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Fact *vs* fiction—how paratextual information shapes our reading processes

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Our life is full of stories: some of them depict real-life events and were reported, e.g. in the daily news or in autobiographies, whereas other stories, as often presented to us in movies and novels, are fictional. However, we have only little insights in the neurocognitive processes underlying the reading of factual as compared to fictional contents. We investigated the neurocognitive effects of reading short narratives, labeled to be either factual or fictional. Reading in a factual mode engaged an activation pattern suggesting an action-based reconstruction of the events depicted in a story. This process seems to be past-oriented and leads to shorter reaction times at the behavioral level. In contrast, the brain activation patterns corresponding to reading fiction seem to reflect a constructive simulation of what might have happened. This is in line with studies on imagination of possible past or future events.

Keywords: emotion; emotion regulation; fact; fiction; fMRI; literature; narrative; reading; theory of mind

INTRODUCTION

When we watch a movie, does it make any difference whether it claims to be 'based on a true story' or advises us that 'the following story is fictional and does not depict any actual person or event'? Does it make a difference whether we read a book labeled 'autobiography' or 'novel'? Many people would say it does.

Starting at an age of 3 years, children are able to tell apart what an object looks like from what it really is (Woolley and Wellman, 1990) and to distinguish between factual and fictional worlds (Woolley and Cox, 2007). It is also known that readers can learn from fiction and integrate information from fictional worlds into their real-world knowledge (Gerrig and Rapp, 2004). Reading fiction has the capacity to modify personality traits (Djikic *et al.*, 2009) and is associated with better performance on scales of empathy and social abilities (Mar *et al.*, 2006). But what causes this difference? In the present study, we investigated the neural mechanisms underlying the processing of factual and fictional contents in reading.

Although, theoretically, all kinds of stories, be they factual or fictional, are objects of narratology, this subdiscipline of literary studies focuses on narrative fiction (Genette, 1990; Smith, 2009). Note that fiction and literature designate independent textual properties. The first refers to a descriptive concept, whereas the second depends on aesthetic evaluation; therefore, a fictional text can but must not also be a literary one and vice versa (Lamarque and Olsen, 1994).

A reader can obtain information about the status of a certain text type (factual or fictional) in at least two ways. The first source of information arises from text-internal genre signals or 'symptoms' of fictionality (Hamburger, 1973; see Genette, 1990 for discussion). But those signals are neither necessary nor sufficient: authors often play with the reader's knowledge and expectations, leading literary scholars to conclude that 'there is no textual property, syntactical or semantic that will identify a text as a work of fiction' (Searle, 1975; see also Zwaan, 1994).

The second source of information, so-called paratext (Genette, 1990), is mostly provided even before the reader opens a book, through cover details, like the name of the author, the title or genre indications (e.g. 'Novel' or 'Autobiography'). Such signals provide key knowledge to the reader and trigger certain expectations. If a story is signaled to be factual (e.g. newspaper, autobiography, historiography), readers expect truthfulness with respect to the real world (Gerrig and Rapp, 2004). On the other hand, the cognitive and emotional involvement in a fictional story (e.g. transportation or immersion) depends on previous knowledge and perceived realism (Green, 2004; see Jacobs, 2011, for different factors underlying immersion in reading). In addition, when a story is labeled as a work of fiction, the reader signs a kind of 'fictional agreement' (Eco, 1994, p. 75), accepting that the author pretends (or makes believe) the content of his story *as if* it was real. Genette (1990) stated that 'a fictional narrative is [. . .] a pretence or simulation of a factual narrative' (p. 757). Similarly, Oatley and Olson (2010) argued that factual and fictional works follow different tasks: cooperation and alignment for real-world interaction on the one hand, imagination and simulation for fictional interaction on the other (see also Mar and Oatley, 2008).

If this were true, we would expect that the mere labeling of a text as fictional invites the reader to enter the game of pretence and simulation (German *et al.*, 2004; Whitehead *et al.*, 2009). That should be associated with similar neuronal patterns as have been observed in studies on mental imagery (Decety and Grèzes, 2006; Dinstein *et al.*, 2007) or simulation of self *vs* others (Decety and Grèzes, 2006). Across these studies, a regularly reported finding is the engagement of the inferior parietal lobule (IPL), which has been found to be involved during the construction of a vivid scene (Summerfield *et al.*, 2010) and, jointly with the posterior cingulate cortex (PCC) and the dorsolateral prefrontal cortex (DLPFC), during mental simulations in order to solve future problems (Gerlach *et al.*, 2011). Whereas readers are primarily interested in information gathering during factual reading they expect enjoyment when reading fictional texts (Galak and Nelson, 2010; Jacobs, 2011). We assume that enjoyment during reading fiction is not exclusively driven by stylistic features, but additionally comes from the extent to which a text invites the reader for relational thinking (Raposo *et al.*, 2010) and simulation processes as mentioned earlier.

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Growing evidence suggests the frontopolar cortex (FPC) to play a role in such processes. The FPC has been found activated in tasks which require constructive mental processes like mind-wandering (Gilbert *et al.*, 2005; Dumontheil *et al.*, 2010), simulation of the future (Schacter *et al.*, 2008) and complex imagery of hypothetical events (Addis *et al.*, 2009). In addition to the IPL, we therefore expect the lateral prefrontal cortex (including FPC and DLPFC) to be engaged in reading fiction. According to Mar and Oatley, (2008), especially fictional texts have the capacity to provide the reader with simulations of social information and experiences that might prepare the reader for similar real-life interactions in the future. The authors proposed the involvement of theory of mind (ToM) processes as one function of the simulation during reading fictional texts and the finding that reading fiction goes along with better performance on scales of empathy and social abilities (Mar *et al.*, 2006) speaks in favor to that assumption. If the neural processes underlying reading fiction recruit the lateral PFC because they resemble those involved in mind-wandering and the imagination of hypothetical events, it seems reasonable to assume that the strength of lateral PFC activation predicts the involvement of brain areas that support mentalizing and perspective taking, especially the medial prefrontal cortex (mPFC) (Decety and Jackson, 2004; Frith and Frith, 2006). This can be examined with psychophysiological interaction (PPI) analysis (see 'Methods' section for further details) which allows to test whether a brain region (i.e. lateral PFC) shows a stronger coactivation with other brain regions during one task (reading fiction) as compared to another (reading facts). The mPFC also constitutes one key region in the text comprehension network (Ferstl and von Cramon, 2002; Ferstl *et al.*, 2008) and a meta-analysis by Mar (2011) revealed a functional overlap in the right mPFC between ToM stories and narrative comprehension stories.

Story comprehension presupposes an understanding of the propositions derived from the meanings of words and sentences (text level) and the integration of this verbatim information with the reader's world knowledge and his knowledge about the discourse context which leads to the construction of a model of what the text is about (situation model; van Dijk and Kintsch, 1983). In our study, the reading of stories in general, independently of the given context (fact or fiction), should replicate results on the story comprehension network reflecting these integration processes, including the mPFC, the inferior frontal gyrus (IFG), the anterior temporal lobes (aTL) and the posterior superior temporal gyrus (Ferstl and von Cramon, 2002; Xu *et al.*, 2005; Ferstl *et al.*, 2008; Yarkoni *et al.*, 2008; Mar, 2011).

To our knowledge, there exist no studies so far which directly investigated the fact/fiction distinction. But previous studies examined the neuronal processing of real life as compared to animated film scenes (Han *et al.*, 2005; Mar *et al.*, 2007, and Abraham *et al.,* 2008b) let their participants indicate whether it was possible to interact with real (e.g. George Bush) or fictional characters (e.g. Cinderella). They found selective activation of the mPFC and the PCC/retrosplenial cortex (RSC) when participants evaluated real persons and concluded that real persons elicit more autobiographical memory retrieval as they have a higher personal relevance (see also Summerfield *et al.*, 2009).

However, as all those studies used slightly different materials across conditions, it cannot be excluded that the results were influenced by semantic or visual properties of the stimuli. In addition, the aforementioned studies used either phrases or film clips but not any more complex linguistic material. The aim of the current study was to investigate the neural mechanisms underlying the processing of factual and fictional contents during the reading of simple stories. In order to exclude linguistic differences between conditions, we only changed the context label declaring the text as either factual or fictional. In particular, this paradigm allowed us to investigate how a certain 'reception agreement' which is offered to the reader determines the neural processing of a given text. As empirical research often uses stimuli with narrative and/or fictional content, e.g. paradigms investigating theory of mind, empathy, or emotion regulation, it might be helpful for empirical psychologists as well as for scholars of literature to learn more about possible differences in the neural processing of factual and fictional contents.

METHODS

Stimuli

We used 80 short narratives (mean number of words: 48, range: 41–57). We adopted half of them from the so-called *black stories* (moses Verlag GmbH, Kempen, www.moses-verlag.de), a game based on short narratives with negatively valenced plots (crimes, disasters, accidents), as to be found in daily news stories, and also in novels or crime stories. Another 40 narratives with comparable settings but neutral emotional valence were created in order to prevent readers from an oversaturation of negatively valenced texts. Prestudies made sure that the style of all micro-narratives is sufficiently neutral or ambiguous to equally correspond to that of a typical newspaper article or to that of a literary story.

Participants

Twenty-four healthy, right-handed volunteers (12 female, mean age: 26.5; age range: 18–45) took part in the study. Participants were German native speakers and skilled readers. Only participants who did not know the *black stories* game and were naive to its content were included. All participants had normal or corrected to normal vision and gave informed written consent in accordance with the local research ethics committee.

Task

A 2×2 repeated measures design was applied with one factor varying the context ('real', 'invented') and the second factor reflecting the story type ('negative', 'neutral'). A total of 80 stories were presented, 20 in each factor combination. We pseudo-randomized the order of conditions as well as the presentation of the narratives across conditions. All participants read exactly the same narratives, only the label prior to each narrative ('real', 'invented') was pseudo-randomized across subjects. During the fMRI experiment, a narrative was presented for 20 s, displayed on five lines (shown 4 s each). We set up the presentation time by using RT data from a pilot study and used the mean reading time in seconds plus one standard deviation ($M = 12{,}63$; s.d. $= 6.45$; in seconds). In pilot tests with volunteers in the scanner, this timing has proved to be comfortable for most reader. Prior to the story, a context label (either 'real' or 'invented') was presented for 3 s in order to signal either a factual or a fictional source. Participants were requested to read the text silently and solve a verification task following each text. By means of a cue ('real?' or 'invented?'—*German: 'Real?'/'Erfunden?'*), participants were asked, as an attention control task, whether the story they just read was real or invented. Participants answered via button press ('yes', 'no'). The verification cues were presented in a pseudo-randomized order so as to avoid motor preparation during the reading phase and to assure an equal assignment of question cues and required responses with regard to each condition. Additionally, participants completed the interpersonal reactivity index (IRI Davis, 1983; German version: Paulus, 2009) which provides a four-dimensional self-report estimate of empathy. In this study, we focus on the 'fantasy' subscale which assesses the individual tendency to put oneself into fictional characters and thus might influence the neural processing during reading fiction (please refer to 'Data Analysis' section for further details).

fMRI data acquisition

Functional data were acquired on a Siemens Tim Trio 3T MR imager. Four runs of 425 volumes were measured using a T_2^*-weighted echo-planar sequence [slice thickness: 3 mm, no gap, 37 slices, repetition time (TR): 2 s, echo time (TE): 30 ms, flip angle: 90°, matrix: 64 × 64, field of view (FOV): 192 mm, voxel size: 3.0 mm × 3.0 mm × 3.0 mm] and individual high-resolution T_1-weighted anatomical data (MPRAGE sequence) were acquired (TR: 1.9, TE: 2.52, FOV: 256, matrix: 256 × 256, sagittal plane, slice thickness: 1 mm, 176 slices, resolution: 1.0 mm × 1.0 mm × 1.0 mm).

Data analysis

Behavioral measures were analyzed with SPSS (SPSS Inc., Chicago, IL, USA). Analysis of fMRI data was conducted with Brain Voyager QX [2.0] (Brain Innovation, Maastricht, The Netherlands; Goebel *et al.*, 2006). Functional data were corrected for head motion and for different slice scan times using cubic spline interpolation. To remove low-frequency signal drifts, a high-pass filter was applied with a cutoff period three times the block length. Spatial smoothing was performed using a Gaussian filter of 8 mm, full width at half maximum. The functional maps of each participant were then transformed into standard Talairach space (Talairach and Tournoux, 1988). Whole-brain statistical analysis was performed according to the general linear model as implemented in Brain Voyager QX. On the first level, the model was generated with two blocked regressors for the reading of stories (invented: reading fiction, real: reading fact) and two additional blocked regressors, one for the context labeling period prior to each story and one for the attention-task period following each story. In this article, we will focus on the main effect of context (invented *vs* real). Individual contrast images from the first-level analysis were applied to a second-level random effects group analysis, in which we tested for the main effect of context (invented *vs* real). All contrasts were corrected for multiple comparisons ($P < 0.05$) at the cluster level using Monte Carlo simulations in order to calculate minimum cluster size thresholds (initial threshold at the voxel level $P < 0.001$ uncorrected). As this is, to our knowledge, the first study investigating the neurobiological mechanism for the processing of fictional as compared to factual contents and in order to provide a comprehensive picture of the results, we conducted the corrections for multiple comparisons ($P < 0.05$) not only with an initial threshold at the voxel level $P < 0.001$ uncorrected, but also at $P < 0.003$ uncorrected and $P < 0.005$ uncorrected, respectively.

In correspondence with our initial hypotheses, we identified the right frontopolar cortex (rFPC) to be involved in reading fiction and selected it as seed region for further PPI analysis (Friston *et al.*, 1997) with a sphere of 8 mm around the peak voxel (45, 47, 10). PPI analysis allows identifying brain regions that show stronger coactivation during one task (reading fiction) as compared to another (reading fact). Particularly, we were interested in whether context-specific rFPC activation (i.e. reading in a fictional mode) is 'coupled' with ToM-related brain areas, especially the mPFC. The PPI regressor was calculated as the element-by-element product of the mean-corrected activity in the rFPC region of interest and the task vector coding for the context-specific effect of reading fiction compared to reading fact. To identify areas of the brain that showed increased activation during reading fiction when rFPC activation increased, individual PPI regressors where entered into a second-level random effects analysis. Finally, we repeated the PPI analysis with individual scores on the IRI fantasy scale as a covariate to examine areas of the brain that showed a stronger coupling with rFPC depending on individual tendency to put oneself into fictional characters. A stronger 'readiness' of individuals to 'transpose themselves imaginatively into the feelings and actions of fictitious characters in books, movies and plays' (Davis, 1983, p. 114) might lead to a stronger coupling between FPC and the mPFC.

RESULTS

Behavioral results

Table 1 shows the descriptive data for the behavioral measures during the verification task. RTs ranged from 1067 to 1235 ms across conditions. A 2 × 2 repeated measures ANOVA was conducted to examine the effects of context (real, invented) and story type (negative, neutral) on RTs during the verification task. The results indicate that participants responded faster when a story had been presented in the real context condition (main effect of context; $F_{1,23} = 5.8$, $P < 0.024$). Results revealed no main effect of story type ($F_{1,23} = 2.8$, $P < 0.106$) and no context × story type interaction ($F_{1,23} < 1$, $P < 0.660$).

A 2 × 2 repeated measures analysis on the percentage of correct responses revealed no main effect of context ($F_{1,23} < 1$, $P < 0.498$) or story type ($F_{1,23} < 1$, $P < 0.404$) and no interaction ($F_{1,23} < 1$, $P < 0.750$). The mean percentage of correct responses across conditions was 94.5 ± 6.8.

fMRI results

First, we calculated the neural activation of story reading by calculating the conjunction of factual reading and fictional reading. As expected, reading stories, independently of the given context (fact or fiction), revealed an activation pattern that is regularly reported in studies on story comprehension (Ferstl and von Cramon, 2002; Xu *et al.*, 2005; Ferstl *et al.*, 2008; Yarkoni *et al.*, 2008; Mar, 2011). Both reading modes shared extensive bilateral activation in the IFG (BA 9, 45, 47), the mPFC (BA 8, 9), temporal poles (TPs: BA 38), amygdala, thalamus and early visual processing areas (BA 17, 18, 19) that extended to the fusiform gyrus. The activation covered also the middle temporal gyrus (MTG) and superior temporal gyrus (STG) extending to the posterior superior temporal sulcus (BA 21, 22, 39) on the left (for further details, please refer to Supplementary Table S1).

Second, we compared factual reading with fictional reading (real > invented) (Table 2 and Figure 1). Reading a text on the assumption that it depicted real events selectively engaged regions in the RSC (BA 30), right TP (BA 38), left lateral premotor cortex (BA 6) and bilateral lateral cerebellum. This activation pattern extended to the ventral striatum and left posterior middle temporal gyrus (MTG: BA 39/19) [cluster level corrected ($P < 0.05$), initial voxel level threshold $P < 0.003$ uncorrected] and to the left STG/MTG (BA 22, 21) [cluster level corrected ($P < 0.05$), initial voxel level threshold $P < 0.005$ uncorrected].

Third, the reverse contrast (invented > real) was used to examine brain areas which were more respondent during reading on the assumption that the texts were invented (Table 2 and Figure 1). This contrast revealed activations in the rFPC/DLPFC (BA 10/9), bilateral mid-cingulate/posterior cingulate cortex (MCC/PCC: BA 24, 31), right dorsal posterior cingulate cortex (dPCC: BA 31) and right IPL/supramarginal gyrus (BA 40). Additional regions were observed in the right FPC/DLPFC (BA 10/46), left dorsal anterior cingulate cortex (dACC: BA 24, 32), left precuneus (BA 7) [cluster level corrected ($P < 0.05$), initial voxel level threshold $P < 0.003$ uncorrected] and right DLPFC (BA 8) [cluster level corrected ($P < 0.05$), initial voxel level threshold $P < 0.005$ uncorrected].

PPI analysis (Table 3) showed that rFPC covaried context dependent (invented > real) with the right ACC/medial frontal gyrus [ACC/MFG: BA 10 ($r = 0.566$, $P = 0.0001$)]. Additional functional interactions could be found in the right MFG (BA 9), right aTL (BA 38), left PCC (BA 31), right IFG (BA 9) and bilateral fusiform gyrus (BA 37) [cluster level corrected ($P < 0.05$), initial voxel level threshold $P < 0.005$ uncorrected]. Additionally, we examined which areas of the brain

Table 1 Descriptive data (mean and standard deviation) of the behavioral measures (reaction time and percentage of correct responses) for all conditions

Conditions	Reaction time (ms)		Percentage correct	
	Mean	s.d.	Mean	s.d.
Real_Negative	1101.99	229.35	94.58	6.74
Real_Neutral	1141.20	239.65	93.54	7.73
Invented_Negative	1167.52	218.34	95.21	5.61
Invented_Neutral	1193.53	169.87	94.79	7.14

Table 2 Brain activation during fact-reading and fiction-reading

Region	Laterality	Broadmann area	Talairach coordinates			t
			x	y	z	
Fact > fiction						
Temporal pole	R	38	42	23	−20	4.10
Cerebellum	R	–	21	−73	−29	4.81
Caudate head*	R	–	3	5	1	3.86
Retrosplenial cortex	L	30	−6	−40	4	4.49
Cerebellum	L	–	−24	−82	−35	4.05
			−14	−76	−32	3.89
Premotor cortex	L	6	−45	2	49	4.87
Posterior middle temporal gyrus*	L	19/39	−45	−64	19	3.88
Middle temporal gyrus/superior temporal gyrus**	L	21/22	−54	−28	−2	3.35
Fiction > fact						
Inferior parietal lobule/supramarginal gyrus	R	40	48	−40	43	−4.32
			42	−40	34	−4.17
Frontopolar cortex/dorsolateral prefrontal cortex	R	10/9	36	44	25	−5.53
Frontopolar cortex/dorsolateral prefrontal cortex*	R	10/46	45	47	10	−3.80
Dorsolateral prefrontal cortex**	R	8/9	33	20	37	−3.38
Mid-cingulate cortex/posterior cingulated cortex	R	24/31	15	−19	37	−5.45
Dorsal posterior cingulate cortex	R	31	15	−43	40	−4.14
Dorsal anterior cingulate cortex**	R	24/32	9	8	37	−3.43
Mid-cingulate cortex/posterior cingulated cortex	L	24/31	−12	−22	43	−4.20
			−15	−16	37	−4.15
Dorsal anterior cingulate cortex*	L	24/32	−9	5	37	−3.55
			−6	17	34	−3.41
Precuneus/superior parietal lobule*	L	7	−21	−52	40	−3.84

Brodman area, Talairach coordinates and t-score for the peak voxel of significantly activated regions; corrected for multiple comparisons at cluster level ($P < 0.05$) with an initial voxel level threshold of $P < 0.001$ (uncorrected). At an initial voxel level threshold of $P < 0.003$* and $P < 0.005$** (uncorrected) additional regions became engaged.

showed higher functional connectivity with rFPC during reading in a fictional mode, depending on self-report scores at the fantasy scale. Individuals who reported a stronger tendency to put themselves into characters of novels and films showed a stronger coupling between rFPC and the right MFG (BA: 10, 8 49 0) (Figure 2), right precuneus/superior parietal lobule (BA 7, 18 − 61 58) and also [cluster level corrected ($P < 0.05$), initial voxel level threshold $P < 0.005$ uncorrected] in the right IPL (BA 40, 36 − 37 61).

DISCUSSION

Reading facts

Reading stories on the assumption that they refer to real events, as reported in a newspaper or a magazine, selectively yielded an activation pattern comprising the RSC, right TP, left MTG/STG, the ventral striatum, the premotor cortex and the cerebellum.

The premotor cortex and the cerebellum which were more strongly activated in the facts condition than in the fiction condition are likely to be part of the mirror neuron system and involved in action observation (Buccino *et al.*, 2001; Calvo-Merino *et al.*, 2006), imitation (Jackson and Decety, 2004) or imagination (Decety and Grèzes, 2006). Reading in a fictional mode also engaged the left lateral temporal regions (MTG/STG) and right TP. Whereas readers expect entertainment from fictional stories they gather for information when reading factual texts (Galak and Nelson, 2010) to update their world knowledge (Zwaan, 1994). In line with that, a study by Hasson *et al.* (2007) revealed that left lateral temporal activation (extending from posterior dorsal STG/MTG to TP) predicted accurate subsequent memory for story content and showed to be more responsive to informative than to less informative story endings. Left lateral STG was also found to be active during attention to action- and space-related story features (Cooper *et al.*, 2011) and appears to become particularly engaged during the imitation of another person (Decety *et al.*, 2002). Moreover, the anterior temporal region has been found to be more engaged when participants observed a real hand rather than a virtual hand performing grasping movements (Perani *et al.*, 2001). Thus, the prior knowledge that a text is a factual one seems to guide the readers comprehension strategies toward an understanding of what happened in a story. The reader's imagination during text processing might be triggered on the actions and their outcomes, as factual stories appear to describe unchangeable, past completed events compared to a more hypothetical consideration of events during fictional reading (see 'Discussion' section below).

In a behavioral study with comparable material, it has been shown that reading in a factual mode resulted in a stronger situation model than reading in a fictional mode (Zwaan, 1994). The construction of such a model requires the reader's understanding of the single events described in a text and their interrelations. This textual information then needs to be integrated into the reader's world knowledge, being represented in autobiographical memory (van Dijk and Kintsch, 1983). In addition to the lateral temporal activations, the RT results of the present fMRI experiment speak in favor of a stronger situation model in the factual reading mode as the participants responded faster in the verification task when a text was presented as 'real' (accordingly, texts read in a factual mode were rated as more familiar in a prestudy). Similarly, Abraham *et al.* (2008a) found shorter RTs for statements that were personal or referred to the past than to impersonal- or future-related statements, as well as for the evaluation of real compared to fictional characters (Abraham *et al.*, 2008b). The texts used in the current experiment comprised events as regularly reported in the daily news, in TV documentaries and newspaper reports. This holds especially for the narratives, depicting accidents and criminal offences, including homicide. As the textual information presented to the participants was identical across conditions, we assume that reading in a factual mode signals a higher personal relevance to the reader and therefore elicits more autobiographical memory retrieval. This interpretation is in line with the activation of the RSC and the striatum we observed for the factual reading condition. Especially the left RSC was found to be responsive to the realness and self-relevance of recalled events (Summerfield *et al.*, 2009) or when answering questions concerning real persons as compared to fictional characters (Abraham *et al.*, 2008b). The ventral striatum is known to be involved in the processing of reward and positive affect (Elliot *et al.*, 2000; Roy *et al.*, 2012), learning (Willems *et al.*, 2010) and social cognition (Singer *et al.*, 2006; Tricomi *et al.*, 2010). The activation we observed in the ventral striatum likely reflects the salience emanating from the action-relevance of the texts when they were read in the fact condition, which fits to the finding that activation in this region has been reported

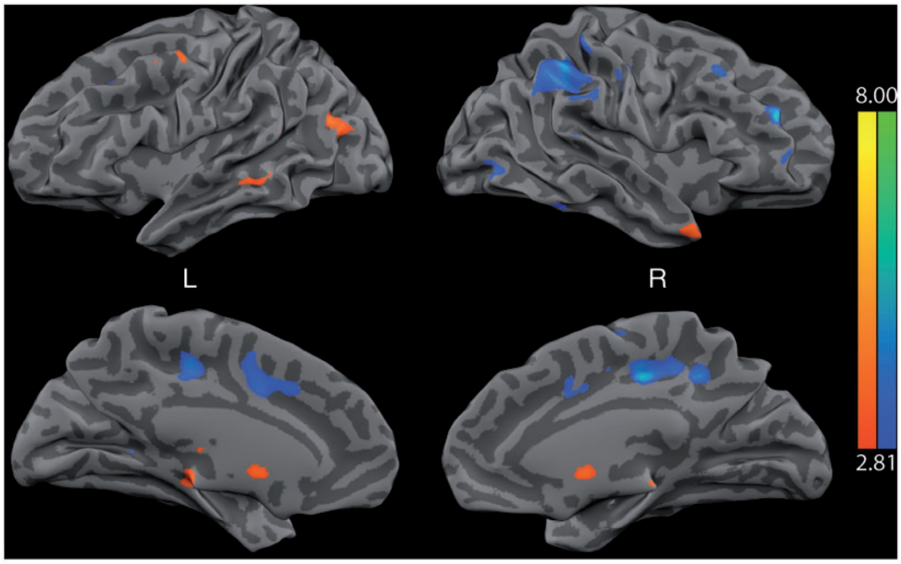

Fig. 1 Brain areas activated when comparing reading facts with reading fiction. Areas of selective activation for the contrast (**A**) real *vs* invented (warm colors) and (**B**) invented *vs* real (cold colors); visualization: cluster level corrected ($P < 0.05$), initial voxel level threshold $P < 0.005$ uncorrected.

Table 3 Task-related PPI analysis of rFPC seed

Region	Laterality	Broadmann area	Talairach coordinates			t
			x	y	z	
Anterior cingulate gyrus/medial frontal gyrus	R	10	3	50	10	4.36
Fusiform gyrus**	R	37	42	−43	−23	5.36
Cerebellum**	R	–	21	−88	−29	4.71
Medial frontal gyrus/anterior cingulate gyrus**	R	9/32	12	38	22	4.40
Medial frontal gyrus/superior temporal gyrus**	R	25/47	12	11	−20	4.34
Thalamus**	L	–	−3	−34	1	4.51
Posterior cingulate**	L	31	−6	−55	25	3.84
Fusiform gyrus**	L	37	−42	−58	−23	4.84

The anterior cingulate gyrus showed a significant coactivation with rFPC during reading fiction (invented > real); corrected for multiple comparisons at cluster level ($P < 0.05$) with an initial voxel level threshold of $P < 0.001$ (uncorrected). At an initial voxel level threshold of $P < 0.005$** (uncorrected), additional regions became engaged.

in response to action-relevant, salient stimuli, even though no reward was connected with these stimuli (Zink *et al.*, 2003).

Our results thus suggest an action-based (and possibly past-oriented) reconstruction of what happened when the events depicted in a text are supposed to be real.

Reading fiction

Reading stories on the assumption that they refer to fictional events such as those narrated in a novel, a short story or a crime story selectively engaged an activation pattern comprising the dACC, the right lateral FPC/DLPFC and left precuneus, which are part of the fronto-parietal control network (Smallwood *et al.*, 2012) as well as the right IPL and dPCC, which are related to the default mode network (Raichle *et al.*, 2001).

The activation we found in the dACC was mainly located in Brodmann areas 24′ and 32′ (Nieuwenhuys *et al.*, 2007). This region is involved in working memory, attention, action monitoring and pain perception. However, it also reacts sensitively to emotional valence and seems to play a role during the evaluation and representation of the value of future action (see Amodio and Frith, 2006 for a review). Together with the DLPFC, the dACC plays an important role in emotion regulation, especially during downregulation of negative emotions. Strikingly, in studies on emotional downregulation, participants were often instructed to imagine, for instance, that the stimuli were not real (Eippert *et al.*, 2007; Hermann *et al.*, 2009), but rather a film scene (McRae *et al.*, 2008).

A prominent role in the fiction contrast can be ascribed to the right lateral FPC as one part of the fronto-parietal control network. Dumontheil *et al.* (2010) found a U-shaped relation between task difficulty and frontopolar activation. According to the authors, the lateral FPC is responsive to very simple tasks, which allow for mind-wandering, as well as for difficult tasks, which require the handling of self-produced information. In a meta-study, Gilbert *et al.* (2005) demonstrated that specific lateral frontopolar activation is associated with longer behavioral RTs and suggested this lateral activation to be related to attention shifts for information generation or stimulus-independent thought. In fact, the lateral frontopolar region has been associated with the simulation of past and future events when compared to the recall of reality-based episodic memories (Addis *et al.*, 2009; see also Schacter *et al.*, 2008). This suggests a process of constructive content simulation taking place during fictional reading. The PPI analysis showed positive functional connectivity between rFPC and brain regions related to ToM and empathy (mPFC, PCC, precuneus, aTL). In accordance with our initial hypotheses, these data support the assumption that reading fiction invites for mind-wandering and thinking about what *might* have happened or could happen. Such simulation processes require perspective taking and relational inferences (Raposo *et al.*, 2010) which make a coactivation of ToM and empathy related areas likely.

Reading texts as fictional thus appears to exceed mere information gathering. Our results suggest that readers perceive the events in a fictional story as possibilities of how something might have been, which leads to an active simulation of events—similar to the simulation of a possible past or a possible future (Schacter *et al.*, 2008; Addis *et al.*, 2009). Along the way, the reader's construction of a situation model then might remain flexible. Zwaan (1994) stated that reading in a fictional (compared to factual) mode implies a focus on the text basis and attention to less important information. During literary

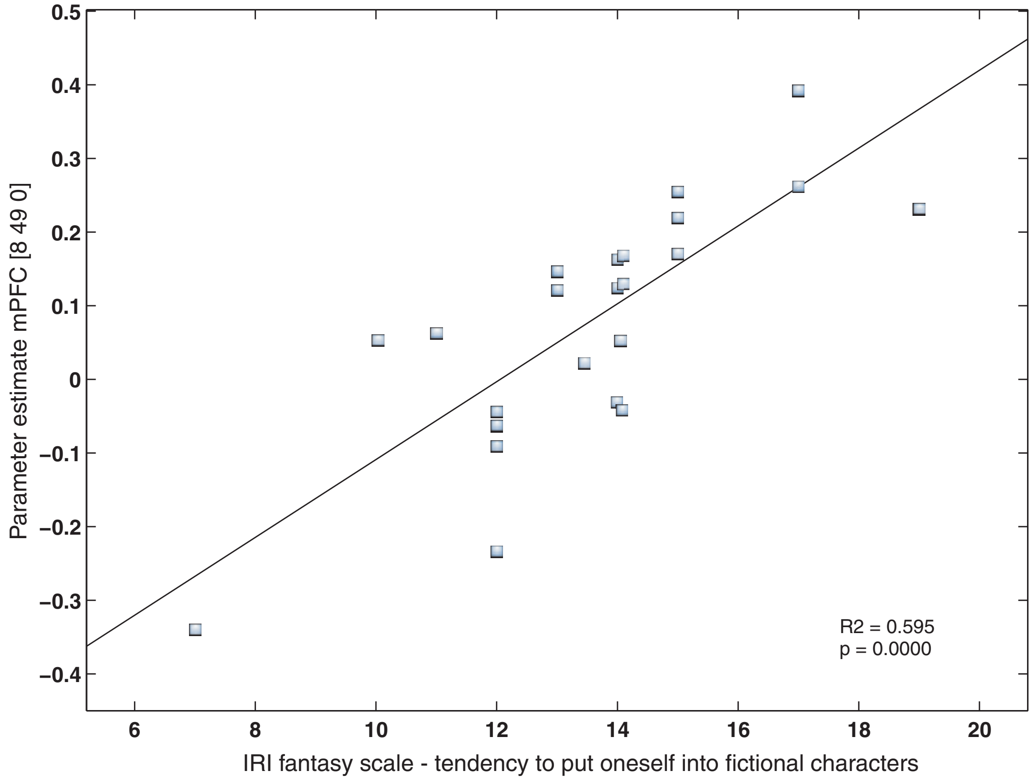

Fig. 2 Positive correlation between the fantasy scale and right FPC—right mPFC connectivity during fiction reading relative to fact reading. The right mPFC showed a stronger coupling with rFPC depending on individual tendency to put oneself into fictional characters.

reading, the reader typically assumes that every word in the text counts and could bear a meaning which might become relevant later (e.g. a knife lying on the kitchen table), a principle also known as Chekhov's gun (see Mar and Oatley, 2008 for further description).

While reading facts seems to elicit mental simulation processes basically regarding actions and their outcomes, reading fiction appears to initiate simulation processes especially concerning the motives behind an action and thereby the protagonist's mind. This interpretation could explain, why large parts of the fiction-activation pattern have been associated previously with social and moral reasoning (Greene *et al.*, 2004; Klucharev *et al.*, 2009), for instance about beliefs and false beliefs (Sommer *et al.*, 2010). According to the latter authors, the evaluation of others' beliefs and false beliefs requires the 'attentive monitoring of a protagonist's behavior' and the 'decoupling between the protagonist's mental state and reality' (Sommer *et al.*, 2010, p. 127). This is also reflected in the PPI pattern we observed with respect to the covariate obtained from the fantasy scale: individuals whose rFPC predicted stronger coupling in the mPFC and rIPL during reading fiction reported a stronger tendency to put themselves into characters of novels and movies. The fantasy scale operationalizes affective empathy which supports the interpretation that the coactivation in the mPFC reflects mentalizing processes. Nevertheless, alternative explanations exist: Ferstl and von Cramon (2002) found the mPFC to be involved in both mentalizing and coherence building during reading and suggested a more general role of the mPFC reflecting the initiation and maintenance of volitional cognitive processes. Further research will be needed to answer the question whether constructive simulation processes during reading fiction go along with ToM-related processing, coherence building or more general integration processes.

The right IPL is especially responsive during the observation and imitation of another person's actions (Decety and Grèzes, 2006; Dinstein *et al.*, 2007), perspective taking (Shane *et al.*, 2009), scene construction (Summerfield *et al.*, 2010) and representation of complex goals (Hamilton and Grafton, 2008). The right IPL seems to be essential for the perception of another person as the agent of an action (Decety *et al.*, 2002; Farrer and Frith, 2002) – moreover the feeling of not being the cause of one's own actions, as reported by a subgroup of schizophrenic patients, was associated with hyper-activation in this region (Farrer *et al.*, 2004). Further in line with our interpretation of fictional reading as a constructive content simulation, the right IPL and the dPCC have been shown to be engaged in thinking about open questions concerning the general- or self-related future (Abraham *et al.*, 2008a).

Taken together, these results for reading stories in a fictional mode are in accordance with the simulation hypothesis (Mar and Oatley, 2008), suggesting a constructive simulation of what might have happened when the events depicted in a text are believed to be fictious.

We observed an activation pattern comprising fronto-parietal control network regions (including FPC, DLPF, dACC) and default mode network regions (IPL, PCC). Interplay of both networks appears to be crucial for internally driven thought (Smallwood *et al.*, 2012) like goal-directed simulations (Spreng *et al.*, 2010; Gerlach *et al.*, 2011). Meaning making requires a balance between inferences upon the text the reader generates via abstraction and association to prior knowledge on the one hand and attentional control to prevent mind wandering away from task (i.e. the text) on the other. It has been shown that frequent mind wandering compromises reading comprehension (Schooler *et al.*, 2004) and leads to longer, uncharacteristic fixations (Reichle *et al.*, 2010). Smallwood *et al.* (2008) reported that too much mind wandering during reading a fictional detective story impaired the construction of a situation model and as such text comprehension. Further investigation will be needed to obtain more insight into the neural processing of reading in a fictional mode, e.g. concerning the relationship between the rFPC and the observed mentalizing regions as the design of our study, especially the PPI analysis, does not allow drawing causal inferences about the precise connections. It might be that the 'better' the simulation processes a story evokes the stronger become mentalizing processes engaged as behavioral studies and the theoretical approach of Mar and Oatley (2008) suggest.

CONCLUSION

In sum, both contexts, the factual and the fictional one, activate processes of imagination but both reflect different levels of simulation (see also Schacter *et al.*, 2008, for an overview). On the one hand, the term *simulation* is used in a broader sense for the representation or inner imitation of actions (see Decety and Grezes, 2006 for a review). Thus, in our study, factual reading would refer to this broader concept of simulation. Fictional reading, on the other hand, seems to represent simulation in the narrower sense of 'imaginative constructions of hypothetical events or scenarios' (Schacter *et al.*, 2008, p. 42). This notion is in keeping with the suggestion of Oatley and Olsen (2010) that factual works relate to the cooperation and alignment of individuals in the real world, whereas fictional works follow primarily the task of imagination and simulation.

SUPPLEMENTARY DATA

Supplementary data are available at *SCAN* online.

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