High responsivity to threat during the initial stage of perception in repression: a 3 T fMRI study

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Repression designates coping strategies such as avoidance, or denial that aim to shield the organism from threatening stimuli. Derakshan *et al.* have proposed the vigilance–avoidance theory of repressive coping. It is assumed that repressors have an initial rapid vigilant response triggering physiological responses to threat stimuli. In the following second stage repressors manifest avoidant cognitive biases. Functional magnetic resonance imaging at 3T was used to study neural correlates of repressive coping during the first stages of perception of threat. Pictures of human faces bearing fearful, angry, happy and neutral expressions were briefly presented masked by neutral faces. Forty study participants (20 repressive and 20 sensitizing individuals) were selected from a sample of 150 female students on the basis of their scores on the Mainz Coping Inventory. Repressors exhibited stronger neural activation than sensitizers primarily in response to masked threatening faces (vs neutral baseline) in the frontal, parietal and temporal cortex as well as in the cingulate gyrus, basal ganglia and insula. There was no brain region in which sensitizers showed increased activation to emotion expression compared to repressors. The present results are in line with the vigilance–avoidance theory which predicts heightened automatic responsivity to threatening stimuli in repression.

INTRODUCTION

More than 30 years ago, Weinberger and colleagues (1979) commenced a new era in research on repressive coping, by renewing interest in repression as an individual difference variable. Generally speaking, repression designates coping strategies such as avoidance, denial or dissociation that aim to shield the organism from distressing or threatening stimuli by disregarding their aversive characteristics (Byrne, 1964; Weinberger, 1990). In the last decades, a large number of studies examined cognitive and physiological correlates of repressive coping style (Furnham *et al.*, 2003). There is now a body of evidence linking repressive coping and poor physical health (Myers, 2010).

According to a widespread conceptualization of repressive coping (Weinberger *et al.*, 1979) repression is defined by high defensiveness, the tendency to deny minor faults and avoid anxiety provoking cognitions, combined with low levels of reported trait anxiety. Thus, individuals scoring high on defensiveness scales and low on anxiety scales are generally classified as repressors, whereas those scoring low

on defensiveness and high on anxiety are classified as sensitizers. While repressors by definition report low levels of trait anxiety, they often paradoxically display higher levels of physiological reactivity (Kohlmann *et al.*, 1996; Derakshan and Eysenck, 1997, 2001; Rohrmann *et al.*, 2002).

In spite of the frequent use of Weinberger *et al.*'s conceptualization, the assessment of coping styles by traditional trait scales incorporates some problems. The items on such instruments do not refer to anxiety-arousing situations, nor do they require subjects to describe specific coping behaviors. The model of coping modes proposed by Krohne (1989, 1993) with its attendant measurement approach aims at overcoming these difficulties. It concentrates on processes of attention orientation that can be observed when individuals are confronted with threat-related cues. The term coping mode refers to the specific configuration of an individual's standing on the two dimensions of cognitive avoidance and vigilance. High habitual avoidance together with low habitual vigilance should be reflected in consistent avoidance. Individuals with such a behavior pattern are labeled repressors according to the traditional coping research, whereas persons manifesting high habitual vigilance and low cognitive avoidance are called sensitizers (Krohne 1989, 1993). Krohne and colleagues constructed the Mainz Coping Inventory (MCI) to measure dispositional preferences for

avoidant and vigilant coping strategies in threatening situations (Egloff and Krohne, 1998; Krohne et al., 2000). Interestingly, convergence has been observed between assessment procedures based on the MCI and on the Weinberger et al. (1979) method that is substantial enough to compare results obtained from both classification systems (Egloff and Hock, 1997).

Taking into account several key findings Derakshan et al. (2007) have proposed the vigilance–avoidance theory of the repressive coping style that owes its origins, in part, to the theoretical contributions of Hock et al. [1996; see also Hock and Krohne (2004) for a brief outline of the repressive discontinuity hypothesis] and Lambie and Marcel (2002). The fundamental assumption of this theory is that there are two successive stages of processing when repressors are exposed to threats. The initial stage occurs rapidly and may involve automatic and non-conscious processes (vigilance stage), whereas the second stage involves controlled and strategic processes and an emphasis on possible coping strategies (avoidance stage). Thus, it is assumed that repressors have an initial rapid vigilant response triggering physiological and behavioral responses involving also attentional biases to threat stimuli. In the following, second stage repressors should manifest avoidant cognitive biases that inhibit the conscious experience of anxiety. Findings from several behavioral studies using different experimental paradigms support the vigilance–avoidance theory of repressive coping (Hock and Egloff, 1998; Calvo and Eysenck, 2000; Schwerdtfeger and Derakshan, 2010). These data document a specific perceptual hypersensitivity of repressive individuals for threatening or negative information. However, according to the results of Mendolia et al. (1996) repressors appear to be dispositionally hypersensitive in the perception of negative as well as positive events or stimuli.

Related to the concept of coping modes is the much broader construct of emotion regulation, which refers to processes by which we influence which emotions we have, when we have them and how we experience and express them (Gross, 1998). According to the process model of emotion regulation (Gross and Thompson, 2007; Gross, 2008) emotion regulatory acts have their primary impact at different points in the emotion generative process. These points represent five subgroups of emotion regulation strategies: situation selection, situation modification, attentional deployment, cognitive change and response modulation. Within this theoretical framework, repressive coping is generally subsumed under the category of attentional deployment (Gross, 2008; Egloff, 2009) and interpreted as automatically generated process of emotion regulation (Gross, 1999; Mauss et al., 2006; Coifman et al., 2007). It has been argued that attentional deployment represents an internal version of situation selection, in that attention is used to select which of many possible 'internal situations' are active for an individual (Gross, 2008). In sum, repressive coping is aimed at decreasing negative emotions (especially anxiety-related affective states) and affective arousal (Weinberger et al., 1979; Krohne, 1996).

In the past only few studies have examined brain activation as a function of coping style. Findings from resting electroencephalographic experiments (Tomarken and Davidson, 1994; Kline et al., 1998) suggest that frontal brain areas could play an important role in repressive coping. Up to now, there exist only two functional magnetic resonance imaging (fMRI) studies investigating cerebral activation in repression. In both cases, the MCI was used to define repressive coping style. Sander et al. (2003) presented acoustically sad and happy intonations to healthy repressive women with the task to identify the emotional valence of the prosodies. It was found that orbitofrontal cortical activation was larger for repressors than for non-repressors. Rauch et al. (2007) examined the neural correlates of repression compared to sensitization during the perception of threatening and non-threatening emotion faces administering a passive viewing task. Using a block design, automatic and controlled processes of emotion perception were examined by showing facial emotion masked by neutral faces or by presenting it unmasked, i.e. clearly visible. Sensitizers tended to show a stronger activation of the amygdala in response to clearly visible fearful faces than repressive persons. In the masked face condition, repressors were overall cortically more responsive not only to fearful (but also to happy facial expressions) than sensitizers. These research findings are at least in part consistent with Derakshan et al.'s vigilance–avoidance theory postulating an enhanced automatic (non-conscious) processing of threat-related information during initial stages of perception in repressive coping. However, in the interpretation of their results Rauch et al. (2007) did not refer to the vigilance–avoidance theory. A substantial limitation of the study of Rauch et al. (2007) represents the lack of an awareness check. Thus, it remains unclear if subjects were truly unaware of the masked emotion faces.

Facial expression of emotions is one of the most important signals encountered in interpersonal relationships (Ekman, 1993; Fridlund, 1994). The facial expression of fear signals potential danger in the environment, but gives little information about the source or location of that threat. Angry faces are also signals of potential danger, but they indicate the source of the threat. Happy expressions are in general friendly signals inviting social interaction and approach (Knutson, 1996).

The perception of emotion faces is a complex process that implicates an interactive network of brain regions. Neural structures underpinning emotion perception from the face are occipito-temporal visual cortical regions (including the fusiform gyrus), the anterior cingulate cortex, the amygdala, the basal ganglia, the orbitofrontal cortex (including parts of the inferior frontal gyrus), the insula and the somatosensory cortices (Adolphs, 2002; Phillips et al., 2003; Vuilleumier and Pourtois, 2007; Fusar-Poli

et al., 2009). This network appears to be also activated when facial expression is presented below the level of conscious awareness (Killgore and Yurgelun-Todd, 2004; Phillips *et al.*, 2004; Liddell *et al.*, 2005; Suslow *et al.*, 2009).

The aim of the current fMRI investigation was to examine differences in automatic brain reactivity to threatening, and non-threatening emotional expression compared to neutral faces as a function of coping style. Fearful, angry, happy and neutral faces were presented for only 33 ms and masked by neutral facial expression to prevent conscious awareness. Subjects were asked to decide which of the above-mentioned four facial expressions was briefly displayed before the neutral face. In this way, we intended to investigate a very early stage of information processing in the brain in repression and sensitization and to control subjects' ability to consciously detect masked facial expression. As in our previous study (Rauch *et al.*, 2007), we administered the MCI (Egloff and Krohne, 1998; Krohne *et al.*, 2000) to assess coping style. In accordance with the vigilance-avoidance theory (Derakshan *et al.*, 2007) we predicted that repressive individuals show a greater cerebral response to threatening faces compared to sensitizers at an automatic processing level. In view of the behavioral results of Mendolia *et al.* (1996) and our previous fMRI data (Rauch *et al.*, 2007) we expected repressors also to manifest stronger brain responses to masked positive (happy) facial expression than sensitizers. Thus, it was hypothesized that repressors are hypersensitive in the automatic processing of threatening as well as positive faces.

METHODS

Participants

Forty right-handed healthy women participated in this fMRI study. Handedness was defined by the Handedness Questionnaire (Raczkowski *et al.*, 1974). All subjects were screened to exclude any previous or current psychiatric, neurological or medical diseases. Participants were free of psychotropic medication and had normal or (by contact lenses) corrected-to-normal vision. Participants' visual acuity was checked prior to the inclusion in the study. The participants read, without any errors, print at least as small as in line 5 when standing 4 ft from the miniature Snellen eye chart. Subjects were screened for imaging safety concerns. The experimental procedure was approved by the institutional ethics committee. Informed, written consent to the study was obtained from all subjects following the Declaration of Helsinki (World Medical Association, 1991). All subjects received a compensation of 35 EUR after their participation in the fMRI experiment.

Study participants were selected from a sample of 150 female students on the basis of their scores on the MCI (Krohne *et al.*, 2000). Twenty women with high scores on the cognitive avoidance scale (>66th percentile of the screening sample) and low scores on the vigilance scale (<33th percentile) were included as consistent repressors in the present study, whereas twenty women with high scores on the

vigilance scale (>66th percentile of the screening sample) and low scores on the cognitive avoidance scale (<33th percentile) were included as consistent sensitizers. Cronbach α was 0.84 for the MCI avoidance scale and 0.89 for the MCI vigilance scale. Repressors differed significantly (P's < 0.001) from sensitizers on both MCI scales (Table 1).

Repressors and sensitizers did not differ in their mean age, verbal intelligence [as measured by the Multiple choice vocabulary test (MWT-B; Lehrl, 1999)] or visual perception and organization [as measured by the Picture Completion subtest of the German adaptation of the Wechsler Adult Intelligence Scale (WAIS-R; Tewes, 1991)] (P's > 0.53). The state version of the State-Trait-Anxiety Inventory (STAI, Spielberger *et al.*, 1970; Laux *et al.*, 1981) was administered after the fMRI experiment to assess state anxiety of study participants. Cronbach α for the STAI state was 0.86. Sensitizers were more anxious after the fMRI experiment than repressors [$t(38) = -2.42$, $P < 0.05$]. The trait version of the STAI (Spielberger *et al.*, 1970; Laux *et al.*, 1981) was administered to measure trait anxiety. Cronbach α for the STAI trait was 0.92. As could be expected, sensitizers had higher trait anxiety scores than repressors [$t(38) = -3.16$, $P < 0.005$]. The Beck Depression Inventory (BDI, Beck and Steer, 1987; Hautzinger *et al.*, 1994) was used to assess the presence of depressive symptoms. Cronbach α for the BDI was 0.83. Sensitizers and repressors did not differ on the BDI ($P > 0.10$).

Measure of coping style: the MCI

The MCI is a stimulus–response inventory (Krohne *et al.*, 2000) that assesses habitual preferences for vigilant and cognitive avoidant coping strategies in four ego-threatening (e.g. public speaking) and four physically threatening situations (e.g. driving with an inexperienced driver). For each situation, five vigilant or sensitizing items (e.g. information search, anticipation of negative events) and five cognitively avoidant or repressive items (e.g. denial, attention diversion) are administered in a true–false response format. To yield scores of habitual coping preferences, scored answers are summed for vigilant and avoidant items across all eight situations.

Table 1 Sociodemographic, cognitive and affective characteristics of study participants

	Sensitizers Mean (s.d.)	Repressors Mean (s.d.)
MCI vigilance	28.2 (3.3)	14 (2.7)
MCI cognitive avoidance	16.5 (4.1)	27.5 (2.4)
Age	22.9 (2.3)	22.4 (2.7)
Verbal IQ (MWT-B)	115.8 (10.9)	117 (13)
Picture completion (WAIS-R)	14.5 (1.3)	14.2 (1.9)
STAI-state	36 (6.7)	31.6 (4.7)
STAI-trait	36.1 (8.7)	29.2 (4.2)
BDI	3.9 (4.7)	2 (2)

Studies on the psychometric properties of the two MCI scales yielded satisfactory results, with coefficients between 0.80 and 0.85 for internal consistency (Cronbach α) and around 0.75 for test–retest reliability (time span: 2 weeks) (Egloff and Krohne, 1998; Krohne et al., 2000; Krohne and Egloff, 2005). Exploratory and confirmatory factor analyses established a two-dimensional structure with a clear separation of vigilant and avoidant coping (Krohne et al., 2001). Employing a latent-class analysis Schmukle et al. (2000) were able to identify the presumed coping patterns of repression and sensitization for the MCI in a large sample of healthy individuals ($n = 871$). Associations between MCI dimensions and other indicators of coping, emotionality, and anxiety- and coping-related constructs confirm the concurrent and discriminant validity of the MCI (Egloff and Krohne, 1998; Krohne et al., 2000). There is a significant overlap between coping style classifications based on the MCI and Weinberger et al.'s (1979) approach (Egloff and Hock, 1997).

Neuropsychological tests

The MWT-B (Lehrl, 1999) was applied to assess verbal intelligence of study participants. The MWT-B includes 37 items. The items consist of lines, each comprising one real word and four pronounceable pseudo-words. The subject is asked to find the correct word.

Picture Completion is a subtest of the WAIS-R (German adaptation: Tewes, 1991) and measures visual perception and recognition of essential details of objects. It consists of 20 small pictures that all have one vital detail missing.

Stimulus materials and procedure

In the fMRI experiment emotional and neutral faces were used as briefly presented targets. Facial stimuli consisted of gray-scale normalized fearful, angry, happy and neutral expressions of ten individuals (Ekman and Friesen, 1976). Neutral faces of the same individuals were applied as masking stimuli. To avoid identity of target and mask in the neutral face condition vertically mirrored faces were used as neutral targets. That is, neutral target faces were produced by mirror inversion (left to right) of neutral mask faces. Eighty trials were shown: 20 with fearful, 20 with angry, 20 with happy and 20 with neutral target faces. Faces were presented in a fixed random sequence with the restriction of no repetition of an individual and no more than one repetition of a target condition on consecutive trials. Each trial had a duration of 9 s. A fixation cross presented for 800 ms preceded a target face shown for 33 ms which was followed by a neutral face for 467 ms. A blank screen followed for 7.7 s. In this time-period subjects had to decide which of the four facial expressions was briefly displayed before the neutral mask face by pressing one of four buttons ('happy', 'angry', 'neutral' and 'fearful'). Judgments and reaction times were registered. Images were presented via projection to the rear end of the scanner (Sharp XG-PC10XE with additional HF shielding). In each hand, participants held a fiber optic response pad with two buttons. One half of the sample gave 'happy' and 'angry' responses with the left pad; the other half gave these responses with the right pad. During the course of the experiment, subjects lay supine in the MRI scanner with their arms extended at their sides. The head position was stabilized with a vacuum head cushion.

The chance level for correct answers was 25% (chance detection rate). To assess the ability of study participants to differentiate the target expression from other expressions a non-parametric index of sensitivity A' was used (Grier, 1971). For each subject four A' values were determined. For the fearful face condition, for example, a hit was defined as giving the response 'fearful' in trials where fearful faces were shown whereas false alarm was defined as responding with 'fearful' in trials where angry faces, happy faces and neutral faces were presented. An A' of 0.5 indicates chance discrimination, whereas 1 indicates perfect detection without false alarms. When a stimulus is around Fechner's original idea of a threshold, A' should be ~0.75.

fMRI data acquisition and data analysis

T2* functional data were acquired at a 3 Tesla scanner (Gyroscan Intera 3T, Philips Medical Systems, Best, NL) using a single shot echoplanar sequence with parameters selected to minimize distortion in the region of central interest while retaining adequate signal-to-noise ratio (S/N) and T2* sensitivity. Volumes consisting of 36 axial slices were acquired (matrix 64×64, resolution $3.5 \times 3.5 \times 3.5$ mm; TR = 2.5 s, TE = 35 ms, FA = 90°). Functional imaging data were motion corrected, spatially normalized to standard MNI space (Montreal Neurological Institute) and smoothed (Gaussian kernel, 6 mm FWHM) using Statistical Parametric Mapping (SPM5; Wellcome Department of Cognitive Neurology, London, United Kingdom, http://www.fil.ion.ucl.ac.uk/spm) implemented in Matlab 7.1. Additionally, T1-weighted inversion recovery and a high-resolution T1-weighted 3D sequence (isotropic voxel, 0.5 mm edge length) were acquired. An event-related analysis design was used. For each subject, trials were averaged separately for each target condition (fearful face, angry face, happy face and neutral face). Thus, the data were reduced to four average trials for each subject. Brain responses to the target categories were isolated by convolving a vector of onset times of the emotional and neutral target conditions with a canonical hemodynamic response function. The general linear model was used to model the effects of interest and other confounding effects.

A whole-brain analysis was conducted to determine brain regions which were differentially activated as a function of repressive and sensitizing coping style. Presenting masked target faces only for 33 ms we could not expect large activation differences between groups. Thus, the significance level in the whole-brain analyses was put at $P < 0.001$ (uncorrected) with clusters defined by at least ten contiguous voxels of significant response. This low cluster threshold was chosen

to maximize sensitivity in the detection of activation differences between study groups. First, activation data (*t*-maps) were calculated for each subject in each of the three emotion face conditions (fearful, angry and happy) relative to the neutral face condition. Second, additional activation data (*t*-maps) were calculated for each subject in the two threatening face conditions (fearful and angry) relative to the happy face condition. Random effects analyses (*t*-tests for independent samples) were performed to examine brain activation differences between groups (on the contrasts: fearful *vs* neutral, angry *vs* neutral, happy *vs* neutral, fearful *vs* happy and angry *vs* happy). Coordinates of significant activations were converted into Talairach and Tournoux (1988) space using the Talairach Daemon (Kochunov and Uecker, 2003). Participants' characteristic and behavioral data were analyzed using PASW Statistics 18.

RESULTS
Detection performance in the fMRI experiment

Mean A' values (non-parametric index of sensitivity) for all target face conditions are shown in Table 2. A 2×4 ANOVA was conducted on A' values with group (repressors and sensitizers) as between-subject variable and emotion face condition (fearful, angry, happy and neutral) as within-subject variable. The ANOVA showed a significant main effect of emotion face condition [$F(3,36) = 5.20$, $P < 0.005$] but no main effect of group [$F(1,38) = 0.46$, $P = 0.50$] and no interaction group × emotion face condition [$F(3,36) = 0.34$, $P = 0.79$]. Whereas mean A' values for fearful, angry and neutral faces were lower than 0.50 (i.e. below chance performance), the A' values for happy faces were somewhat higher than 0.50. The mean overall A' value for happy faces (0.55, s.d. = 0.15) was significantly higher than chance discrimination [$t(39) = 2.03$, $P < 0.05$] but still far from perfect recognition. Most importantly, there was no evidence for detection differences between repressors and sensitizers for any of the emotion face conditions.

According to the results of a 2×4 ANOVA based on response latencies with group (repressors and sensitizers) as between-subject variable and emotion face condition (fearful, angry, happy and neutral) as within-subject variable there

was no main effect of emotion face condition [$F(3,36) = 0.69$, $P = 0.56$], no main effect of group [$F(1,38) = 0.74$, $P = 0.39$] and no interaction group × emotion face condition [$F(3,36) = 0.34$, $P = 0.80$]. Thus, repressors did not differ from sensitizers with respect to response latencies in detecting facial expression. Mean response latencies for all target face conditions are shown in Table 2.

Whole-brain neuroimaging results: between-group comparisons
Brain response to fearful faces compared to neutral faces

Comparisons between the two study groups revealed greater activation in the inferior and middle frontal gyrus, insula, cingulate gyrus and middle temporal gyrus for repressive individuals relative to sensitizing individuals for the fearful *vs* neutral contrast. Moreover, repressors exhibited enhanced precuneus activation and caudate head activation in response to fearful faces compared to sensitizers (see Table 3 for details). Compared to repressors there were no brain regions in which sensitizers demonstrated increased activation to fearful (*vs* neutral) facial expression.

Brain response to fearful faces compared to happy faces

Fearful faces elicited stronger activation in the left supramarginal gyrus [BA 40, peak voxel *x*, *y*, *z*: −50, −54, 30 (MNI coordinates), cluster size: 226, *Z*-score = 4.14, $P < 0.001$], and the left superior frontal gyrus [BA 9, peak voxel *x*, *y*, *z*: −16, 50, 28 (MNI coordinates), cluster size: 12, *Z*-score = 3.71, $P < 0.001$] in repressors compared to sensitizers. There was no brain region in which sensitizers showed increased activation to fearful (*vs* happy) facial expression compared to repressors.

Table 2 Mean A' values (non-parametric sensitivity index) and mean response latency for the target face conditions as a function of coping style

	Sensitizers Mean (s.d.)	Repressors Mean (s.d.)
A' fearful face	0.47 (0.16)	0.48 (0.26)
A' angry face	0.44 (0.17)	0.42 (0.17)
A' happy face	0.52 (0.14)	0.57 (0.15)
A' neutral face	0.42 (0.29)	0.47 (0.16)
Latency fearful face	2033 (591)	1850 (702)
Latency angry face	2098 (743)	1871 (770)
Latency happy face	1998 (684)	1882 (493)
Latency neutral face	2016 (649)	1841 (668)

Table 3 Brain areas where repressors showed more activation in response to fearful facial expression (compared to neutral faces) than sensitizers

Brain Region	(BA)	Hemisphere	MNI coordinates			Size	Z-score
			x	*y*	*z*		
Inferior frontal gyrus	47	L	−28	32	4	74	4.32
	46	R	32	30	20	15	3.65
Middle frontal gyrus	9	L	−34	30	24	21	4.03
Insula	13	R	32	4	22	26	3.99
Cingulate gyrus	32	L	−14	18	30	12	3.44
Precuneus, parietal lobe	31	L	−20	−54	34	14	3.95
Middle temporal gyrus	21	L	−50	−26	−8	15	3.74
Caudate head		R	8	22	4	179	3.70

Coordinates of the maximal point of activation and the associated *Z*-values are shown. The activations are significant at $P < 0.001$ (uncorrected).

Brain response to angry faces compared to neutral faces

Compared to sensitizing individuals repressive individuals exhibited enhanced activation of inferior, medial, middle and superior frontal areas in response to angry faces. In addition, repressors showed more activation to angry faces (*vs* neutral faces) than sensitizers in the anterior cingulate, parietal sub-gyral gray matter, post-central and parahippocampal gyrus (Table 4 and Figure 1). Compared to repressors there were no brain areas in which sensitizers demonstrated increased activation to angry (*vs* neutral) facial expression.

Brain response to angry faces compared to happy faces

Repressors showed an enhanced response to angry faces (*vs* happy faces) in the medial, middle, and superior frontal lobe and the inferior parietal lobule compared to sensitizers. Furthermore, repressors showed more activation to angry faces (*vs* happy faces) than sensitizers in the bilateral putamen, the right claustrum and left sub-lobar areas (Table 5). There were no brain areas in which sensitizers demonstrated more activation to angry (*vs* happy) facial expression than sensitizers.

Table 4 Brain areas where repressors showed more activation in response to angry facial expression (compared to neutral faces) than sensitizers

Brain region	(BA)	Hemisphere	MNI coordinates			Size	Z-score
			x	y	z		
Inferior frontal gyrus	47	L	−28	24	−16	97	4.12
	47	R	26	12	−18	66	3.71
Medial frontal gyrus	11	L	0	40	−10	31	3.80
Middle frontal gyrus	11	L	−26	42	−6	34	3.79
	6	R	32	−2	56	10	3.61
Superior frontal gyrus	11	R	14	48	−10	40	3.63
Anterior cingulate	32	R	2	36	−2	38	3.75
Parietal lobe, sub-gyral	40	R	32	−50	32	39	4.06
Postcentral gyrus	2	R	32	−30	34	20	3.90
Middle temporal gyrus	22	L	−54	−50	2	16	3.60
Parahippocampal gyrus	36	R	42	−22	−14	19	4.04

Coordinates of the maximal point of activation and the associated Z-values are shown. The activations are significant at $P < 0.001$ (uncorrected).

Brain response to happy faces compared to neutral faces

Happy faces caused stronger activation of the right inferior frontal gyrus [BA 47, peak voxel *x, y, z*: 30, 16, −22 (MNI coordinates), cluster size: 43, Z-score = 4.04, $P < 0.001$] and
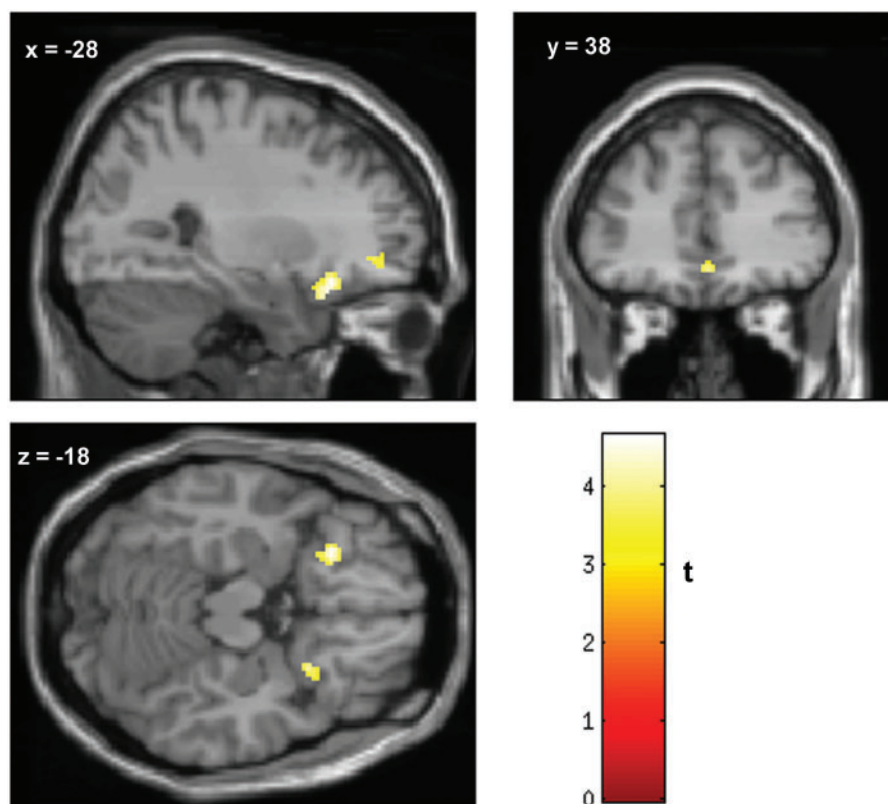

Fig. 1 Between-group differences in brain responses to angry facial expression compared to neutral faces. Enhanced brain activations of repressors in relation to sensitizers (sagittal view: activation in the left inferior and middle frontal gyrus; coronal view: activation in the anterior cingulate; axial view: activation in the left and right inferior frontal gyrus). Coordinates in the reference frame of MNI space. Reader's right is subjects' right.

Table 5 Brain areas where repressors showed more activation in response to angry facial expression (compared to happy faces) than sensitizers

Brain region	(BA)	Hemisphere	MNI coordinates			Size	Z-score
			x	y	z		
Medial frontal gyrus	8	R	4	40	48	58	3.50
Middle frontal gyrus	8	R	42	20	52	43	4.08
Superior frontal gyrus	6	L	−4	28	64	17	3.63
	9	R	22	52	40	20	3.72
Inferior parietal lobule	40	L	−54	−52	40	22	3.60
Putamen		L	−32	−20	−2	18	3.87
		L	−28	−2	−8	24	3.70
		R	22	6	−4	18	3.52
Claustrum		R	36	4	−6	16	4.11
Sub-lobar area		L	−14	14	−10	38	3.89

Coordinates of the maximal point of activation and the associated Z-values are shown. The activations are significant at $P < 0.001$ (uncorrected).

the left cingulate gyrus [BA 31, peak voxel x, y, z: −24, −46, 32 (MNI coordinates), cluster size: 12, Z-score = 3.84, $P < 0.001$] in repressors compared to sensitizers. Compared to repressing individuals there were no brain regions in which sensitizers demonstrated increased activation to happy (vs neutral) facial expression.

DISCUSSION

In this study, we demonstrated significant differences in brain response to facial emotions between repressors and sensitizers at an automatic processing level. According to our results, repressors exhibit stronger neural activation than sensitizers in response to masked threatening (angry and fearful) as well as masked happy facial expression in several areas of the brain. Parts of the frontal, parietal and temporal cortex were found to respond more strongly to facial emotions in repressors than in sensitizers. This is at least in part consistent with findings from resting electroencephalographic experiments (Tomarken and Davidson, 1994; Kline et al., 1998) and a previous fMRI study on the response to prosodic information (Sander et al., 2003) suggesting that (orbito-)frontal brain areas could play an important role in repressive coping.

Furthermore, we observed also more reactivity of the cingulate gyrus, basal ganglia and insula to emotional expression in repressors compared to sensitizers. Considering the total volume of significantly more activated voxels the extent of the activation differences between repressors and sensitizers in the brain was much larger (about six to seven times) for the threatening faces (angry and fearful) than for the happy faces. Regardless of baseline no brain area showed significantly higher activation in sensitizing individuals than in repressors during the automatic processing of any of the facial emotions.

The present findings confirm our hypothesis that repression is associated with hypersensitivity in the automatic

processing of threatening as well as positive stimuli. Our fMRI data suggest that repressing persons are more responsive to threatening and also, but to a lesser extent, happy facial expression than sensitizing persons at a very early stage of information processing. According to the vigilance-avoidance theory (Derakshan et al., 2007) there are two successive stages of processing when repressors are exposed to threats. It is assumed that a repressor has an initial rapid vigilant response triggering physiological and behavioral responses followed by a second stage characterized by avoidant cognition. Our results support the vigilance-avoidance theory in that repression appears to be associated with an increased brain activity in response to threatening compared to neutral facial expression at an automatic, non-conscious stage of information processing. Neural structures underlying facial emotion processing such as the inferior frontal gyrus, the anterior cingulate and the basal ganglia seem to be especially responsive to threat-related faces in repression during the initial stage of perception.

The present data suggest some group differences in brain activation during the automatic processing of fearful vs angry faces. This could be explained by the assumption that masked fearful faces engage an at least partially different neural network compared with masked angry faces. Previous studies on the automatic perception of fearful facial expression have reported activation of the caudate nucleus (Liddell et al., 2005; Phillips et al., 2004; Fan et al., 2011), insula (Liddell et al., 2005; Fan et al., 2011) and precuneus (Phillips et al., 2004; Fan et al., 2011) in response to fearful faces. In these areas, we observed more activation responses to masked fearful (but not to masked angry) expression in repressors than in sensitizers. Very little is known about the neural mechanisms underlying automatic processing of angry faces. We found more activation of the medial and superior frontal gyrus, the post-central and parahippocampal gyrus in repressors than in sensitizers for masked angry but not for masked fearful faces. Medial and superior frontal regions have been found to be activated during the conscious perception or recognition of (unmasked) angry faces (Kesler-West, et al. 2001; Jehna et al., 2011). There is also evidence that the parahippocampal gyrus is engaged in the processing of angry facial expression [Fusar-Poli et al., 2009; but see Nomura et al. (2004) for discrepant findings].

Our study provides some evidence that repression is characterized by heightened automatic brain responsivity to positive (happy) facial expression compared to sensitization. The present data are consistent with the findings of our previous fMRI study (Rauch et al., 2007) suggesting a stronger brain activity to masked happy faces in repressors compared to sensitizers. Furthermore, they are also in line with the behavioral results from Mendolia et al. (1996) according to which repressors appear to be hyper-responsive in the perception of positive and negative stimuli. However, it remains unclear whether threat-sensitive individuals such as repressors perceive smiling or happy faces at an early stage

of processing as unambiguously positive. According to Ekman (1985) smiles can have other meanings than that of an expression of true felt happiness. False smiles, for example, can mask negative emotional states or smiles can represent facial expressions of contempt. Individuals who have the fear being ridiculed and laughed at could interpret happy facial expression as threatening (Gilboa-Schechtman et al., 1999), especially at an early stage of perception or in case no context or situational information is available to disambiguate smiling facial expression. In this view, it appears plausible that repressing individuals may perceive briefly presented happy faces as potentially threatening and therefore react similarly to smiling faces as to fearful or angry faces.

Importantly, despite the differences in brain responsivity repressors did not differ from sensitizers in detection performance (accuracy of emotion identification and response latencies). Both study groups exhibited a chance level performance in identifying angry, fearful and neutral facial expressions and appeared equally engaged in the task. Thus, it can be concluded that repressors as well as sensitizers were in general not consciously aware of the anger, fear and neutral faces presented in our experiment. For both groups, identification rates for happy faces were somewhat above chance level but still far from perfect recognition.

Thus far, research on the neurobiology of emotion regulation has primarily focused on conscious or deliberate regulation strategies such as cognitive reappraisal (a cognitive-linguistic strategy that alters the trajectory of emotional responses by reformulating the meaning of a situation) or suppression (a strategy directed toward inhibiting behaviors associated with emotional responding) (Goldin et al., 2008; Ochsner and Gross, 2008; McRae et al., 2009). As pointed out in the introduction, according to the process model of emotion regulation (Gross, 1998, 2008) repressive coping can be interpreted as a regulation style primarily characterized by attentional deployment. It is assumed that repressive copers deflect attention away from potentially threatening stimuli and show an attentional defense.

In our study, repressors showed stronger automatic responses to emotional and especially threatening stimuli in many brain areas compared to sensitizers. A plausible explanation for our results that appears to contradict the assumption of Gross (1999, 2008) could be that stronger brain activation in repressors is indicating increased attention allocation to emotional stimuli. Remarkably in this context is, however, that repressors were not better in recognizing emotional or threatening faces even though they manifested significantly stronger activation of several frontal cortical areas compared to sensitizers. One might speculate that in repressive copers a defensive process is already at work immediately after the initial unconscious registration of a briefly flashed emotional stimulus. Interestingly, fMRI findings implicate the orbitofrontal and rostral anterior cingulate cortex in automatic disengagement of attention away from

emotional information or implicit resolution of emotional conflict (Etkin et al., 2006; Pourtois et al., 2006; Phillips et al., 2008). According to our results, repressors exhibited stronger activation in both of these brain areas assumed to be involved in the automatic attentional control of emotion processing than sensitizers at least in the angry face condition.

Since we examined cerebral responses to generally not consciously perceived stimuli our findings strengthen the view that repression is generated by automatically elicited processes (Gross, 1999; Mauss et al., 2006; Coifman et al., 2007; Koole and Rothermund, 2011). However, it remains unclear at this point whether stronger brain responses are better interpreted as reflecting spontaneous emotion reactivity or as automatic emotion regulation process (i.e. enhanced attention to emotional information). Mauss et al. (2007) have proposed to distinguish between emotion reactivity and (automatic) emotion regulation but this theoretically important but preliminary distinction has still to be validated by future research. One of the challenges for the field moving forward will be to reach consensus on what criteria are necessary and sufficient in order to conclude that automatic emotion regulation has occurred (Berkman and Lieberman, 2009).

For all emotion face conditions (compared to the neutral face baseline), repressors manifested a greater responsivity of the inferior frontal gyrus (BA 47) and the cingulate gyrus than sensitizers. Strikingly, there was also a stronger response in a rather large part of the caudate nucleus to fearful faces in repressors compared to sensitizers. The anterior and posterior cingulate gyrus as well as the head of the caudate are known to be involved in subliminal emotion face processing (Phillips et al., 2004; Liddell et al., 2005). Caudate neurons appear to have a role in detecting salient features of unattended sensory inputs, such as novelty and emotional valence, and may contribute to unconscious alerting to novel or emotional stimuli (Berns et al., 1997; Vuilleumier et al., 2003).

The inferior frontal cortex has been found to respond to facial emotion presented supra- and subliminally in previous studies (Ishai et al., 2005; Liddell et al., 2005) and appears involved in attention allocation and memory encoding of stimuli with a high arousal value (Brewer et al., 1998; Yamasaki et al., 2002). More importantly, it has been shown that the inferior frontal cortex (BA 47) could exert inhibitory influences on emotional and limbic responses (Hariri et al., 2003; Phan et al., 2005). According to Lee et al. (2008) the inferior frontal cortex has a modulating role in the control of emotional expression by suppressing automatic mimicry or mirror responses. Against this background, our result of higher activation of the inferior frontal gyrus (BA 47) in repressors compared to sensitizers may reflect automatic processes of down-regulation of emotional expression (or emotional response in general) in repressive coping.

As pointed out above, repressors often display high levels of physiological reactivity (e.g. increased blood pressure, heart rate or cortisol response) to threats and stress (Kohlmann et al., 1996; Derakshan and Eysenck, 1997, 2001; Rohrmann et al., 2002). Interestingly, extent of activation of the anterior cingulate, head of caudate nucleus and insula to emotion faces has been found to be associated with heart rate acceleration (Critchley et al., 2005). Moreover, it has been shown recently that heightened activation in the posterior cingulate, insular and (dorso-) lateral prefrontal (BA 8, 9, 10) cortices to stressors covaries with exaggerated blood pressure reactivity (Gianaros et al., 2007). It appears that these brain areas control peripheral physiology by reciprocal neural connections with cell groups in sub-cortical and brain stem areas. In our study, we observed stronger responses of the cingulate gyrus, insular and dorso-lateral prefrontal areas (BA 8, 9) to threatening faces in repressors. Heightened threat-induced activation of these brain areas involved in peripheral cardiovascular control may partly account for repressors' tendency to show exaggerated cardiovascular activity to stressors.

According to Krohne's (1989, 1993) model of coping modes repression designates coping strategies that aim to shield the organism from distressing stimuli that induce emotional arousal. Repressive coping behavior is interpreted as arousal motivated. It is assumed that repressors manifest avoidant cognitive biases because their experience of emotional states is very intensive or because an impending strong and possibly uncontrollable increase in arousal should be prevented. The present fMRI data support these theoretical considerations to some extent insofar as repressors showed automatically a stronger response to emotional stimuli than sensitizers in brain areas that appear to be directly involved in the elicitation of peripheral physiological reactions. Strong automatic physiological reactions (e.g. heart rate) might contribute to a high intensity of emotional experience in repression necessitating a down-regulation of emotion and/or reduction of arousal.

Various studies suggest that repressive coping but not sensitization is linked with poor physical health (see Myers, 2010, for a review). Repressive coping style was shown to be a predictor of increased risk for hypertension, myocardial infarction and other cardiac events (e.g. Rutledge and Linden, 2000; Denollet et al., 2008). The unfavorable cardiovascular function observed in repression could be the consequence of a hyper-responsiveness of the sympathetic nervous system to stressful events (e.g. Derakshan and Eysenck, 1997; Grossman et al., 1997) along with a low conscious awareness of bodily state and symptoms (Schwartz, 1990). The disposition to react automatically (i.e. without effort, intention or awareness) to emotionally valenced information might represent an important factor contributing to a generally increased autonomic activity in repression which, under adverse circumstances, could lead in the long term to cardiovascular diseases. High habitual responsivity

to emotional (and especially threatening) stimuli at an automatic processing level could represent a critical issue that should be taken into account when designing psychological interventions for repressive patients.

The generalizability of our findings is limited, as we included young, healthy women as participants. Kline et al. (1998) found differences in EEG activity between repressive men and women. Therefore, it is necessary that subsequent research on this topic examines also (sub-)samples of men. In our study, we focused on consistent repression and consistent sensitization. It remains to be examined what kind of automatic brain response to threat is shown by individuals characterized by other coping modes [i.e. high-anxiety or fluctuating coping (high vigilance associated with high cognitive avoidance)] and non-defensiveness (low vigilance associated with low cognitive avoidance, see Krohne 1989, 1993). The present study lacks the assessment of psycho-physiological signals (e.g. heart rate, electrodermal activity). To explore the linkage between brain and peripheral psycho-physiological response in repression, it is indispensable to record physiological signals during fMRI scanning in future studies.

Assuming that repressors have an initial rapid vigilance response involving also attentional biases, one might have expected differences between repressors and sensitizers regarding their detection performance. Our data indicate that at a very low level of stimulus intensity there are no differences between repressors and sensitizers in their ability to consciously detect facial expression. Both groups showed (near) chance level performance in identifying facial expressions in the present experiment. In the future, it would be of interest to increase duration of stimulus presentation and to examine identification of stimuli shown near threshold of conscious perception as a function of coping mode.

Conflict of Interest

None declared.

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