Fiction feelings in Harry Potter: haemodynamic response in the mid-cingulate cortex correlates with immersive reading experience

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Immersion in reading, described as a feeling of 'getting lost in a book', is a ubiquitous phenomenon widely appreciated by readers. However, it has been largely ignored in cognitive neuroscience. According to the fiction feeling hypothesis, narratives with emotional contents invite readers more to be empathic with the protagonists and thus engage the affective empathy network of the brain, the anterior insula and mid-cingulate cortex, than do stories with neutral contents. To test the hypothesis, we presented participants with text passages from the Harry Potter series in a functional MRI experiment and collected post-hoc immersion ratings, comparing the neural correlates of passage mean immersion ratings when reading fear-inducing versus neutral contents. Results for the conjunction contrast of baseline brain activity of reading irrespective of emotional content against baseline were in line with previous studies on text comprehension. In line with the fiction feeling hypothesis, immersion ratings were significantly higher for fear-inducing than for neutral passages, and activity in the mid-cingulate cortex correlated more strongly with immersion ratings of fear-inducing than of neutral passages. Descriptions of protagonists' pain or personal distress featured in the fear-inducing passages apparently caused increasing involvement of the core structure of pain and affective empathy the more readers immersed in the text. The predominant locus of effects in the mid-cingulate cortex seems to reflect that the immersive experience was particularly facilitated by the motor component of affective empathy for our stimuli from the Harry Potter series featuring particularly vivid descriptions of the behavioural aspects of emotion. ***NeuroReport*** **25:1356–1361 © 2014 Wolters Kluwer Health | Lippincott Williams & Wilkins.**

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Introduction

The phenomenon called immersion has been described as a feeling of 'getting lost in a book' [1]. It has been studied at subjective-experiential and behavioural levels (e.g. Green [2]), but largely ignored in cognitive neuroscience, and its neuronal correlates during reading have been so far unexplored [3]. In a recent neurocognitive model of literary reading, neural, affective and cognitive mechanisms likely to be involved with immersive processes have been proposed to involve the activation of familiar situation models, sensory-motor grounded affective and bodily resonance, and autobiographical emotional memories of similar real situations [4,5]. These are assumed to result in a feeling of familiarity, or the experiencing of nonaesthetic, narrative or fiction emotions [6] such as empathy, sympathy and identification [7], or vicarious anger or fear. According to the fiction feeling hypothesis of the model, narratives with emotional contents, especially negative, arousing and suspenseful ones, facilitate immersion by inviting readers to be more empathic with protagonists compared with neutral texts, thus engaging the affective empathy network, described by Walter [8] to include the anterior insula (AI), the mid-cingulate cortex (mCC), the amygdala, the secondary somatosensory cortex and the inferior frontal gyrus. Among them, AI and mCC were identified in a meta-analysis [9] as the shared neural network between pain empathy and pain experience, also associated with empathy of personal distress [10]. Using the labelling by Vogt [11], Lamm *et al.* [9] defined mCC as 'the border of anterior medial cingulate cortex and posterior anterior cingulate cortex', which is analogous to the '(dorsal) anterior cingulate cortex' used by other researchers (e.g. Craig [12]), who proposed that interconnected von Economo neurons in both regions enable fast and highly integrated representations of emotional moments and behaviours and generate metarepresentations of 'global emotional moments'.

Here we investigated a specific version of the fiction feeling hypothesis that assumes that readers immerse in texts reaching the sensory-motor grounded affective resonance and autobiographical emotional memories through metarepresentations of 'global emotional moments' generated in the AI and mCC. Indirect evidence supporting this hypothesis comes from Altmann

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et al. [13], who showed that stories with negative, arousing, but – at the same time – liked contents engaged the medial prefrontal cortex, which was functionally coupled with the left AI.

To test our hypothesis, we presented entire text passages from the Harry Potter series comparing the neural correlates of immersion ratings when reading fear-inducing versus neutral contents. Pain, fear and personal distress are the focus of affective empathy that is essential for altruistic, prosocial behaviour in the social context [14]. Furthermore, self–other matching for autonomic/emotional states of pain and fear has been evident across species (e.g. rodents and monkeys [15,16]). Therefore, we expected (i) higher immersion ratings for fear-inducing passages, which often describe pain or personal distress, as compared with neutral passages, and (ii) significant correlations of immersion ratings with activity in the affective empathy network, particularly AI and mCC, associated with pain empathy for fear-inducing, but not for neutral, passages.

Participants and methods

Participants

Twenty-four right-handed native German speakers (16 women) gave written consent to take part in the experiment, which was approved by the ethics committee of the Freie Universität Berlin and conducted in compliance with the Code of Ethics of the World Medical Association (Declaration of Helsinki). Their ages ranged from 18 to 31 years (mean $\pm$ SD $= 23.71 \pm 3.67$). All participants had read at least one Harry Potter book and were therefore familiar with its context enough to understand the novel-specific contents. They all had normal or corrected-to-normal vision, and reported no neurological or psychiatric disorders. Participants were adequately compensated monetarily or with course credits for their participation.

Stimuli

To prepare our stimulus material we screened all seven Harry Potter novels (German translations by Klaus Fritz, Carlsen Verlag, Hamburg) for text passages representing either strongly fear-inducing or particularly neutral moments or events. Eighty text passages were selected as stimuli: each of 40 passages entered the ‘Fear’ or ‘Neutral’ categories and were presented together with 40 fillers used to balance the emotional contents. The selection of passages was based on a pilot study of emotional ratings on the dimensions of valence, arousal, fear and happiness (see Hsu *et al.* [17] for further details). Each passage was about four lines in length. Passage selection further ensured the following: (i) understanding the passage did not require a high level of familiarity with Harry Potter novels; (ii) emotional connotations of the passage clearly evolved at the very beginning; and (iii) respective emotional contents were unambiguous and consistent throughout the passage. To control for other factors potentially influencing reading performance, we matched numbers of letters, words, sentences and subordinate sentence per passage, the number of persons or characters (as the narrative element), the type of intercharacter interaction and the incidence of supranatural events (i.e. magic) involved in text passages across the emotional categories.

Design

The 120 text passages were divided into two subsets of 60, each containing 20 passages per emotional condition, maintaining control for all relevant variables mentioned above. During the experiment, each participant read one subset in German and the other one in English. Each subset was presented to 12 participants in German and English each. Only the data for reading in German and for the ‘Fear’ and ‘Neutral’ conditions were used for analyses in this study (see Hsu *et al.* [17] for analyses of the complete data following a bilingualism research question).

Procedure

The experiment consisted of four runs, each containing 15 German passages and 15 English passages. The order of presentation was pseudorandomized so that the distribution of the language switch positions was balanced in each run and across all participants. Similar to the design of a previously successful functional MRI (fMRI) experiment on text-reading [13], each passage was presented for 14 s in the MR scanner, distributed along four lines (shown consecutively for 3.5 s each), and then followed by 14 s of fixation cross. The visual input was presented on a computer screen and was reflected onto the participants’ eyes by means of a mirror.

To keep participants attentive, four randomly selected passages in each run were immediately followed by an emotion-unrelated, context-specific, yes/no question (e.g. ‘Was Harry in a train station?’ ‘Was the alarm clock broken again?’), to which participants responded by button press.

Functional magnetic resonance imaging data acquisition

Functional data were acquired on a Siemens Tim Trio 3 T MR scanner (Erlangen, Germany). Four runs of 440 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: 70°, matrix: 64×64, field of view (FOV): 192 mm, voxel size: $3.0\,\text{mm} \times 3.0\,\text{mm} \times 3.0\,\text{mm}$] and individual high-resolution T1-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: $1.0\,\text{mm} \times 1.0\,\text{mm} \times 1.0\,\text{mm}$).

Functional magnetic resonance imaging preprocessing

The fMRI data were preprocessed and analysed using the software package SPM8 (*http//www.fil.ion.ucl.ac.uk/spm*). Preprocessing consisted of slice-timing correction, realignment for motion correction, and sequential co-registration. Structural images were segmented into grey matter, white matter, cerebrospinal fluid, bone, soft tissue and air/background with the 'New Segment' module [18]. A group anatomical template was created with the DARTEL (Diffeomorphic Anatomical Registration using Exponentiated Lie algebra [19]) toolbox from the segmented grey and white matter images. Transformation parameters for structural images were then applied to functional images to normalize them to the brain template of the Montreal Neurological Institute (MNI) supplied with SPM. For the univariate analysis, functional images were resampled to a resolution of 1.5 mm × 1.5 mm × 1.5 mm and spatially smoothed with a kernel of 6 mm full-width at half-maximum during normalization.

Post-hoc immersion ratings

For the current study, we collected post-hoc ratings from 20 native German speakers (15 women, age 18–34 years, mean age ± SD = 22.95 ± 4.5) who were rewarded with course credits. They all liked the Harry Potter novel series and had read at least one book of it. The participants were asked to read each passage in the authorized German translation and to provide ratings on immersion by matching their subjective experience with the description 'I forgot the world around me while reading' on a scale from 1 (totally untrue) to 7 (totally true) on an online questionnaire. The rating was based on the reading experience and narrative engagement scales by Appel *et al.* [20]. We calculated the mean immersion values of each passage for further analyses.

Functional magnetic resonance imaging data analysis

Statistical parametric maps were obtained by multiple regressions of the data onto a model of the haemodynamic response. At the subject level, we constructed one model of parametric analyses. This model contained regressors for [German-Fear], [German-Neutral] and [Fillers] conditions, and each passage lasted 14 s. The context-specific questions were modelled as the fourth condition, and each question was presented for 4 s. The six realignment parameters were modelled as six additional regressors. For the [German-Fear] and [German-Neutral] conditions, we entered the mean values of immersion ratings for each passage in the condition as parametric modulators for linear regression.

Regressors were convolved with the canonical haemodynamic response function in SPM8. For each participant, contrasts of the [German-Fear > fixation] and the [German-Neutral > fixation] conditions were used at the group level to model a random-effect one-way analysis of variance. A conjunction contrast of the [German-Fear > fixation] and [German-Neutral > fixation] conditions was made in the analysis of variance analysis to cover the neural correlates of reading in this study. Contrasts representing the parametric modulatory effects of passage immersion ratings on haemodynamic responses in both the [German-Fear] and the [German-Neutral] conditions were used at the group level to model a random-effect paired *t*-test analysis to explore potential differential correlation between immersion ratings and BOLD responses between two experimental conditions.

The fMRI analyses were conducted at the whole brain level; we used an initial voxel-level threshold of uncorrected P value less than 0.005, and then a cluster-level threshold of family-wise error corrected P value less than 0.05 for the entire image volume, as suggested by Lieberman and Cunningham [21], for studies in cognitive, social, and affective neuroscience. The labels reported were taken from the 'TD Labels' [22] in the WFU Pickatlas Tool. The Brodmann areas (BAs) were further checked with the Talairach Client using nearest grey matter search after coordinate transformation with the WFU Pickatlas Tool.

Results

Behavioural performance

All participants correctly responded to context-specific questions for German passages in the scanner above chance (≥62.5%) with an overall mean accuracy of 81.47 ± 13.16%.

Conditional comparison for passage immersion ratings

In the Student *t*-test, immersion ratings of fear-inducing passages (mean ± SD = 3.75 ± 0.29) were significantly higher than those of neutral passages (mean ± SD = 3.18 ± 0.26; Student's *t*-test: $P < 0.001$).

Functional magnetic resonance imaging results

Conjunction of fear-inducing and neutral narratives

Results of the conjunction contrast of [German-Fear > fixation] and [German-Neutral > fixation] conditions are summarized in Table 1 and displayed in Fig. 1a, showing the neural substrates associated with the general reading process irrespective of emotional contents in the current study.

Differential parametric effects of immersion

With respect to our hypothesis, we found one cluster in the middle cingulate gyrus (BA 32, family-wise error-corrected cluster-level $P = 0.037$, cluster size: 414 voxels, containing three peaks: MNI coordinates [*x y z*] = [8 14 39], [12 23 42], and [3 23 31]) (Fig. 1b), in which the correlation between immersion ratings and BOLD responses was significantly more positive when reading fear-inducing passages than when reading neutral passages, as shown in the contrast estimates in the coordinate [8 14 39] (Fig. 1c).

Table 1 Results of the conjunction analysis for [German-fear > fixation] and [German-neutral > fixation] reading conditions

H	Regions	Voxel	*P*	*T*	BA	[*x*, *y*, *z*]
L + R	Occipital pole (lingual gyrus)	97949	0.000	26.83	17	[−12 −97 −8]
				25.29	17	[18 −87 −3]
				24.75	18	[22 −87 −11]
L	Precentral gyrus			21.94	6	[−48 −3 49]
L	STS (STG and MTG)			18.52	22	[−54 −39 4]
				17.58	22	[−58 −33 1]
L + R	Medial SMA (SFG)	2874	0.000	16.72	6	[−3 2 66]
				7.52	6	[8 11 54]
R	STS (STG, MTG, including aTL)	7428	0.000	12.82	22	[50 −28 −0]
				11.15	22	[54 −12 −9]
				10.84	38	[53 12 −20]
R	LPFC (MFG and IFG) and precentral gyrus	8102	0.000	10.26	8	[54 6 45]
				9.38	6	[57 −3 43]
				8.52	45	[56 30 7]
L + R	Pons and midbrain	743	0.000	5.18		[2 −36 −39]
				4.75		[−2 −36 −32]
				3.07		[3 −33 −23]

aTL, anterior temporal lobe; BA, Brodmann area; H, hemisphere; IFG, inferior frontal gyrus; L, left hemisphere; LPFC, lateral prefrontal cortex; MFG, middle frontal gyrus; MTG, middle temporal gyrus; R, right hemisphere; SFG, superior frontal gyrus; SMA, supplementary motor area; STG, superior temporal gyrus; STS, superior temporal sulcus; *T*, *t* values.

Discussion

This study investigated the fiction feeling hypothesis of the neurocognitive model of literary reading [5], which states that emotional contents, especially negative, arousing and suspenseful ones, activate the affective empathy network and facilitate immersive reading experience.

For the conjunctional contrast focussing on brain activation during narrative reading, results are in line with a previous study on short story reading [13] and a meta-analysis on neural correlates of text comprehension [23]. The bilateral medial superior frontal gyrus (BA 6) has been associated with encoding written language [23]. The bilateral lateral prefrontal and temporal cortices are part of the Extended Language Network [23].

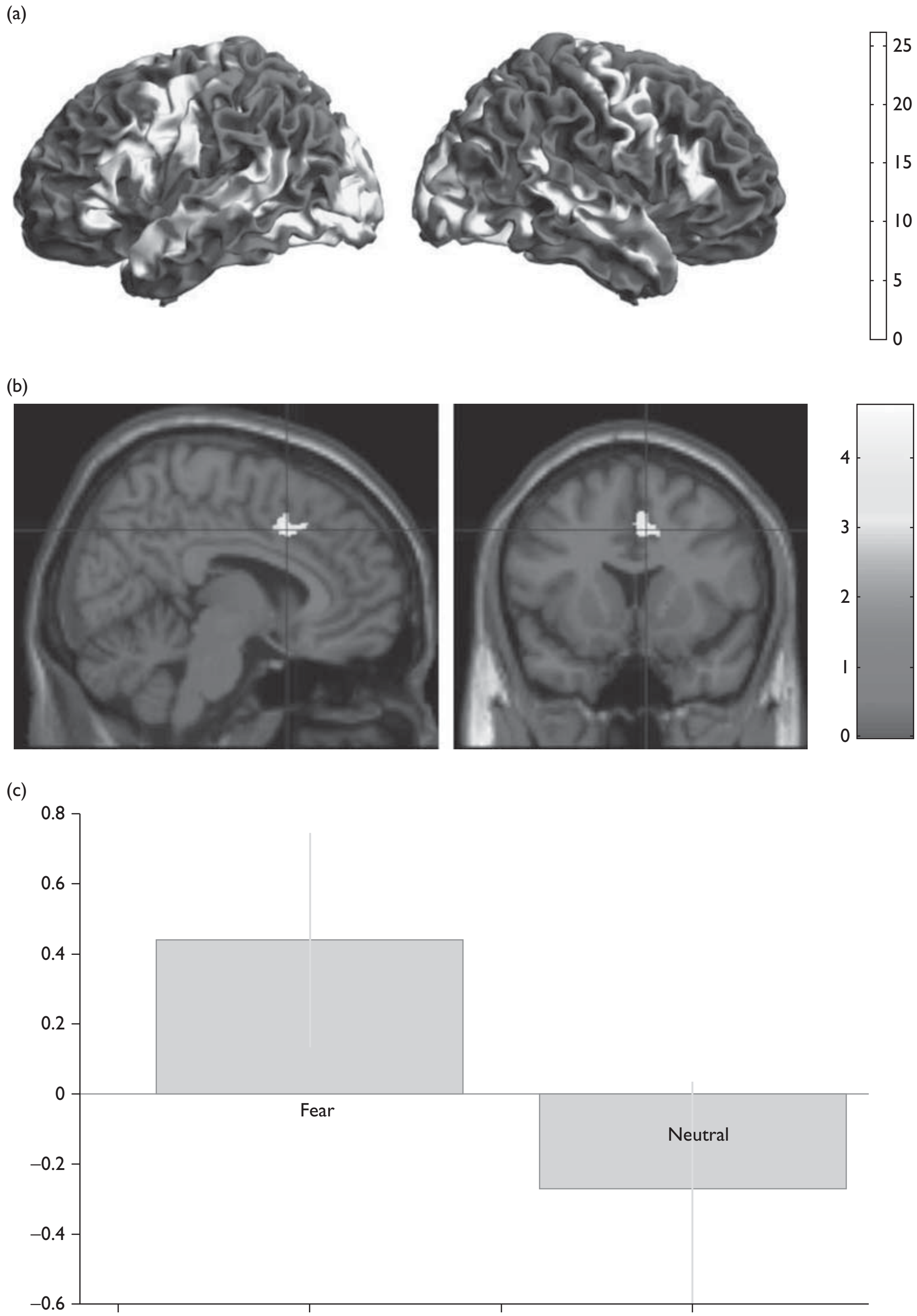
At the behavioural level, although participants obviously immerse in both fear-inducing and neutral passages (mean rating values of immersion in both conditions were between three and four out of seven), they felt significantly more immersed in fear-inducing than in neutral passages. This suggests that, although emotional content such as descriptions of vicarious fear is not necessary for immersive reading experience, arousing, negatively valenced texts do indeed facilitate immersive processes.

At the neuronal level, we expected immersion ratings to correlate more strongly with haemodynamic responses in AI and mCC, the core substrates of affective empathy [8,9], when reading fear-inducing versus neutral passages. Although being first associated with pain empathy [9], AI and mCC were also reported to be responsive to pain of others in patients with congenital insensitivity to pain [24]. Thus, it has been proposed that these regions might also be associated with empathy of personal distress [10], or understanding and sharing of the same emotion perceived in others [9]. As expected, mCC, but not AI (discussed in the next paragraph), showed higher correlation with immersion experience for passages of the Fear condition featuring many descriptions of protagonists' pain or personal distress as compared with the Neutral condition.

With regard to both structures, Craig [12] considered mCC to be the limbic motor cortex and the site of emotional behavioural initiation, whereas AI is the sensory counterpart. With respect to our stimuli from Harry Potter series, in which behavioural aspects of emotion are particularly vividly described, the motor component of affective empathy (i.e. mCC) might predominate during emotional involvement, and facilitate immersive experience. This assumption is in line with the claim of Gygax *et al.* [25] that descriptions of behavioural components of emotions, as opposed to the labelling of emotions *per se*, are better markers of readers' mental representations of the protagonists' affective status – which might explain why our effects were restricted to mCC and did not extend to AI.

Our study is the first attempt to understand the neural mechanisms of immersive reading experience. Consistent with the assumption that pain empathy is crucial for the cohesion of social groups [14], correlations between immersion and BOLD responses were most pronounced for fear-inducing stimuli. Although the Harry Potter series offer exceptionally beloved literary materials, we remain of course cautious not to generalize the present results to all daily immersive reading experiences. Further studies are necessary to elucidate the relationship between the reading process, affective empathy, and immersion at the behavioural and neuronal levels.

Fig. 1



fMRI results. (a) Results of the conjunction contrast of [German-Fear > fixation] and [German-Neutral > fixation] conditions. The grey scale indicates *t* values. (b) The mid-cingulate gyrus showing a significant correlation difference between passage immersion ratings and BOLD response in the Fear versus Neutral conditions, cross-hair highlighting the peak voxel (Montreal Neurological Institute coordinate [*x y z*] = [8 14 39]). (c) The estimated response strength in the peak [8 14 39] for both experimental conditions. The error bars represent 90% confidence intervals.

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Conflicts of interest

There are no conflicts of interest.

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