provide a first conclusion analyzing the brain responses in communicative intention processing with different expressive means, i.e., linguistic or extralinguistic gestural means. Their findings showed that a common brain network including the MPFC, the bilateral posterior superior temporal sulcus and TPJ, and the precuneus, is recruited for the comprehension of communicative intentions, independent of the modality through which it is conveyed.

With the present works, we provided a new theoretical grounded experimental paradigm that allows for detailed investigation of each of the four regions implicated in intention attribution. The nature of intention reading is crucial both in healthy people and in people suffering from an alteration of this fundamental ability, an ability that connects people to each other.

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Notes

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