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Short Communication

When we like what we know – A parametric fMRI analysis of beauty and familiarity

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ABSTRACT

This paper presents a neuroscientific study of aesthetic judgments on written texts. In an fMRI experiment participants read a number of proverbs without explicitly evaluating them. In a post-scan rating they rated each item for familiarity and beauty. These individual ratings were correlated with the functional data to investigate the neural correlates of implicit aesthetic judgments. We identified clusters in which BOLD activity was correlated with individual post-scan beauty ratings. This indicates that some spontaneous aesthetic evaluation takes place during reading, even if not required by the task. Positive correlations were found in the ventral striatum and in medial prefrontal cortex, likely reflecting the rewarding nature of sentences that are aesthetically pleasing. On the contrary, negative correlations were observed in the classic left frontotemporal reading network. Midline structures and bilateral temporoparietal regions correlated positively with familiarity, suggesting a shift from the task-network towards the default network with increasing familiarity.

1. Introduction

Interest in the field of neuroaesthetics has grown remarkably during the last years, with theoretical works (Cela-Conde, Agnati, Huston, Mora, & Nadal, 2011; Chatterjee, 2004; Di Dio & Gallese, 2009; Dissanayake, 1992; Leder, Belke, Oeberst, & Augustin, 2004; Lindell & Mueller, 2011; Livingstone, 2002; Nadal & Pearce, 2011; Ramachandran & Hirstein, 1999; Zaidel, 2010; Zeki, 1999; Zeki, 2004) as well as with a number of experiments approaching the study of preference, appraisal, and aesthetic judgment with neuroscientific methods such as functional magnetic resonance imaging (fMRI), positron emission tomography (PET), magnetoencephalography (MEG), or electroencephalography (EEG). Despite recent advances in neuroaesthetics of visual arts, the domain of literature has, surprisingly, been left almost untouched (but see Jacobs, 2011; Kringelbach, Vuust, & Geake, 2008; Mar, 2011; Schrott & Jacobs, 2011). When using the term 'aesthetics' in the current paper we will refer to it in the broad sense in which it is commonly used in neuroaesthetics "to encompass the perception, production, and response to art, as well as interactions with objects and scenes that evoke an intense feeling, often of pleasure" (Chatterjee, 2011, p. 53). As everybody who has ever enjoyed a book or a poem will confirm, literature and poetry have a high potential to elicit aesthetic feelings (Jacobs, 2011; Mar, Oatley, Djikic, & Mullin, 2011; Miall, 2008). They are subject to specific disciplines with ancient traditions, namely rhetoric and poetics, reaching back to Greek and Roman antiquity (Aristotle, Quintilian), as well as philosophical aesthetics, established in the 18th century (Baumgarten, Burke, Kant). Prior neuroimaging studies have investigated the aesthetic perception of visual art (Cupchik, Vartanian, Crawley, & Mikulis, 2009; Kirk, Skov, Hulme, Christensen, & Zeki, 2009; Vartanian & Goel, 2004), abstract geometrical patterns (Jacobsen, Schubotz, Höfel, & von Cramon, 2006), faces (Aharon et al., 2001; Ishai, 2007; Winston, O'Doherty, Kilner, Perrett, & Dolan, 2007), music (Blood et al., 2001; Ishizu & Zeki, 2011; Koelsch, 2010), architecture (Kirk, Skov, Christensen, & Nyaard, 2009), or dance movements (Calvo-Merino, Jola, Glaser, & Haggard, 2008). Among the 40 publications that were considered in a recent meta-analysis on subjective pleasantness (Kühn & Gallinat, 2012), one experiment used words as stimuli and another consisted of menu reading. However, to our knowledge, there are currently no studies available that looked at the neural correlates of aesthetic judgments of literature and/or poetry. This gap makes a neuroaesthetics of literature timely. The aim of this paper is to start with closing this gap by presenting a reanalysis of previously published data (Bohrn, Altmann, Lubrich, Menninghaus, & Jacobs, 2012) in which participants silently read proverbs and other short sentences while undergoing fMRI. In the novel analysis functional neuroimaging data were correlated with familiarity and beauty ratings that participants gave on the same material after the scanning session outside of the

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scanner. With this paradigm we expected to identify regions involved in an implicit aesthetic judgment on written text material and compare it with previous findings from other modalities. Our expectation was that we would find activity in areas that have been reported to be involved in the aesthetic perception of other domains and that are typical for reading and language processing. In the following we will therefore give a brief introduction into the field of neuroaesthetics and recent findings concerning neural correlates of the processing of art.

Experimental neuroscience of aesthetics usually takes one of the two following perspectives: From a more object oriented perspective, one can compare stimulus categories that vary along a dimension believed to intrinsically affect the aesthetic experience, such as symmetry (Jacobsen et al., 2006). Consequently, preference-ratings are averaged per condition across participants and direct contrasts of e.g. art vs. non-art conditions are calculated to gain information about stimulus characteristics that influence the mean aesthetic judgment and their neural underpinnings. From a more subject oriented perspective, based on the notion that 'beauty is in the eye of the beholder', subjective appraisals are collected and neural activity during the perception of preferred and less preferred stimuli are compared (Calvo-Merino et al., 2008; Di Dio, Macaluso, & Rizzolatti, 2007). A review by Di Dio and Gallese (2009) concludes that despite great heterogeneity across results from different studies, aesthetic experiences of visual artworks seem to be based on sensorimotor areas, emotion networks, and reward-related centres.

While our previous paper focused on the first perspective (Bohrn et al., 2012), the novel analysis presented here opens the second perspective by zooming in on subjective aesthetic appraisals. The present results are therefore not informative in regard to which formal stimulus properties have led to positive or negative aesthetic judgments (such as rhetorical figures; see Bohrn et al., 2012). The question of certain stimulus characteristics that predict aesthetic judgments is an interesting but separate issue, because the perception of formal attributes in artworks may dissociate partly from evaluative judgments (Bromberger, Sternschein, Widick, Smith, & Chatterjee, 2011). A similar design has been chosen by Calvo-Merino et al. (2008) who showed participants dance moves inside the MR scanner and had them later judge the stimuli on several dimensions including "like–dislike". By investigating the effects of two parameters (beauty and familiarity) instead of focusing on only one dimension we present an extended paradigm here. The familiarity dimension was chosen, because prior experience with a stimulus is known to be a main predictor of individual differences in aesthetic judgments (Cela-Conde et al., 2011; Reber, Schwarz, & Winkielman, 2004; Reber, Winkielman, & Schwarz, 1998). In many cases familiarity and beauty judgments will converge: people tend to like what they know (Bornstein, 1989; Zajonc, 1968) and a feeling of familiarity might be falsely attributed to preferred items (Monin, 2003). While closely linked practically, theoretically these dimensions can be dissociated and they can result in qualitatively different evaluations (Leder et al., 2004). We can immediately find something beautiful that we have never seen before, and one can think of artworks that one dislikes very much, although or even because one has seen them many times.

Here we present a reanalysis of previous data (Bohrn et al., 2012) in which we investigate the parametric effect of post hoc beauty and familiarity ratings on the BOLD response during reading of different kinds of proverbs and non-rhetorical sentences. We expected to find sensitivity for aesthetic preference in regions that have previously been found in the aesthetic evaluation of paintings, such as the caudate nucleus, the occipital gyri, the cingulate sulcus, and the fusiform gyri (Vartanian & Goel, 2004), as well as in general reward-related areas such as the ventral striatum (VST; Aharon et al., 2001; Blood & Zatorre, 2001), the ventromedial prefrontal cortex (VMPFC; Blood & Zatorre, 2001; Jacobsen et al., 2006) and orbitofrontal cortex (OFC; Blood & Zatorre, 2001; Ishizu & Zeki, 2011; Kawabata & Zeki, 2004), and the anterior cingulate cortex (ACC; Schultz, 2002; Vartanian & Goel, 2004). Although the reward network had originally been attributed to the rewarding feelings associated with food, drugs, sex (Ishai, 2007) and other primary reinforcements, as well as for abstract monetary reward (Delgado, Nystrom, Fissell, Noll, & Fiez, 2000; Elliott, Friston, & Dolan, 2000), more recently parts of it have also been found activated during the perception of art (Lacey et al., 2011). Different components of the reward system have frequently been associated with processing aesthetically pleasing objects. Vartanian and Goel (2004) observed a double correlation when participants made explicit aesthetic judgments of visual artworks: activity in the right caudate nucleus decreased with decreasing preference ratings and activity in the left ACC and bilateral occipital gyri increased with increasing preference ratings. Jacobsen et al. (2006) had participants judge liking and symmetry of abstract geometrical figures and found stronger activation in frontomedian cortex and left intraparietal sulcus for beautiful than for non-beautiful figures. Aharon et al. (2001) found increased activity in several parts of the reward network, specifically in the nucleus accumbens (Nacc), ventral tegmentum, amygdala, and OFC during passive viewing of attractive compared to average faces. The medial OFC was identified when contrasting beautiful against ugly pictures (Kawabata & Zeki, 2004) and in similar contrasts in the auditive domain (Ishizu & Zeki, 2011). Recent findings indicate that the involvement of the reward system, especially of the OFC, in aesthetic judgments is modulated by contextual information (Kirk, Skov, Hulme et al., 2009) as well as by the level of expertise (Kirk, Skov, Christensen et al., 2009). In their seminal paper, Blood and Zatorre (2001) reported enhanced activity in the VST, midbrain regions, amygdala, OFC, and VMPFC for when participants experienced intensely pleasurable shivers-down-the-spine elicited by listening to music.

A number of experimental studies using behavioural measures have observed emotional reactions towards literature and/or poetry (Cupchik & Laszlo, 1994; Cupchik, Oatley, & Vorderer, 1998; Mar, 2011; Mar et al., 2011; Oatley, 1995; for a review see Jacobs, 2011). We therefore expected to find the engagement of structures known for emotion processing (such as the amygdala or the insular cortex) to be related to aesthetic responses. These structures have also been found previously for the aesthetic perception of artworks (Cupchik et al., 2009) and faces (Winston, O'Doherty, Kilner, Perrett, & Dolan, 2007).

Further candidate regions for the aesthetic perception of literature are the bilateral occipital gyri which have also been found in several experiments across visual modalities, for instance in watching dance moves (Calvo-Merino et al., 2008), visual artworks (Cupchik et al., 2009; Vartanian & Goel, 2004) but not for auditive stimuli. The bilateral occipital gyri comprise the primary and secondary visual cortices and enhanced activity in these regions together with activity in the lateral PFC might be related to top-down modulated visual attention to an aesthetically pleasing visual stimulus (Cela-Conde et al., 2004; Cupchik et al., 2009).

Unlike most of the studies discussed so far, in the design of the current experiment no explicit aesthetic judgment was required from the participants. The reason for choosing explicit rating tasks during the fMRI session is probably to strengthen the effect by having participants focus on the aesthetic qualities of the items and to make them engage in higher cognitive stages of interpretation and evaluation of art specific attributes, although many processes that influence the aesthetic experience are implicit and do not have to be made conscious (Leder et al., 2004). When modelling explicit aesthetic judgments it is difficult to decide, whether activations are related to an aesthetic experience or simply due to making a judgment. Data obtained with the current design are free from artifacts due to judgment making.

In sum, this paper investigates whether reading is accompanied by an implicit aesthetic evaluation and if so, whether the neural correlates of this subjective evaluation recruit the emotion system in a way comparable to the much better investigated aesthetic perception of visual art. By modelling beauty and familiarity of the stimuli in a parametric fashion our goal is to disentangle and describe these two different components of this affective-aesthetic evaluation.

2. Results and discussion

2.1. Behavioural results

Because the familiarity ratings were not normally distributed, Kendalls-Tau-b was used to calculate correlations between beauty and familiarity. The scatter-plot in Fig. 1 indicates that beauty and familiarity ratings were moderately correlated ($\tau = .435$, $p < .001$). This positive correlation is in line with the well documented preference for familiarity effect (Carbon & Leder, 2005; Kuchinke, Trapp, Jacobs, & Leder, 2009; Reber et al., 1998; Zajonc, 1968). Overall, participants preferred familiar proverbs over novel proverbs and over proverb substitutions and proverb variants (Bohrn et al., 2012). This preference, however, might also be explained with regard to the historical evolution of the material: A familiar proverb may be familiar precisely because specific aesthetic qualities account for its cultural success. To avoid correlations in the GLM and to be able to interpret effects on BOLD activity independently for the two scales, beauty and familiarity predictors were orthogonalized in the way described in Section 2.5 before entering them into the GLM.

2.2. Imaging results

A number of clusters revealed significant effects for the predictor that modelled individual post-scan familiarity ratings, as well as for the predictor that modelled individual residuals of post-scan beauty ratings, after parceling out familiarity effects. Distinct regions emerged for beauty and familiarity evaluation. Table 1 lists the peak coordinates, effect sizes, and cluster sizes of the regions that showed parametric effects of implicit beauty and familiarity evaluation.

2.3. Stimulus main effect

The unmodulated main effect of sentence reading is depicted in Fig. 2a, coordinates are provided in Table 1. The activations replicate well documented effects of sentence reading and semantic processing, (Binder, Desai, Graves, & Conant, 2009; Keller, Carpenter, & Just, 2001) and cover large parts of the left frontal lobe, as well as the left (and, although weaker also the right) MTG/STG. As the stimuli were presented visually, the bilateral occipital lobes were strongly activated. Furthermore the bilateral precentral gyri showed heightened activation. This activation includes the frontal eye fields that most likely represent saccade generation during the reading process (Leff, Scott, Rothwell, & Wise, 2001; Paus, 1996) but recent theories also link motor activation to processes of understanding (Pulvermuller, Hauk, Nikulin, & Ilmoniemi, 2005).

2.4. Effect of beauty

Three clusters were identified, in which the predictor that modelled individual post-scan beauty ratings showed significant effects on BOLD activation. The two main clusters in the VST and the ACC are depicted in Fig. 2b, coordinates are provided in Table 1. One central cluster identified by Vartanian and Goel (2004) was the right caudate nucleus extending to putamen. In the present study, subjective ratings of beauty showed a parametric modulation of the BOLD activation in the same region (and at a more lenient threshold also in the left VST), suggesting that the more rewarding a sentence was during initial reading, the more beautiful it was

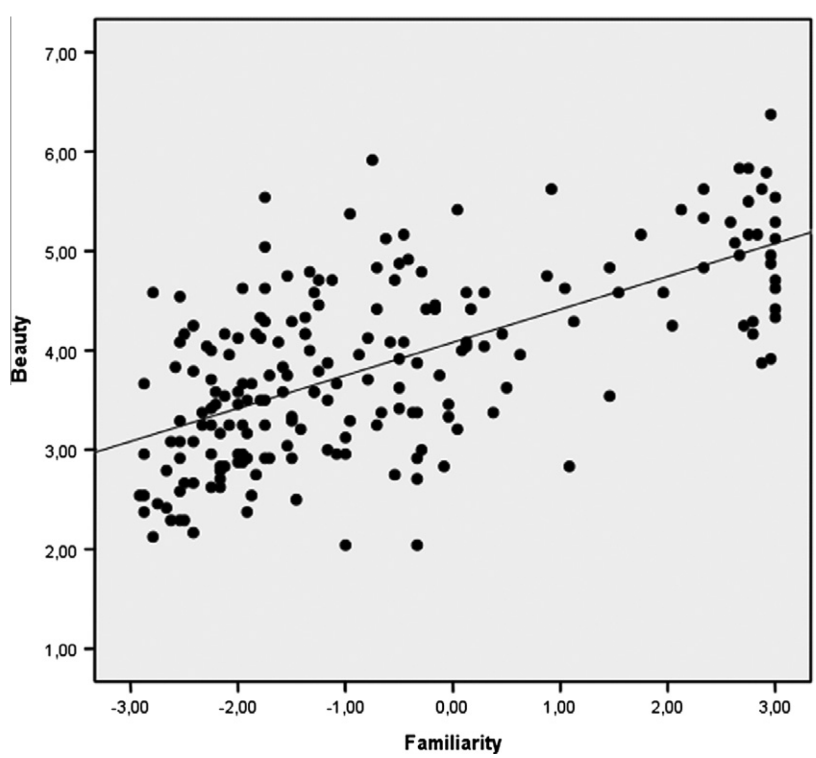

Fig. 1. Correlation of post-scan beauty and familiarity ratings Kendalls-Tau-b = .435, $p < .001$.

Table 1
Parametrical effects of beauty and familiarity ratings.

Region		Peak (x,y,z)			Voxel	T
Beauty						
R	Caudate (Caudate Body)	13	9	10	25	4.13
L	Cerebellum	−10	−34	−13	24	3.87
L	Anterior Cingulate (BA 32)	0	43	11	48	3.67
Familiarity						
L	Precuneus (BA 7, extending into PCC)	−3	−71	40	1443	5.60
L	Medial Frontal Gyrus (BA 10)	−4	49	13	416	4.82
L	Angular Gyrus (BA 39)	−36	−72	33	201	4.80
R	Middle Temporal Gyrus (BA 39)	42	−72	27	92	4.09
R[a]	Middle Frontal Gyrus (BA 11, extending into IFG)	35	36	−13	761	−7.38
L[a]	Middle Frontal Gyrus (BA 11, covering IFG/MTG/STG)	−34	37	−16	2353	−6.88
L[a]	Precentral Gyrus (BA 4)	−48	−7	46	150	−6.10
R[a]	Inferior Occipital Gyrus (BA 19)	37	−79	−4	516	−5.95
R[a]	Medial Frontal Gyrus (BA 6)	4	45	36	73	−4.02

Note: Peak coordinates are reported in Talairach space.
[a] Negative parametrical correlations.

judged in a second post-scan reading. The caudate part of the striatum has an established role in processing reward related information (e.g., Elliott et al., 2000) and has been found to be correlated with the attractiveness of faces that held eye-contact with the subjects (Kampe, Frith, Dolan, & Frith, 2001), and also in response to positive words (Hamann & Mao, 2002). As predicted, a second cluster with parametric relation to beauty ratings was identified in the anterior rostral part of the MFC. The MFC is a highly connected area involved in numerous processes around the representation and updating of potential actions and outcomes and thus holds a central function in social cognition (Amodio & Frith, 2006). In their review paper on the MFC, Amodio and Frith (2006) specifically associate the anterior rostral part of the ACC with self-knowledge, person knowledge and mentalizing. However, other structures that are typically also involved in mentalizing, such as the left and right parietal junction and medial parietal cortex were not found in the present study. It is therefore less likely that the activation found in the MFC is representing strong mentalizing processes, but rather general emotional processes. The region in the MFC that showed a parametric effect of beauty ratings, is functionally connected to the amygdala, OFC, insula and hippocampus, and is generally involved in emotion tasks, such as valence ratings, emotional Stroop tasks, or mood induction (Bush, Luu, & Posner, 2000). As our stimuli consisted mainly of proverbs and proverb-like sentences that are usually about social and moral behaviour, processing these items could also have involved social cognition and thereby highlight the commonalities of aesthetic and moral evaluations (Eagly, Makhijani, Ashmore, & Longo, 1991; Takahashi et al., 2008; Tsukuira & Cabeza, 2011). Our results replicate the activation pattern of Vartanian and Goel (2004) in a different modality (reading) and in the absence of an explicit aesthetic judgment task, thereby ruling out the possibility that activations are rather related to making a judgment than to the aesthetic experience. We therefore interpret them as an indication for spontaneous aesthetic evaluation going on during the reading process that is independent of familiarity evaluation. The third cluster we found was located in the left cerebellum. Although cerebellar activity is sometimes reported in neuroaesthetics (Vartanian & Goel, 2004) it is rarely discussed and sometimes even excluded from analysis. This is very unfortunate, given that a recent meta-analysis demonstrates involvement of the cerebellum in a number of cognitive and affective tasks (Stoodly & Schmahmann, 2009). Other parts of the reward system, however, such as the OFC (Aharon et al., 2001; Kawabata & Zeki, 2004) or the amygdala, were not found in the present experiment. This finding is unexpected at first glance, because the OFC is among the most frequently found regions in neuroscientific experiments on aesthetic processing. However, as most of these experiments used explicit judgments designs (Ishizu & Zeki, 2011; Kawabata & Zeki, 2004; Kirk, Skov, Hulme, et al., 2009; Kirk, Skov, Christensen, et al., 2009) this could be a hint for a role of the OFC rather in cognitive parts of the aesthetic experience than in implicit evaluations. The work of Kirk, Skov, Hulme, et al. (2009) and Kirk, Skov, Christensen, et al. (2009) also shows that activation in the OFC is modulated by higher cognitive input, such as context information in the form of words. However, Aharon et al. (2001) reported the OFC also for implicit ratings, but their study used faces as stimuli, which are biologically more relevant than proverbial sentences and might therefore cause stronger reactions. We also did not observe beauty-related activation changes in the occipital gyri, unlike prior experiments (Calvo-Merino et al., 2008; Chatterjee, Thomas, Smith, & Aguirre, 2009; Cupchik et al., 2009; Vartanian & Goel, 2004). An explanation could be that other experiments did not control for subjective familiarity, as we did observe parametric effects of familiarity evaluation in the bilateral inferior occipital gyri. In the present experiment familiar sentences were preferred over all other categories (Bohrn et al., 2012), and activation in the ventral occipital cortex was negatively correlated with familiarity. Thus it is plausible that we did not observe positive correlations of beauty evaluation and BOLD-response in the occipital gyri. Nevertheless, the parametric responses of reward related structures in the caudate nucleus and the ACC indicate processes of spontaneous aesthetic evaluation during sentence reading.

2.5. Effect of familiarity

As evident from Fig. 2c and Table 1 the parametric regressor coding familiarity had overall higher effect sizes than the regressor coding for beauty. Part of this difference could be attributed to methodological issues such as the larger variance in the stimulus material on the familiarity dimension (ranging from highly conventional proverbs to completely unknown proverbs) than on the beauty dimension. The activation pattern shows that the degree of familiarity with a stimulus strongly affects the processing of written text. Familiarity is a variable that in most experiments on neuroaesthetics is either neglected or controlled for, but hardly investigated on its own. Thus, its influence on processing figurative language, for instance, has only recently been recognized (Schmidt & Seger, 2009). In a recent experiment that actually trained participants on metaphor familiarity and calculated a parametric analysis, increasing familiarity translated into a general, bilateral decrease in neural activity (Cardillo, Watson, Schmidt, Kranjec, & Chatterjee, 2012). We observed positive correlations with familiarity ratings in regions associated with a task-off state, such as anterior and posterior midline structures, bilateral clusters in the

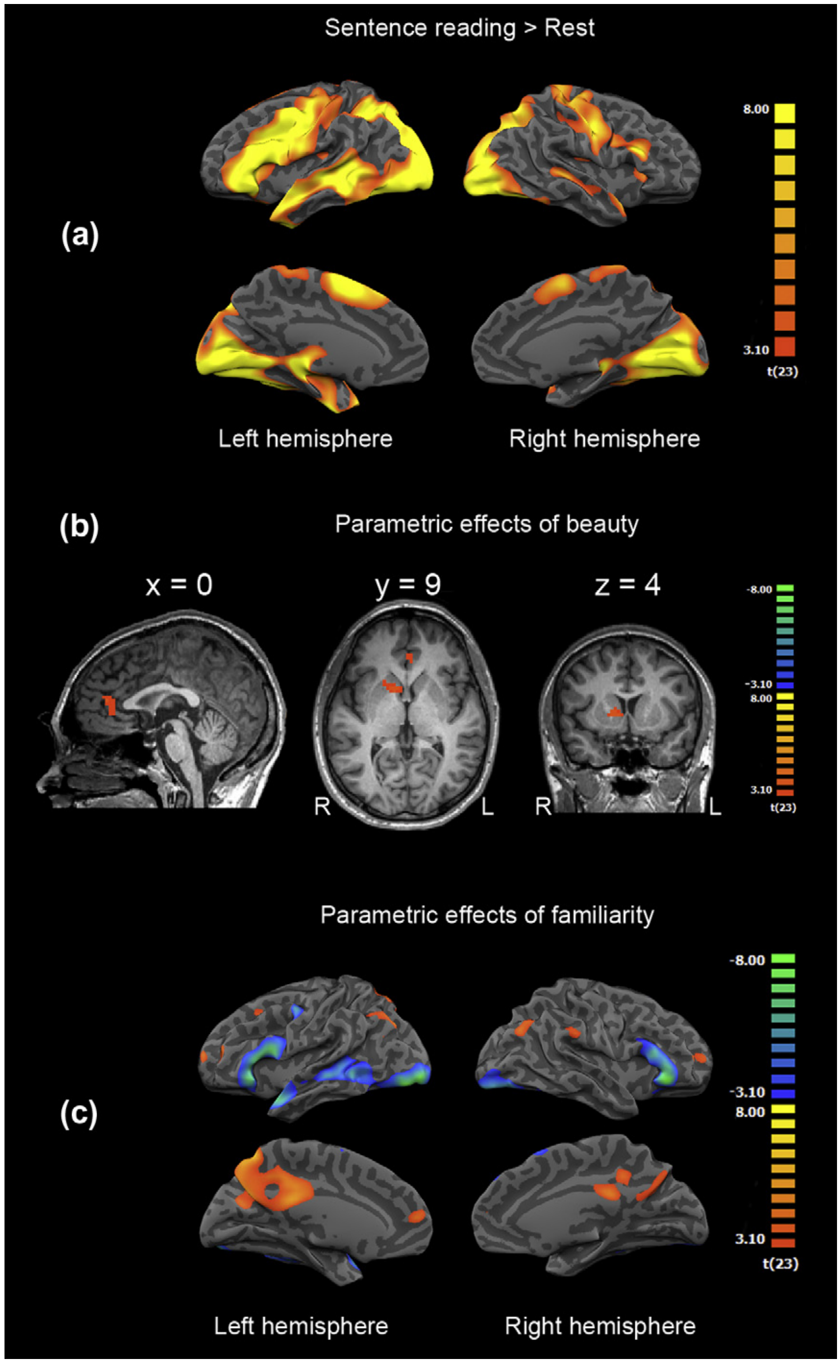

Fig. 2. (a) Main effect of sentence reading (voxel height threshold at $p < .005$, cluster width threshold of 118 voxel); (b) parametric effects of beauty evaluation (voxel height threshold at $p < .005$, cluster width threshold of 24 voxel); (c) parametric effects of familiarity evaluation (voxel height threshold at $p < .005$, cluster width threshold of 63 voxel). All results are corrected for multiple comparisons.

temporo-parietal region (Brodmann area 39) and the bilateral middle frontal gyri (Fox et al., 2005) that together form the default mode network (Buckner, Andrews-Hanna, & Schacter, 2008). On the other hand, increasing novelty of a sentence was most likely related to higher processing effort and stronger involvement of the whole left dominant fronto-temporal reading network. The cortical areas that were negatively correlated with stimulus familiarity are all located in regions typically found for sentence reading and were all part of the regions that accounted for the stimulus main effect. The regions that showed a positive correlation with stimulus familiarity, however, were not part of the stimulus main effect and are atypical for sentence reading. However, we do not claim a special role of the default mode network in reading familiar sentences or phrases. We rather interpret the results as showing how with increasing stimulus novelty the perceptual and semantic systems get more strongly involved and that in parallel the default mode network (also called 'task-off-network') is tuned down.

2.6. General discussion

Our findings suggest that spontaneous aesthetic evaluation takes place during silent reading, even if the task does not involve explicit preference evaluation. The regions we find correspond partially to the regions found previously for aesthetic evaluation in other modalities (Kühn & Gallinat, 2012). Like Vartanian and Goel (2004) we identified parametric responses towards more or less beautiful stimuli in the right caudate nucleus, the anterior cingulate and the cerebellum, although not in the visual cortex. Those differences might be related to stimulus modality (sentences vs. paintings) and time of rating (instant preference rating vs. post-scan rating). By parametrically modelling beauty and familiarity, two often confounded parameters, we started to disentangle these effects. Our results add to a growing corpus of evidence for affective and aesthetic components in the processing of written text (Citron, 2012; Jacobs, 2011; Kuchinke et al., 2005) that call for an elaboration of current models of reading that are silent with regard to affective variables (Grainger & Jacobs, 1996; Kintsch & van Dijk, 1978; Perry, Ziegler, & Zorzi, 2010; but see Jacobs, 2011). Furthermore we demonstrate that the perceptual and semantic system in the bilateral inferior occipital cortex, inferior frontal cortex, and left MTG/STG are activated more strongly, the less familiar a sentence is. According to rhetorical theory, the impression of familiarity may be artificially induced by techniques of repetition (such as rhetorical figures, sound patterns or features of arrangement or composition). Many rhetorical devices enhance the affective, aesthetic and persuasive effects as well as the memorability of a certain elaborated speech or text by subtle forms of repetition that are hardly noticeable to the average recipient. For example, anaphora (repetition of the beginning of successive clauses), alliteration (repetition of letters, sounds or syllables at the beginning of successive words) or parallelism (repetition of word order or sentence structure) can increase the emotional as well as cognitive impact of spoken or written words and could make them appear more pleasant, more plausible and more familiar. Rhetorical elaboration may even create the illusion that a specific phrase has been heard or read before, when in fact it has not ('false memory effect'; Garry & Wade, 2005). Future experiments should therefore investigate more closely, to what extent the semantic system but also reward related areas are activated by stylistic vs. semantic characteristics of text segments and could try to differentiate the global concept of 'beauty' by using rating scales with more language-specific variables.

3. Materials and methods

3.1. Participants

Participants in the fMRI experiment consisted of twenty-six healthy, native German speaking participants (mean age 25 years, range 20–45; 13 female, 13 male; all right-handers) who considered themselves right-handed as determined by the Edinburgh handedness inventory (Oldfield, 1971) and did not report a history of neuropsychiatric disorders or psychoactive medication. All had normal or corrected-to-normal vision and were screened for obvious reading deficits using the SLS-E (Salzburger Lesescreening, unpublished adult version). Informed consent was obtained from all participants and the experiment was approved by the local ethics committee.

3.2. Stimuli

As described in Bohrn et al. (2012), five different stimulus categories were created, each comprising 40 items.

a. familiar proverbs, frequently used in German (e.g., *All roads lead to Rome*),
b. unfamiliar German proverbs (e.g., *Not every cloud rains*),
c. proverb variants, corresponding to the familiar proverbs, in which a single word was replaced by another word to give the proverb a different meaning (e.g., *All sins lead to Rome*),
d. proverb substitutions, corresponding to the familiar proverbs, in which a word was replaced by a close synonym, thereby preserving the original meaning, but violating the conventional form (e.g., *All streets lead to Rome*),
e. non-rhetorical sentences, which lacked proverb-characteristic stylistic features and had a valid literal interpretation (e.g., *It is healthy to do modest exercise*).

All but the non-rhetorical sentences featured numerous proverb-characteristic rhetorical elements, such as phonological similarities (rhyme/alliteration), metre, parallelism, and ellipses. While matching on lexical parameters as well as valence and rhetorical features was important for the contrast-based analysis, the current parametric approach took advantage of the wide range of familiarity and beauty within the stimulus set as all items were collapsed across conditions.

3.3. Material and task

Participants were reading one-line sentences in the scanner (2 s presentation time), preceded by a fixation cross and followed by a blank screen (both of variable time, jittered between 2 and 12 s). After each item they performed a semantic categorization task. Anatomical and functional imaging was performed with a 3T Siemens (Erlangen, Germany) Tim Trio MRI scanner fitted with a 12-channel head coil. The task design, material, and scanning parameters are described in more detail in Bohrn et al. (2012). The semantic categorization task was not analyzed further and mainly fulfilled the purpose of keeping participants engaged in the sentences. The task was performed in between reading the items, separated from the reading phase by a jittered inter-stimulus-interval. Participants were presented with a stimulus category and had to decide if the preceding proverb/sentence fitted into this category. Participants saw the category label only after reading the proverb/sentence to minimize decision processes during the reading phase. Importantly participants did not have to perform a task during the stimulus presentation time (apart from passive reading and trying to understand the proverb/sentence) and no explicit aesthetic judgment was required at any time inside the scanner. Frequently, experiments on neuroaesthetics require participants to give explicit aesthetic judgments (e.g., beautiful/ugly) to a number of stimuli while brain activity is recorded (Jacobsen et al., 2006; Kirk, Skov, Hulme et al., 2009; Vartanian & Goel, 2004; Winston, O'Doherty, Kilner, Perrett, & Dolan, 2007). While the intention of such a paradigm is to make sure participants are in a mind-state of aesthetic perception (to the extent in which this is possible inside a MR-scanner), the other side of the coin is the possibility of creating an artificial task-induced mind-state. By doing so, one has to deal with potential confounds between the neural correlates of aesthetic judgment and artifacts from decision processes due to the rating. To avoid this pitfall, we let participants read the stimuli silently and had them perform a semantic judgment task in between with the sole purpose of keeping the participants awake and concentrated. To answer the semantic categorization task, participants had to read and try to understand the proverb/sentence, which probably put them in a mind-set with a focus on semantic processing, but they did not have to make any decisions or evaluations during the reading phase. By jittering the intervals between reading and the distracter task, we were able to separately model the reading and the judgment phase. Each of the four runs comprised eight items per condition in an order that was counterbalanced across participants and runs. After the functional scan participants gave explicit aesthetic judgments outside of the MR-scanner. They rated each item on a 7-point Likert 'beauty'-scale ranging from 1 (*not beautiful at all*) to 7 (*very beautiful*). No further instructions were given concerning the definition of 'beauty', thereby allowing for consideration of stylistic quality, overall pleasantness, but also approval of the social or moral value. While aesthetic theory (Baumgarten, 1735; Burke, 1757; Kant, 1790; Rosenkranz, 1853) discusses a number of different responses (such as pleasure, liking, awe, being moved or even feeling disgust) to diverse qualities of artistic or natural objects (beautiful, ugly, sublime, disgusting), for our experiment, we chose the umbrella-term 'beauty' above other more specific dimensions, because in lay concepts of aesthetic appeal, as well as in experimental aesthetics, the single most important and most frequently used aesthetic virtue term is 'beauty' (Istók et al., 2009; Jacobsen, Buchta, Köhler, & Schröger, 2004; Marty et al., 2003). Rhetorical and literary language, too, is often described as being "beautiful", even though literature altogether is no longer simply called the "belles letters". (Classical rhetoric and poetics define its aesthetic effects as "pleasing", *delectare*. Cf. Cicero, *De oratore*; Horace, *Ars poetica*). We, therefore, expected that a beauty rating might capture the overall aesthetic appeal of proverbs. Afterwards the participants rated if the sentence had been familiar to them in this specific wording prior to the experiment. The familiarity scale ranged from −3 (*definitely unfamiliar*) to +3 (*definitely familiar*) with zero indicating that they were not sure.

3.4. Data analysis

Correlations between familiarity and beauty ratings were calculated using PASW 18 (IBM SPSS Statistics). BrainVoyager QX 2.1 (Brain Innovation, Maastricht, The Netherlands) was used to analyze the anatomical and functional MRI data (Goebel, Esposito, & Formisano, 2006). The data were preprocessed with slice-scan time correction, intra-session image alignment, linear trend removal, high pass filtering (using a Fourier filter of 2 cycles) and spatial smoothing with an 8 mm full-width-half-maximum Gaussian kernel (Bohrn et al., 2012). For spatial normalization the individual T1 images were transferred into Talairach space (Talairach & Tournoux, 1988).

For the statistical analyses of the functional data, a voxel-wise General Linear Model (GLM) at the single-participant-level was calculated, based on design matrices that included one unweighted predictor to account for effects of stimulus presentation, into which all sentence types were collapsed, two weighted predictors, who parametrically modelled beauty and familiarity of the presented items, respectively. The estimated 3D motion parameters obtained during preprocessing and a predictor for the button-response window with 2 s duration were added to the model as predictors of no interest. The main regressor that modelled the stimulus presentation, as well as the parametrically weighted regressors each covered the 4s period during stimulus presentation prior to the semantic categorization task and were convolved with a theoretical Two Gamma hemodynamic response function (Friston et al., 1998). Fixation and rest periods were not modelled. The model was independently fitted to the signal of each voxel. Because of the relatively strong correlation of familiarity and beauty ratings (Fig. 1), these two dimensions were orthogonalized by calculating individual linear regression analysis per participant with familiarity as a dependent variable and beauty as a regressor. The resulting standardized residuals were used to build the parametric predictor of beauty. A Pearson correlation between familiarity ratings and standardized residuals of beauty was non-significant at $r < .001$. Brain regions that responded to the ratings in a parametric way were identified by contrasting the parametrically modulated predictors against baseline. The reported group analysis was conducted following a whole-brain random effects model with *z*-normalization of the time courses and correction for serial correlations. A height-threshold of $p < .005$ was applied, and to correct for multiple comparisons, a cluster width-threshold was estimated using a Monte-Carlo simulation with 1000 iterations. This procedure resulted in a width-threshold of 118 voxel for the stimulus main effect, 24 voxel for the beauty parameter, and 63 voxel for the familiarity parameter. Clusters below the correction level are neither reported nor visualized.

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