

The involvement of emotion recognition in affective theory of mind

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Abstract

This study was conducted to explore the relationship between emotion recognition and affective Theory of Mind (ToM). Forty subjects performed a facial emotion recognition and an emotional intention recognition task (affective ToM) in an event-related fMRI study. Conjunction analysis revealed overlapping activation during both tasks. Activation in some of these conjunctly activated regions was even stronger during affective ToM than during emotion recognition, namely in the inferior frontal gyrus, the superior temporal sulcus, the temporal pole, and the amygdala. In contrast to previous studies investigating ToM, we found no activation in the anterior cingulate, commonly assumed as the key region for ToM. The results point to a close relationship of emotion recognition and affective ToM and can be interpreted as evidence for the assumption that at least basal forms of ToM occur by an embodied, non-cognitive process.

Descriptors: Intention recognition, Emotion recognition, Simulation, Mirror neuron system, Embodied perception, Amygdala

The study of social cognition is a rather new but rapidly growing field in the neurosciences. One of the milestones of the field was the paper by Brothers (1990), who defined social cognition as “the processing of any information which culminates in the accurate perception of the dispositions and intentions of other individuals.” (Brothers, 1990, p. 28; see also Brothers, 2002, p. 367). Part of the information used for the recognition of dispositions and intentions are, according to Brothers, identity, category of posture, direction of movement, quality of vocalization, and facial expression. Following this definition, emotion recognition and Theory of Mind (ToM) are two core components of social cognition. Emotion recognition is the ability to infer an emotional state of another individual, mainly from acoustic and visual features like vocalization and facial expression. ToM and its often used synonyms “mind reading,” “mentalizing,” or “mental state attribution” can be defined as the ability to attribute mental states, such as beliefs, desires, and intentions to oneself and others (Frith & Frith, 2001). According to Brothers (1990), the representation of another person’s emotional state and the knowledge about posture and movement

direction should culminate in the recognition of intentions. Thus, Brothers’ (1990) concept of social cognition is very close to the original ToM concept developed by Premack and Woodruff (1978), who assume that ToM can be used to make predictions about the behavior of others, which can also be conceptualized as the recognition of intentions.

Following this conceptualization of social cognition, emotion recognition in turn can be described as a part of intention recognition or ToM. From an ontogenetic point of view, it has been shown that emotion recognition develops earlier than the ability to mentalize (Montague & Walker-Andrews, 2001; Saxe, Carey, & Kanwisher, 2004). There is also evidence that the ability to recognize emotions is an important component for the development of an understanding of intentionality (Phillips, Wellman, & Spelke, 2002). However, there are only few studies on the relation between emotion recognition and ToM. Most, but not all (see Langdon, Coltheart, & Ward, 2006 and Phillips, MacLean, & Allen, 2002 for divergent results) of these studies, support the idea of such a close relation between emotion recognition and ToM showing a correlation between the performance in emotion recognition and ToM in children as well as in adults (Bora, Vahip, Gonul, Akdeniz, Alkan et al., 2005; Brüne, 2005a; Buitelaar & van der Wees, 1997; Dyck, Pieck, Smith, & Hallmayer, 2006; Henry, Phillips, Crawford, Ietswaart, & Summers, 2006). These results are in line with the model of Coricelli (2005), who defines ToM as a two component process: First, an unconscious automatic process consisting of the basic aspects of intention

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recognition such as emotion recognition, emotional contagion, and action recognition; second, a conscious process comprising hypotheses testing, which results in a decision about the most likely intention of the other person.

To our knowledge, on a neurobiological level, this interconnection between emotion recognition and ToM has not been studied so far, because existing functional imaging studies have investigated both processes only separately. Therefore, the present study was conducted as a first attempt to fill this gap.

According to Haxby, Hoffman, and Gobbini (2002), the neuronal basis for emotion recognition consists of a core system for a primary visual analysis of stimuli and an extended system for the analysis of the emotional content. The core system consists of inferior occipital gyrus, lateral fusiform gyrus, and superior temporal sulcus (STS). The extended system consists of limbic areas like amygdala and insula. Most of these regions were identified in a number of neuroimaging studies using functional magnetic resonance imaging (fMRI) (e.g., Gur, Schroeder, Turner, McGrath, Chan, et al., 2002; Hariri, Bookheimer, & Mazziotta, 2000; Ishai, Schmidt, & Boesiger, 2005). In general, there seems to be consistency that these areas are involved in facial emotion recognition (e.g., Adolphs, 2002; Blair, 2003; Haxby et al., 2002).

There are two main theoretical accounts on ToM and its underlying neuronal correlates: The more cognitive “meta-representational Theory-Theory” and the more perceptual “Simulation-Theory” (see Brüne, 2005b, for an overview). Cognitive theories assume that, based on acquired meta-representations about the world, one recognizes the mental state of another person by building a theory about his state. Gallagher and Frith (2003) propose the medial prefrontal cortex, especially the anterior cingulate cortex (ACC), the temporal poles, and the posterior STS with the adjacent temporo-parietal junction as core structures for the generation of these meta-representations of others’ mental states. All these structures are seen to be associated with several sub-functions of mentalizing. The medial prefrontal cortex seems to be the key structure that encodes mental states decoupled from reality (Gallagher & Frith, 2003). The temporal poles are the region where, based on past experience, a wider semantic and emotional context in terms of scripts is processed. This region therefore promotes the understanding of mental states (Frith & Frith, 2003). Activation in the medial prefrontal cortex (e.g., Castelli, Happé, Frith, & Frith, 2000; Gallagher, Happé, Brunswick, Fletcher, Frith & Frith, 2000; Gallagher, Jack, Roepstorff, & Frith, 2002; Gallagher & Frith, 2004; Spiers & Maguire, 2006; Vogeley, Bussfeld, Newen, Herrmann, Happé, et al., 2001) as well as in the temporal poles (Gallagher & Frith, 2004; Spiers & Maguire, 2006; Völlm, Taylor, Richardson, Corcoran, Stirling, et al., 2006) was found in ToM studies using a broad range of different designs.

Simulation-theorists suppose that the mental state of others is recognized by a simulation process (e.g., Gallese & Goldman, 1998; Gallese, Keysers, & Rizzolatti, 2004). The related core structures for such a simulation process are located in areas that belong to the so-called mirror neuron system (Gallese, 2007). Another structure that is associated with simulation processes, but does not belong to the mirror neuron system, is the somatosensory cortex (Adolphs, Damasio, Tranel, Cooper, & Damasio, 2000; Avenanti, Bolognini, Maravita, & Aglioti, 2007; Cheng, Yang, Lin, Lee, & Decety, 2008; Winston, O’Doherty, & Dolan, 2003). The mirror neuron system was originally found to be activated in primates not only when performing an action, but also

when observing a similar action being performed by a fellow (di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992; Gallese, Fadiga, Fogassi, & Rizzolatti, 1996). In the human brain, mirror neurons can be found in Brodmann area 44 (BA 44) in the inferior prefrontal cortex (Rizzolatti, Fogassi, & Gallese, 2002) and in the inferior parietal cortex (Gallese & Goldman, 1998; Keysers & Gazzola, 2006). Activation in the inferior prefrontal gyrus was found during the observation (Buccino, Binkofski, Fink, Fadiga, Fogassi, et al., 2001; Gazzola, Rizzolatti, Wicker, & Keysers, 2007) and imitation of actions (Filimon, Nelson, Hagler, & Sereno, 2007; Iacoboni, Woods, Brass, Bekkering, Mazziotta, & Rizzolatti, 1999) and an important function of this region is the representation of action goals (Koski, Wohlschläger, Bekkering, Woods, Dubeau, et al., 2002). An area that is strictly related to the human mirror neuron system is the STS (Rizzolatti & Craighero, 2004). Neurons in the STS lack motor attributes (Rizzolatti & Craighero, 2004), but are critically involved in imitation processes (Iacoboni, Koski, Brass, Bekkering, Woods, et al., 2001). The STS is regarded as a key region in both approaches: The Theory-Theory and the Simulation-Theory. It seems to play an important role in the initial analysis of visual social cues (for a review, see Allison, Puce, & McCarthy, 2000), in biological motion recognition (Bonda, Petrides, Ostry, & Evans, 1996), in imitation (Iacoboni et al., 2001), and in the recognition of intentions (Pelphrey, Morris, & McCarty, 2004). The STS was found in many ToM studies irrespective of the task design (Baron-Cohen, Ring, Wheelwright, Bullmore, Brammer, et al., 1999; Calder, Lawrence, Keane, Scott, Owen, et al., 2002; Castelli, et al., 2000; Den Ouden, Frith, Frith, & Blakemore, 2005; Hoffman & Haxby, 2000; Majoram, Job, Whalley, Gountouna, McIntosh, et al., 2006; Wicker, Perret, Baron-Cohen, & Decety, 2003). In contrast, the involvement of the inferior frontal gyrus was only found in few studies explicitly investigating ToM (Baron-Cohen, et al., 1999; Farrow, Zheng, Wilkinson, Spence, Deakin et al., 2001; Hooker, Verosky, Germine, Knight, & D’Esposito, 2008; Kim, Kim, Jeong, Ki, Im, et al., 2005; Russell, Rubia, Bullmore, Soni, Suckling, et al., 2000). However, some studies have given further evidence for an involvement of areas associated with the mirror neuron system in ToM. Areas of the mirror neuron system are involved in the prediction of actions in different contexts (Iacoboni, Molnar-Szakacs, Gallese, Buccino, Mazziotta, & Rizzolatti, 2005), their activation can be modulated by motivation (Cheng, Meltzoff, & Decety, 2007), and activation in some of these areas signals violation of action sequences (Buccino, Baumgaertner, Colle, Buechel, Rizzolatti, & Binkofski, 2007).

Beside differences in their assumption about core regions, the Theory-Theory- and the Simulation-Theorists agree that there are additional brain regions that play a role in ToM providing the necessary information to understand emotional mental states when necessary (Frith & Frith, 2001; Gallese et al., 2004). One of the most important of these areas is the amygdala. Lesion studies provide evidence for an involvement of the amygdala in mental state attribution (Shaw, Lawrence, Radbourne, Bramham, Polkey, & David, 2004; Stone, Baron-Cohen, Calder, Keane, & Young, 2003). However, since most of the studies on ToM investigated cognitive ToM tasks and did not include any emotional components in their design, amygdala activation was not reported in those studies. In contrast, when an emotional component was included into the ToM task, amygdala activation was found, as with the recognition of expressive gestures (Gallagher & Frith, 2004) and the recognition of intentional

behavior (Castelli et al., 2000). This also holds true for the recognition of mental states with the Reading the Mind in the Eyes Test (Baron-Cohen et al., 1999), although this result could not be consistently replicated (Russell et al., 2000). Because of the important role of the amygdala in emotion recognition (Adolphs, 2002; Blair, 2003; Haxby, Hoffman, & Gobbini, 2002, see above), these findings again support the assumption of a close relation between emotion recognition and ToM.

Furthermore, there are some interesting functional imaging studies on the observation and imitation of emotional expressions that might provide a link between emotion recognition and ToM. These studies found activation in the amygdala as well as in areas of the mirror neuron system during the observation and imitation of emotions in children (Pfeifer, Iacoboni, Mazziotta, & Dapretto, 2008) and in adults (Carr, Iacoboni, Dubeau, Mazziotta, & Lenzi, 2003; Leslie, Johnson-Frey, & Grafton, 2004; Schulte-Rühter, Markowitsch, Fink, & Pifke, 2007; Van der Gaag, Minderaa, & Keyers, 2007). Leslie et al. (2004) showed a common neural basis for imitation of emotional expressions and finger movements in the mirror neuron system. Carr et al. (2003) assume that facial emotions are identified via an interaction of simulation processes of the expression taking place in the mirror neuron system and the activation of the amygdala, which is responsible for processing the emotional content.

Taking these findings together, there is convincing evidence that the medial prefrontal gyrus including the ACC and the STS are involved in ToM. The mirror neuron system is involved in the understanding and prediction of simple movements and in the observation and imitation of emotional expressions, and the amygdala is involved in the imitation and recognition of emotions. Moreover, existing data suggest that at least basal processes of ToM such as the recognition of intentions can be localized in areas of the human mirror neuron system. But until now, only little is known about the interplay of emotion recognition and ToM and its neuronal basis.

As a first approach to investigate the relationship of ToM and emotion recognition, the aim of the present study was to analyze the relationship of emotion recognition and affective ToM. For this purpose, a new affective ToM task was developed that investigates a basic aspect of affective ToM: The recognition of emotional intentions. By using varying instructions, processes of emotion recognition and affective ToM were induced within an identical experimental setting using the same stimuli and requiring equal motor responses. In light of the existing literature, we assumed that emotion recognition and affective ToM are two closely related processes, with affective ToM being the higher order social cognitive process that is based on emotion recognition. To confirm this assumption on the behavioral and the neural level, we tested the following hypothesis:

- (1) The close relationship between emotion recognition and affective ToM is reflected by a significant correlation between performance measures during the emotion recognition and the affective ToM task.
- (2) The recognition of intentions takes longer than the recognition of emotions.
- (3) On a neural level, the close relationship between emotion recognition and affective ToM is reflected by overlapping activation in structures known to be associated with emotion processing and intention recognition. Therefore, a conjunction analysis of both tasks should reveal significant activation in the amygdala, the inferior prefrontal gyrus, and the STS.

- (4) During affective ToM, we expected additional activation in the STS, the inferior prefrontal gyrus, the ACC, and the temporal pole compared to emotion recognition because these areas are known to be involved in intention recognition.

Methods

Participants

Forty voluntary undergraduate students (20 females) participated in the study. Their mean age was 25.25 years (range 19–32 years; $SD = 3.52$). All participants were right-handed and had normal or corrected-to-normal vision. Before participating in the study, subjects gave their written informed consent. The study was approved by the local ethics board of the University of Giessen Medical School and conducted in accordance with the Declaration of Helsinki.

Experimental Design

Stimulus material consisted of 32 portrait photos of eleven actors. The faces depicted an emotional expression of joy, anger, fear, or disgust or a neutral one. The pictures were taken from our own set of facial stimuli, which were modified by means of a morphing-program in order to obtain emotional facial expressions with different intensities by stepwise morphing a neutral and an emotional face of maximal expression. The stimuli used for this study were pictures with 80% intensity, derived from the morphing program (80% from a picture with an emotional expression and 20% from a picture with a neutral expression) to avoid the use of exaggerated emotional expressions and to assure that the task was not too easy. Pictures of seven out of the eleven actors were available for each emotion and four with neutral expressions, resulting in 3 pictures per person and 32 stimuli overall.

In a validation study of the stimulus material, the stimuli were presented to 93 undergraduates (age 22.25; range 19–34 years; $SD = 2.9$; 48 females). Subjects had to rate the intensity of each of the emotions: fear, anger, happiness, and disgust on a 5-point scale from not present (1) to full present (5) on a computer. An emotional expression was categorized as recognized if the depicted emotion had the highest rating of all emotions under investigation. The mean recognition rate for the emotional expressions used in the present study was 87.5% ($SD = 10.8$). The emotional expressions of fear had a mean recognition rate of 81.1% ($SD = 11.3$), the emotional expressions of anger of 92.9% ($SD = 7.2$), the emotional expression of disgust of 76.3% ($SD = 19.3$), and the emotional expression of happiness of 99.8% ($SD = 0.4$). The mean rating for the four neutral expressions was 1.3 ($SD = 0.01$). The differences in the mean recognition rate of the different emotional categories should not influence our results, because we used the same stimuli in all conditions and did not analyze the emotions separately.

The experimental design of the fMRI study consisted of three conditions implemented by different instructions: affective ToM, emotion recognition, and a control condition. Within these conditions, the four different emotional expressions and a neutral facial expression were depicted. The task was to evaluate whether the preceding statement fitted the actual picture. Each trial started with the presentation of a statement, followed by a facial picture, with the choice 'yes' or 'no' below. The participants had to signal their decision by a button press. The statements

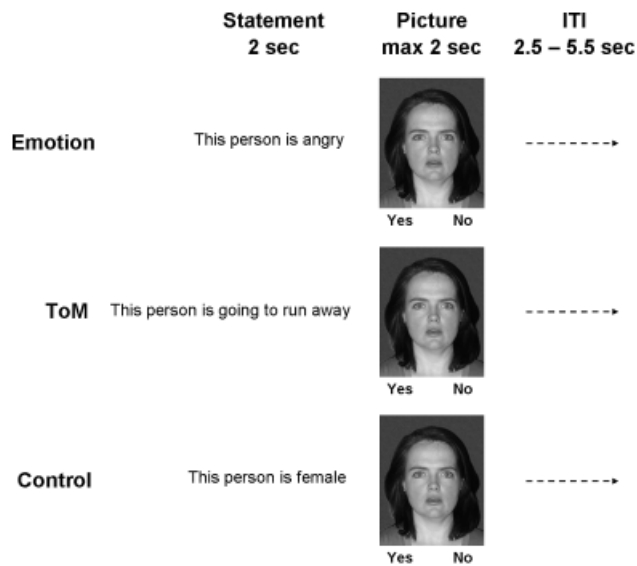


Figure 1. Experimental conditions and design, exemplarily shown for the emotion fear.

described an emotional state, an emotional intention, or a physical feature of the depicted person. For the affective ToM and the emotion recognition conditions, four statements were used belonging to four basic emotions: fear, disgust, anger, and joy, (e.g., Ekman, 1994; for an overview, see Ortony & Turner, 1990). The emotional intention recognition always referred to an explicit future action driven by one of the four basic emotions. The prediction of actions and, with this, the recognition of action intentions can be seen as a basic process of ToM (Premack & Woodruff, 1978). Because all the intentions in our task were driven by an emotional state, we refer to them as affective ToM and not as ToM in general. Each statement for the emotion recognition and for the intention recognition condition was presented four times with a picture of a stimulus person with a matching emotion and four times with a picture of a stimulus person with a non-matching emotion. The statements in the control condition were presented in around half of the trials with a picture of a person with a matching physical feature and in the other half of the conditions with a non-matching physical feature. Each picture of the stimulus person was shown once in each condition, resulting in three presentations altogether. An example for the three experimental conditions is given in Figure 1, and all statements used are listed in Table 1.

The three experimental conditions consisted of the same stimulus material and were presented in pseudorandomized or-

der. Each statement was shown eight times, resulting in 32 trials per condition and a total of 96 trials.

The statements were presented for 2 s, immediately followed by the picture. When no button was pressed, the picture remained for 3 s. A button press terminated the display of the picture and the fixation cross appeared for the remaining trial. The mean inter-trial interval was 4 s (2.5–5.5 s). The total experimental time was approximately 19 min. The experiment was implemented in the Presentation software, version 9.50 (Neurobehavioral Systems, Albany, CA). The stimuli were projected onto a screen behind the scanner, visible for the participants via a mirror fixed atop of the head coil. The total scanning time was about 30 min, including prescans, anatomical scan, and functional imaging.

Based on the fMRI findings, we conducted a post-hoc behavioral experiment to investigate whether we find evidence for a facilitation of the recognition of emotional intentions by the recognition of emotions. We hypothesized that emotional intentions are recognized faster if the same person is presented in the trial before with the according emotion than when the same person is presented in the trial before with a neutral expression. In this experiment, we presented the same trials as in the fMRI study but in a different order to 20 student participants (mean age = 24.25 years; range 20–29; $SD = 2.4$; 9 females) outside the scanner. We varied three conditions, in which the emotional intention recognition trials were preceded by a neutral trial, an implicit emotional trial, or an explicit emotional trial. For the neutral trials, the control statements were followed by pictures with neutral facial expressions. For the implicit emotion trials, the control statements were followed by an emotional facial expression. In the explicit emotional trials, emotion recognition statements were followed by an emotional facial expression (for examples of the three conditions, see Figure 2). Each condition was presented 20 times. To avoid a response choice preference for ‘yes’ answers in 12 trials per condition, the trial preceding the affective ToM trial was congruent and in 8 trials, the proceeding trial was incongruent showing the same person with another emotional expression or asking for another emotion. To test the facilitation hypothesis, we analyzed only the congruent trials assuming that a facilitation process occurs by the presentation of the emotion in the trial preceding the affective ToM trial.

fMRI Data Acquisition

Data acquisition was accomplished via a 1.5 Tesla GE Signa whole-body magnetic resonance tomograph (General Electric, Milwaukee, WI). The functional images were acquired with a T2*-weighted gradient echo planar imaging sequence (TR = 3000 ms; TA = 100 ms; TE = 50 ms; flip angle 90°; field of view = 224 mm; 64 × 64 matrix). Thirty slices per scan were

Table 1. English Translations of the Statements and the Original German Statements for the Three Conditions. German Statements Are Written in Italics

	Emotion recognition	Intention recognition	Neutral condition
Anger	This person is angry <i>Diese Person ärgert sich</i>	This person is going to bluster <i>Diese Person schimpft gleich</i>	This person is female <i>Diese Person ist weiblich</i>
Fear	This person is afraid <i>Diese Person fürchtet sich</i>	This person is going to run away <i>Diese Person läuft gleich weg</i>	This person has blonde hair <i>Diese Person ist blond</i>
Disgust	This person is disgusted <i>Diese Person ektelt sich</i>	This person is going to avert her face <i>Diese Person wendet sich gleich ab</i>	This person is older than 30 <i>Diese Person ist älter als 30</i>
Joy	This person is happy <i>Diese Person freut sich</i>	This person is going to cheer <i>Diese Person jubelt gleich</i>	This person weighs more than 70 kilos <i>Diese Person wiegt mehr als 70 kg</i>

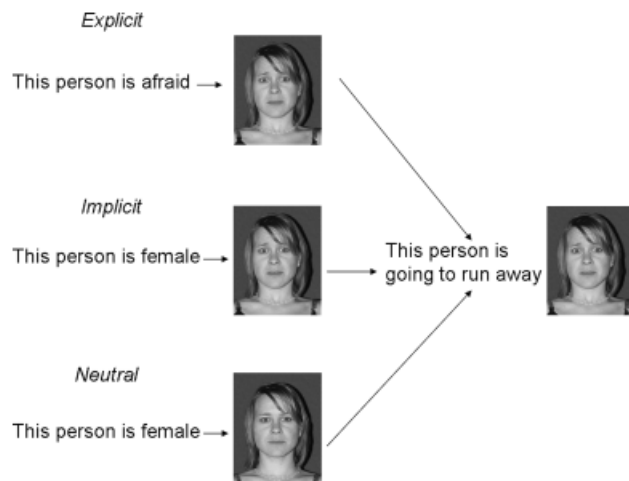


Figure 2. Experimental design of the behavioral experiment displaying the three experimental conditions (left side) and the emotional intention recognition trial following each condition (right side).

collected ascending in interleaved order with a slice-thickness of 5 mm ($3.5 \times 3.5 \times 5$ mm voxel size). A total of 387 scans was collected during the experiment.

Data analysis. Data analysis was done with SPM2 (Wellcome Department of Cognitive Neuroscience, London, UK). Data preprocessing consisted of slice time correction to the temporally middle slice, realignment, normalization to the standard space of the Montreal Neurological Institute brain (MNI brain), and spatially smoothing with a 10-mm full width at half maximum kernel. A first-level fixed effects analysis was calculated for each person. Regressors for each condition consisting of all correct responses were defined. To account for the residual variance, a regressor of no interest with all trials with wrong answers was defined. A synthetic hemodynamic response function and its spatial and temporal derivatives were used for response modeling. To minimize the influence of movement-related variance, the 6 movement parameters of the realignment procedure were included as covariates of no interest.

In a second-level random effects analysis, individual contrasts from the first-level were taken together for the group analysis. Activation in and between the different conditions was analyzed with one-sample *t*-tests. The resulting *p*-values of the *t*-statistic were corrected for multiple comparisons with the familywise error

correction method (FWE-corrected). With the resulting *t*-maps of the one-sample *t*-tests for affective ToM > Baseline and Emotion recognition > Baseline, a conjunction-analysis for affective ToM and emotion recognition was conducted to reveal common activation in the two conditions. For this purpose, a *t*-map was calculated that included only areas with significant activation under both conditions. Furthermore, a within-subject one-way analysis of variance (ANOVA) was conducted to identify areas with increasing activation during an increasing requirement to put oneself in the position of the depicted person (ToM > Emotion recognition > Control condition). Regions of Interest (ROIs) for the ACC and BA 44, the key regions for ToM, and for the amygdala, the key region for emotion processing, were extracted from the WFU Pick-Atlas v2.4 (<http://www.fmri.wfubmc.edu/cms/software>) and edited with MARINA (Walter, Blecker, Kirsch, Sammer, Schienle, et al., 2003). ROI analyses were conducted with the WFU Pick-Atlas. Significance threshold for the analyses was $p < .05$ familywise error corrected (FWE-corrected), for the ROI analyses $p < .05$ FWE-corrected within a ROI and $p < .001$ FWE-corrected within a ROI for the conjunction analysis. The cluster threshold for all analyses was set to 5 contiguous voxels.

Performance data and reaction time of the correct answers were analyzed with SPSS Version 13.0 (SPSS Inc., Chicago, IL). Because reaction times and percent correct answers from the fMRI study were not normally distributed, we used non-parametric tests for the analyses. The main effect was analyzed with the Friedman test for repeated measurement on one factor. Differences between the conditions were analyzed with the Wilcoxon test. Correlation analyses were run using Kendall's tau. Reaction times from the behavioral study were normally distributed and analyzed with a repeated measures ANOVA. Post-hoc tests were done with one-sample *t*-tests. Moreover, effect sizes were calculated for the ANOVA (η^2) and for the post-hoc tests (Cohen's *d*).

Results

fMRI-Study

Behavioral Data

There was a significant main effect of condition in reaction time ($\chi^2(2) = 34.4, p < .001$) with the longest reaction time for the affective ToM condition and the shortest for the neutral condition (Figure 3, right). Post-hoc tests revealed that reaction times in the affective ToM condition were significantly higher than in the emotion recognition condition ($Z = 3.5, p < .001$,

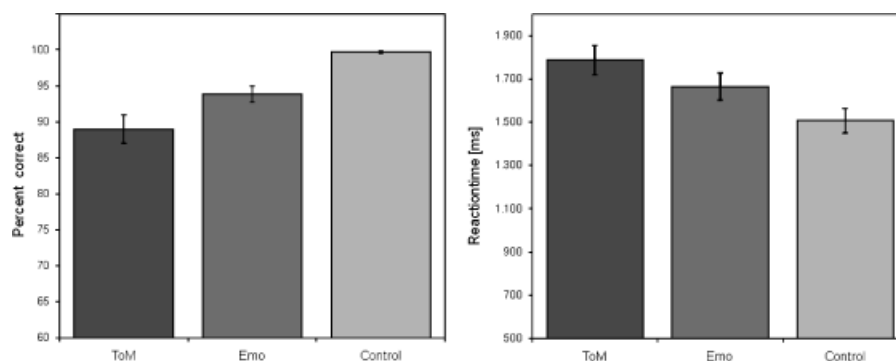


Figure 3. Behavioral results from the fMRI study. Mean (+/- standard error) percentage of correct answers (left) and reaction times (right) for the three experimental conditions. Note: All comparisons between conditions are significant ($p < 0.01$).

Table 2. Areas with Significant Activation During ToM and Emotion Recognition

Area	Brodmann area	Cluster size	MNI-coordinates			t-value
			x	y	z	
Postcentral gyrus	BA 3	2449	-42	-24	60	15.66
Precentral gyrus	BA 6		-39	-12	66	14.89
Inferior prefrontal gyrus	BA 47		-39	18	-9	13.59
Culmen		4015	36	-51	-30	15.44
Culmen			21	-57	-21	14.08
Lingual gyrus	BA 18		6	-84	-12	12.23
Inferior prefrontal gyrus	BA 47	1216	33	24	-12	14.34
Middle frontal gyrus	BA 9		45	12	33	12.91
Inferior prefrontal gyrus	BA 47		54	21	-3	10.74
Amygdala		29	21	-6	-18	11.62
Superior frontal gyrus	BA 6	779	0	15	60	11.28
Cingulate gyrus	BA 32		6	21	42	10.92
Medial frontal gyrus	BA 6		-3	-6	57	8.82
Globus pallidus		474	-12	0	0	11.03
Substantia nigra			-9	-21	-18	10.80
Parahippocampal gyrus/Amygdala	BA 30		-18	-33	-6	9.97
Globus pallidus		118	15	0	3	10.81
Thalamus			12	-15	12	7.81
Superior temporal gyrus	BA 39	28	-54	-54	3	10.04
Middle frontal gyrus	BA 47	39	-51	42	-3	9.76
Middle temporal gyrus	BA 22	19	51	-39	0	9.40
Inferior parietal lobule	BA 40	12	36	-57	45	8.69

Note: Conjunction of affective ToM and emotion recognition; $p < .001$, FWE-corrected within the ROI; t -threshold 6.11. Further activation peaks within the significant activated clusters are inserted.

$d = 0.29$) and in the control condition ($Z = 4.97$, $p < .001$; $d = 0.7$) and that reaction times in the emotion recognition condition were higher than in the control condition ($Z = 4.3$, $p < .001$; $d = 0.42$).

The same pattern occurred for the number of correct answers (main effect condition: $\chi^2(2) = 40.13$, $p < .001$, Figure 3, left). Participants made fewer errors in the control condition than either in the affective ToM ($Z = 4.5$, $p < .001$; $d = 1.21$) or in the emotion recognition condition ($Z = 4.3$, $p < .001$; $d = 1.19$) and made fewer errors in the emotion recognition condition than in the affective ToM condition ($Z = 3.34$, $p < .01$; $d = 0.48$). The number of correct responses for affective ToM and emotion recognition were significantly correlated ($r = .71$, $p < .01$), but neither the correlation between correct responses during affective ToM and the control condition ($r = -.016$, n.s.) nor the correlation of correct responses during emotion recognition and control condition ($r = -.030$, n.s.) revealed significance.

Functional Imaging Data

Common activation during emotion recognition and affective Theory of Mind. The conjunction analysis revealed activation in a large network of areas (see Table 2 and Figure 4A and Figure 5, left) including inferior frontal gyrus, STS, inferior parietal lobe, somatosensory cortex, amygdala, basal ganglia, thalamus, and occipital lobe ($p < .05$ FWE-corrected within the ROI; t -threshold 6.11).

Affective Theory of Mind specific activation. Comparisons between affective ToM and emotion recognition were computed to detect areas with stronger activation during mentalizing than during emotion recognition and vice versa. There was stronger activation for affective ToM than for emotion recognition in four clusters ($p < .05$, FWE-corrected; t -threshold 5.15): Left inferior frontal gyrus, right temporal pole and bilateral superior temporal sulci extending into the supramarginal gyrus (Table 3, Figure

4B). ROI analyses further revealed an enhanced BOLD-signal in the left amygdala (MNI coordinates: $-18 -6 -4$; $p = .015$ FWE-corrected within the ROI, $T_{\max} = 3.50$, Cluster size 23 voxels, t -threshold 2.92; see Figure 5, right) and in BA 44 bilaterally (MNI coordinates: $-54 21 9$; $p < .001$, FWE-corrected within the ROI, $T_{\max} = 4.82$, Cluster size 36 voxels, t -threshold 2.95; MNI coordinates: $54 21 9$; $p = .004$, FWE-corrected within the ROI, $T_{\max} = 4.12$; Cluster size 16 voxels, t -threshold 3.01). There was no stronger activation during emotion recognition than during affective ToM, even with a lowered significance level at $p < .001$, uncorrected. Activation in the ACC did not differ significantly between conditions (t -threshold left ACC 3.26 and t -threshold right ACC 3.29).

Table 4 displays significantly activated voxels ($p < .05$, FWE-corrected; t -threshold 4.73) with strongest activation during affective ToM, medium activation during emotion recognition, and least activation during the control task as revealed by the one-way ANOVA with condition as within-subject factor. These voxels were located in the superior temporal sulci and the left inferior frontal gyrus (Figure 4C). ROI analyses further revealed activation in the left BA 44 (MNI coordinates: $-54 21 9$, $p = .003$, FWE-corrected within the ROI, $T_{\max} = 3.90$, Cluster size 19 voxels, t -threshold 2.84), but not in the ACC (t -threshold left ACC 3.13 and right ACC 3.16), amygdala (2.82 t -threshold) or right BA 44 (t -threshold 2.68).

Post-hoc correlations were done to investigate whether higher activation during affective ToM than during emotion recognition may be caused by stimulus presentation time or by task difficulty. For this purpose, simple regressions were conducted between reaction time of the correct answers and brain activation and between percent correct answers and brain activation. However, simple regression revealed no significant association between reaction time and brain activation during affective ToM and during emotion recognition ($p < .05$, FWE-corrected; t -threshold 5.26), the same was true for the percent correct answers ($p < .05$, FWE-

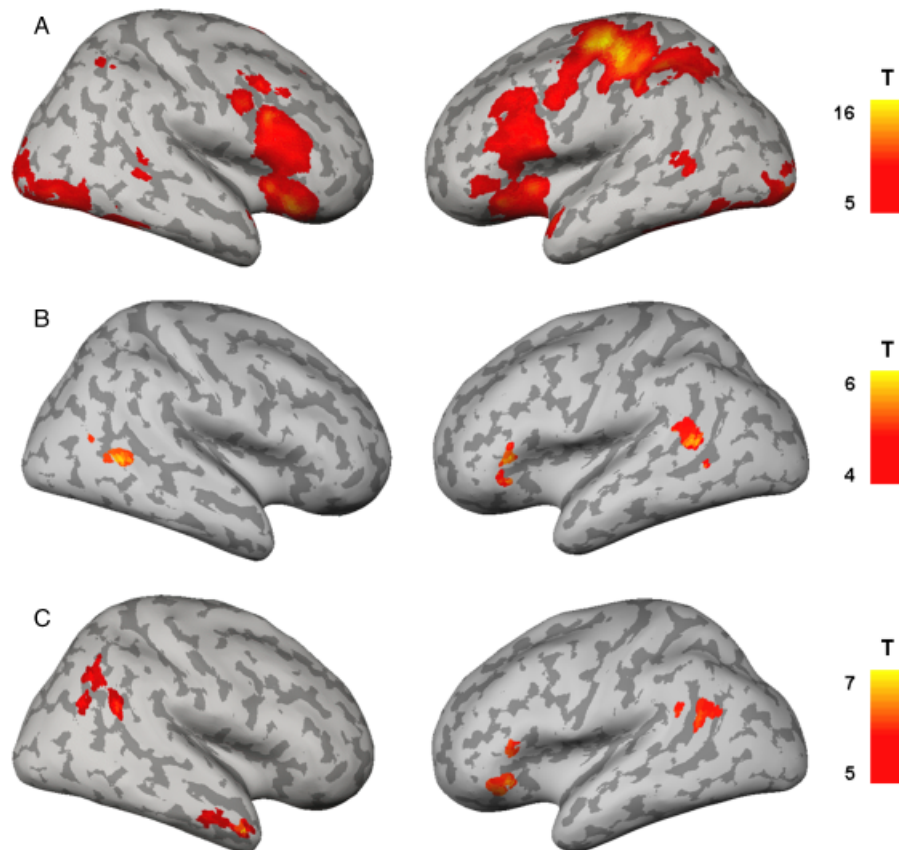


Figure 4. Cortical structures with significant activation during emotion recognition and affective ToM. A: Results of the conjunction analysis, displaying jointly activated clusters during emotion recognition and ToM ($p < .001$, FWE-corrected within the ROI). B: Results of the ANOVA, displaying clusters with strongest activation during affective ToM, and weakest activation during the control condition ($p < .05$, FWE-corrected). C: Clusters with stronger activation during affective ToM than during emotion recognition ($p < .05$, FWE-corrected).

corrected; t -threshold 5.26). Even when using a less stringent correction method for multiple testing, the false discovery rate (FDR) that controls the number of expected false positives within the significantly activated voxels (Genovese, Lazar, & Nichols, 2002), simple regression analyses revealed no significance. The t -threshold using this method was $t = 2.11$.

Behavioral Experiment

Analyses of the results of the behavioral experiment revealed a trend for a main effect of condition ($F(2,18) = 2.91$, $p = .081$; $\eta^2 = .19$). Post-hoc tests showed that the reaction time in the

neutral condition was longer than in the implicit emotional ($t(19) = 2.46$, $p = .024$; $d = 0.53$) and in the explicit emotional trials ($t(19) = 2.17$, $p = .043$; $d = 0.52$). Reaction time in the two emotional conditions did not differ ($t(19) = 0.22$, $p = .83$; $d = 0.03$). Figure 6 displays the reaction times for the three conditions.

Discussion

This study aimed to investigate the effects of emotion recognition and affective ToM on brain activation with a new experimental paradigm that allows the study of emotion recognition and the recognition of emotional intentions. We hypothesized that we would find overlapping brain regions activated during both emotion recognition and affective ToM and additional activation in areas associated with intention recognition during affective ToM. On the behavioral level, we expected a correlation between performance during emotion recognition and affective ToM with longer reaction times for affective ToM than for emotion recognition. In order to differentiate between emotion recognition and affective ToM, the study used identical stimulus material and identical response alternatives for all conditions but different instructions. The emotion recognition task demanded a decision about the emotion, the affective ToM task about the intention, and the control task about a physical feature of the depicted person.

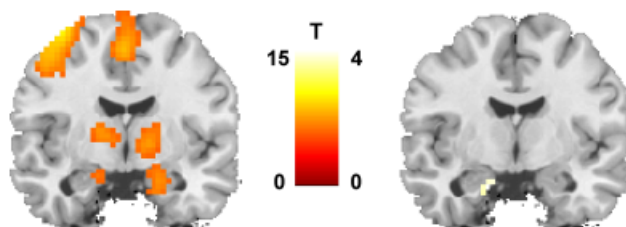


Figure 5. Significant activation of the amygdala during emotion recognition and affective ToM. Left: Results of the conjunction analysis, displaying joint activation during emotion recognition and affective ToM ($p < .001$, FWE-corrected within the ROI). Right: Results from the ROI-analysis, displaying voxels with stronger activation during affective ToM than during emotion recognition ($p < .05$, FWE-corrected within the ROI, right).

Table 3. Areas with Higher Activation During Affective ToM than During Emotion Recognition

Area	Brodmann area	Cluster size	MNI-coordinates			t-value
			x	y	z	
Middle temporal gyrus	BA 21	47	54	9	-30	6.60
Inferior temporal gyrus	BA 20		60	-6	-24	5.62
Inferior prefrontal gyrus	BA 47	81	-45	24	-6	6.50
Superior temporal gyrus	BA 39	91	57	-57	21	5.93
Angular gyrus	BA 39		54	-63	27	5.69
Inferior parietal lobe	BA 40		45	-66	42	5.65
Supramarginal gyrus	BA 40	43	-57	-57	21	5.81
Middle temporal gyrus	BA 39		-42	-60	24	5.43

Note: (Affective ToM > Emotion recognition; $p < 0.05$, FWE-corrected; t -threshold 5.15). Further activation peaks within the significantly activated clusters are inserted.

In line with most of the previous studies (Bora et al., 2005; Brüne, 2005a; Buitelaar & van der Wees, 1997; Dyck et al., 2006; Henry et al., 2006), there was a positive correlation between the amount of correctly recognized emotions and correctly recognized intentions indicating a relationship between these two processes. This relationship between emotion recognition and affective ToM could also be observed in the fMRI data in terms of overlapping brain activity in the two conditions. A conjunction analysis revealed common activation bilaterally in superior temporal sulci, inferior frontal gyri reaching into the insula, in the globus pallidus and the amygdala, right middle frontal gyrus, and left somatosensory cortex and thalamus. These results are in accordance with studies on imitation and observation of emotional expressions, which found activation in the amygdala and in areas of the mirror neuron system during the observation of emotional facial expressions (Carr et al., 2003; Leslie et al., 2004; Schulte-Rühter et al., 2007; Van der Gaag et al., 2007) as well as with studies showing the importance of the somatosensory cortex for the recognition of emotions (Adolphs et al., 2000; Hennenlotter, Schroeder, Erhard, Castrop, Haslinger, et al., 2005; Pitcher, Garrido, Walsh, & Duchaine, 2008; Pourtois, Sander, Andres, Grandjean, Reveret, et al., 2004; Winston et al., 2003). The activation in structures associated with the mirror neuron system, as well as in the insula and amygdala, can be interpreted in terms of action representation as a necessary process for the understanding of emotions in others (Carr et al., 2003). According to this assumption, emotions of others are understood by mental simulation taking place in the mirror neuron system. This information is then relayed by the insula to the amygdala where the emotional content is processed.

An explanation that goes beyond this interpretation is that the representation of emotional expressions also preactivates the neuronal network necessary for emotional intention recognition

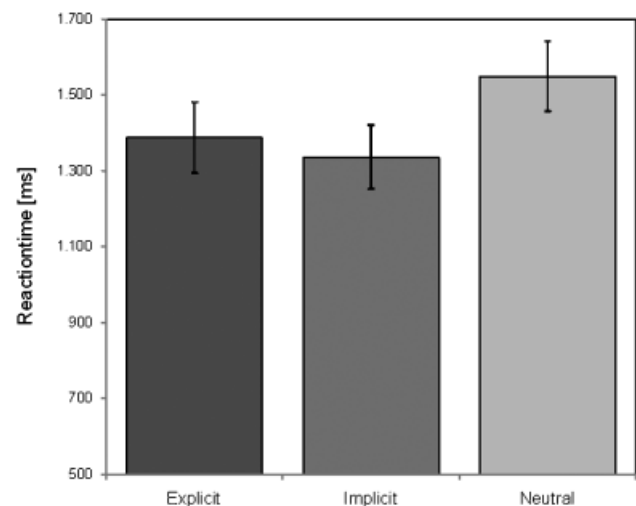
Table 4. Clusters with Strongest Activation During Affective ToM and Weakest Activation During the Control Condition

Area	Brodmann area	Cluster size	MNI-coordinates			t-value
			x	y	z	
Middle temporal gyrus	BA 39	62	-57	-54	9	5.82
Inferior prefrontal gyrus	BA 47	46	-54	30	0	5.80
Middle temporal gyrus	BA 39	50	57	-63	9	5.69

Note: (Affective ToM > Emotion recognition > Control; $p < 0.05$, FWE-corrected; t -threshold 4.73).

and thus facilitates the recognition of the emotional intentions. This interpretation is in line with the result that only areas already activated during emotion recognition showed stronger activation during affective ToM. No additional areas were identified as activated during affective ToM compared to emotion recognition. Moreover, in the confirmatory behavioral experiment, we found shorter reaction times during emotional intention recognition when the trials were preceded by a trial with an emotional expression compared to those trials preceded by a trial with a neutral expression. This effect was independent from the emotional expression presented explicitly in an emotion recognition context or implicitly in a neutral context. The results from the behavioral level support our assumption that emotion recognition preactivates the network necessary for emotional intention recognition and thus facilitates affective ToM.

Unlike previous studies on ToM, we found no activation of the medial prefrontal cortex/ACC but in the inferior prefrontal gyrus, the STS, and the temporal pole. This holds true for the conjunction analysis, the contrast between affective ToM and emotion recognition, and the comparison of all conditions. Activation in the ACC was linked to cognitive processes related to the presence of conflicting response alternatives (Paus, 2001). In the context of ToM, this process is described as a decoupling mechanism in the ACC, which enables mental states to be rep-

**Figure 6.** Results from the behavioral experiment: Reaction times (means and standard error) during emotional intention recognition for the three preceding conditions.

resented independent of reality (Gallagher & Frith, 2003). This decoupling is especially necessary in classical ToM tasks, such as false belief tasks where one has to recognize that a person has a mental state about the world that differs from the real world. Activation in the inferior prefrontal gyrus and in the STS, however, is associated with the attribution of intentions and intentional movements (Castelli et al., 2000; Pelphrey et al., 2004; Winston, Strange, O'Doherty, & Dolan, 2002), the recognition of biological movements (Bonda et al., 1996), the identification of complex goal-directed motions (Schultz, Imamizu, Kawato, & Frith, 2004), and the representation of action goals (Koski et al., 2002). The involvement of areas associated with the human mirror neuron system and the missing activation of the ACC in the present study are in good accordance with the view of simulation theorists like Gallese (2006), arguing that the attribution of intentions occurs by default via embodied simulation rather than higher cognitive mechanisms. He states that "... action prediction and the ascription of intentions—at least of simple intentions—do not appear to belong to different cognitive realms, but both pertain to embodied simulation mechanisms underpinned by the activation of chains of logically related mirror neurons" (Gallese, 2006, p. 18). This interpretation is also in line with the additional activation of the temporal poles during affective ToM in comparison to emotion recognition. Activation in the temporal poles is thought to provide a framework of associated emotional scripts for ToM (Frith & Frith, 2003), which allows the simulation of possible actions based on the knowledge of the emotion.

On the basis of the lack of activation in the ACC, but the involvement of areas associated with the mirror neuron system and the longer reaction times for affective ToM than for emotion recognition, we hypothesize that emotional intention recognition occurred by an additive simulation mechanism: The recognition of the emotion by a mental simulation of the emotional expression and the recognition of the emotional intention by the mental simulation of the emotional expression together with the additional mental simulation of possible actions. The STS and the inferior prefrontal gyrus seem to be critically involved in emotion recognition and recognition of emotional intentions, resulting in activation during both processes and additional activation during the recognition of the intentions. Thus, the facilitation of the recognition of emotional intentions by emotion recognition seems to occur by two reasons: (1) the need of the mental simulation of the emotion to infer the correct intention, and with this (2) a pre-activation of those areas necessary for the simulation of prospective actions. However, these conclusions have to remain speculative, because the existence of mirror neurons in the human brain is still controversial and we cannot demonstrate a simulation process, but only assume it. Another interpretation that is possible and does not rely on the assumption of a simulation mechanism, either explicit or implicit, is the idea of direct perception (Gallagher, 2008). Gallagher (2008) proposes that in daily interactions all information necessary to understand emotions as well as the intention of others is visible and can be assessed by direct perception: "When I see the other's action or gesture, I see (I immediately perceive) the meaning in the action or gesture. I see the joy or I see the anger, or I see the intention in the face or in the posture or in the gesture or action of the other" (Gallagher, 2008, p. 542). In this case, the increased activation and longer reaction times during affective ToM in comparison to emotion recognition can be explained by a more complex and probably also additional perceptual process.

Another possibility to explain the activation differences between emotion recognition and affective ToM that is in line with both the direct perception approach as well as the simulation approach is priming by the statements. If direct perception is smart (as Gallagher, 2008 proposes) and has access to concepts of mental states, the statements might prime a perceptual network, e.g., how someone looks who is going to bluster that has to be matched with the following stimulus. On the other hand, simulation theorists propose that simulation processes in the mirror neuron processes can predict action goals (Kilner, Friston, & Frith, 2007). The priming by the statements might have elicited according simulation processes in the mirror neuron system, and the result is matched with a simulation of the actual expression of the shown person. Moreover, direct perception as well as simulation should rely on the amygdala, which enriches the mere action representation/neutral perception with emotional information. Taken together, if we adhere to the literature ascribing more conscious cognitive processes to the ACC and more unconscious automatic processes to STS, inferior prefrontal gyrus, temporal poles, and amygdala, it is insignificant how we interpret the activation: In any case, the activation pattern we found points to the fact that an embodied process occurred during emotion recognition as well as affective ToM. However, these interpretations cannot rule out the possibility that if one has been confronted with an ambiguous complex situation such embodied processes would fail, and an involvement of the ACC would become necessary.

An unexpected result was the stronger activation of the left amygdala during affective ToM compared to emotion recognition. Activation in the right amygdala during emotion recognition and affective ToM can be attributed to emotional resonance (Carr et al., 2003), while the stronger activation during affective ToM than during emotion recognition in the left amygdala seems to be related to the active conscious processing of the intention (Castelli et al., 2000). In a study by Shaw et al. (2004), patients with early amygdala damage showed stronger ToM impairment than patients with adulthood amygdala damage. Interestingly, the early damage group mainly consisted of patients with lesions of the left amygdala and the adulthood group of patients with right-sided lesions, pointing to the possibility of lateralization effects. Grèzes, Berthoz, and Passingham (2006) assume that the amygdala is especially important for the estimation of threat against oneself. This points to the possibility that attributing the intention of another person during the affective ToM task was associated with an increased self-reference in comparison to the attribution of the emotional state. Altogether, these results support the assumption that, in general, the amygdala is involved in mentalizing and that the left amygdala has a specific role for the attribution of emotional intentions.

To rule out the possibility that the higher activation during affective ToM is simply due to the longer stimulus presentation, a simple regression with brain activation and reaction time (as a measure of stimulus duration) was conducted. We found no area where the duration of stimulus presentation was significantly correlated with brain activation, neither in the emotion recognition condition nor in the affective ToM condition. Moreover, to pursue the possibility that the differential brain activation between affective ToM and emotion recognition is due to the differences in task difficulty, we calculated a simple regression with brain activation and percent correct answers within the two conditions. This regression also revealed no significant result. Therefore, the stronger activation during the affective ToM task

seems not to be caused by stimulus presentation duration or task difficulty, but to the additional processes involved in ToM.

The study has several shortcomings. The generalizability of our results is reduced by the fact that we investigated only affective ToM processes. This lack of a non-affective ToM condition is a shortcoming, and it will be an important task for future studies to identify those regions of the social cognition network that are involved in both emotional and non-emotional intention recognition. Furthermore, future studies should not only investigate the relationship of affective and non-affective ToM, but also the relationship with empathy, a closely related process. There are several lines of evidence for an association between empathy and activation in the mirror neuron system (e.g., Carr et al., 2003; Schulte-Rüther et al., 2007). Another shortcoming rising from the experimental design using the same stimuli in all conditions is the use of emotional faces in the neutral control condition, making it an implicit emotion recognition task and thus more difficult to find differences in brain activation, especially in areas of the limbic system like the amygdala. Moreover, conditions differed in their

difficulty, as evident from the reaction times and percent correct answers, with a ceiling effect in the control condition. Therefore, we analyzed the correlation between the behavioral indices of task difficulty and brain activation in the emotion recognition and affective ToM condition and found no relationship. Nevertheless, this cannot rule out the possibility that there were at least subtle influences of task difficulty on brain activation. Due to the ceiling effect in the control condition, we could not examine the relationship between task performance and brain activation for this condition. Moreover, it would be interesting to test in further studies with more trials per emotion condition whether the type of emotion differentially influences activation during affective ToM.

In conclusion, with the present study using a novel affective ToM task, we could demonstrate that emotion recognition and affective ToM are two closely related components of social cognition. Both processes share a common neuronal network of areas assumed to be involved in embodied simulation or perception processes as core regions: the amygdala and areas belonging to the mirror neuron system.

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