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ORIGINAL RESEARCH

Neural correlates of personality dimensions and affective measures during the anticipation of emotional stimuli

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Abstract Neuroticism and extraversion are proposed personality dimensions for individual emotion processing. Neuroticism is correlated with depression and anxiety disorders, implicating a common neurobiological basis. Extraversion is rather inversely correlated with anxiety and depression. We examined neural correlates of personality in relation to depressiveness and anxiety in healthy adult subjects with functional magnetic resonance imaging during the cued anticipation of emotional stimuli. Distributed particularly prefrontal but also other cortical regions and the thalamus were associated with extraversion. Parieto-occipital and temporal regions and subcortically the caudate were correlated with neuroticism and affective measures. Neuroticism-related regions were partially cross-correlated with anxiety and depression and vice versa. Extraversion-related activity was not correlated with the other measures. The neural correlates of extraversion compared with those of neuroticism and affective measures fit with concepts of different neurobiological bases of the personality dimensions and point at predispositions for affective disorders.

Keywords Extraversion · Neuroticism · Emotion processing · fMRI · Affective disorders

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Introduction

The relation between personality dimensions and affective disorders is subject of longstanding discussions, beginning with the ancient Greeks (Kotov et al. 2010). Nowadays, neurobiological aspects of personality factors or dimensions may serve as one approach to the neurobiology of and the predisposition for affective disorders (Foster and MacQueen 2008).

A variety of dimensional personality models have been developed. Amongst these models, two factors have been shown consistently: One factor addressing neuroticism or negative affectivity, the other factor including positive affectivity or extraversion (e.g. Carver and Connor-Smith 2010; DeYoung and Gray 2009; Keightley et al. 2003; Kotov et al. 2010). The first model attempting to link personality and biological mechanisms was the model of Eysenck proposing neuroticism and extraversion as main factors of personality dimensions (DeYoung and Gray 2009). Other factors as psychoticism, conscientiousness, openness, agreeableness, disinhibition versus constraint have been proposed, but were less broadly supported.

In particular the association between neuroticism and affective disorders, particularly major depression and anxiety disorders has been noted early and continuously (reviews: e.g. Clark et al. 1994; Enns and Cox 1997; Jylha and Isometsa 2006, meta-analyses: Kotov et al. 2010; Malouff et al. 2005). The other personality 'superfactor' in several models of personality opposed to neuroticism is extraversion (Klein et al. 2009). The relation between extraversion and affective disorders is less pronounced: A recent meta-analysis (Kotov et al. 2010) resulted in a trend of correlation between major depressive disorder and low extraversion, the correlations between low extraversion and anxiety disorders as panic disorder, social phobia, obsessive compulsive disorder, and posttraumatic stress disorder revealed medium effect sizes.

Besides being a risk- or predisposing factor for affective disorders, particularly neuroticism has been shown to influence the course and response to differential treatment strategies in depression with high neuroticism predicting a negative response to treatment in general, but particularly to psychotherapy (Keightley et al. 2003). A stronger disturbance of emotion regulation was proposed as reason for this lower response to psychotherapy in highly neurotic patients (Keightley et al. 2003). Due to these associations between personality and affective disorders, personality traits can serve as an approach to dimensional and subclinical correlates of affective disorders.

Neuroimaging studies as one way to examine the neurobiology of mental processes have related a broad network of brain regions to personality traits: Neuroticism has been shown to correlate with activity in insula during the anticipation of aversive stimuli (Simmons et al. 2006), cingulate cortex during emotional conflict (Haas et al. 2007) and anticipatory fear (Kumari et al. 2007), prefrontal cortex in response to positive stimuli (Britton et al. 2007) and negative stimuli (Canli et al. 2001; Simmons et al. 2006), parieto-occipital areas due to fearful facial expressions (Chan et al. 2009) and subcortical brain regions in response to anticipatory fear (Kumari et al. 2007). Addressing the association between amygdalar activity and neuroticism, results are mixed, with positive correlations in some studies (Cunningham et al. 2010; Haas et al. 2007), but also a number of studies finding no correlation with different tasks (Britton et al. 2007; Canli et al. 2002; Canli et al. 2001; Chan et al. 2009; Deckersbach et al. 2006; Kumari et al. 2007; Simon et al. 2010).

In response to positive stimuli of different quality, extraversion has been shown to correlate with amygdalar activity (Canli et al. 2002; Canli et al. 2001; Vaidya et al. 2007) and with activity in anterior cingulate (Canli et al. 2004; Canli et al. 2001; Kumari et al. 2004). Further regions reported to be associated with extraversion were dorsolateral and inferior prefrontal (Canli et al. 2001; Kumari et al. 2004), subcortical (Canli et al. 2001; Kumari et al. 2004; Simon et al. 2010) and occipital brain areas (Amin et al. 2004).

We wanted to address the neurobiological aspects of the relationship between the personality-dimensions neuroticism and extraversion on the one hand and affective measures on the other hand within the frame of an emotion task. Cognitive and emotional processes in neuroticism share negative biases with depression concerning attention, interpretation and memory of emotional stimuli (Martin 1985; Mathews and MacLeod 1994). In contrast, extraversion is characterized by increased experience of positive emotions (Costa and McCrae 1980) and greater sensitivity to positive or rewarding stimuli (Banich et al. 2009; Lucas and Diener 2001). In mood and anxiety disorders and also in healthy subjects with depressed or anxious mood, one of the main affected cognitive processes is the attitude towards the future, which is biased towards negative expectations or 'pessimism' (Beck's cognitive triad, Beck 1967; Lavender and Watkins 2004; Pyszczynski et al. 1987). This negative bias is most pronounced in ambiguous situations, in which anticipation can either be negative, i.e. pessimistic, or anxious (Barlow 2000), or positive, corresponding to an optimistic view. Neuroticism has been shown to correlate with pessimism (Marshall et al. 1992), some authors even proposing a major overlap or identity of the two concepts (Smith et al. 1989). Highly extraverted subjects on the other hand should not display marked pessimistic or anxious reactions during the anticipation of negative and ambiguously cued emotional stimuli as extraversion typically is characterized by a sensitivity to pleasurable stimuli and reward and more frequent and intense expression of positive affect (Winter and Kuiper 1997).

Furthermore, pessimism has been shown to be a negative predictor for somatic and mental health (Scheier and Bridges 1995) and, for instance, for suicidal acts in depression (Oquendo et al. 2004).

Due to the relevance of anticipatory processes in mental health and affective disorders, we have developed a task addressing the cued anticipation of emotional pictures on the neural level using functional magnetic resonance imaging. To expect a negative event in situations with a possibly negative, but also possibly positive outcome, is a typical representation of pessimism, which we could show on the neural level. Therefore we particularly emphasize the anticipation of known ambiguously cued, potentially negative stimuli representing a condition which is prone to evoke pessimistic attitudes. In previous studies using this task we found a similarity of the patterns of brain activation during the anticipation of clearly negative and ambiguously cued, potentially negative stimuli (Herwig et al. 2007). This similarity increased with increasing state depression in healthy subjects (Herwig et al. 2007) and in patients with a depressive episode (Herwig et al. 2010). Main regions involved in this pessimistic anticipatory processing were ventro- and dorsolateral prefrontal cortex, bilateral insular cortex, the extended amygdalar complex and thalamus.

Despite the similarity and partial overlap of the concepts of personality dimensions and affective measures, there remain differences. We therefore investigated the neural correlates strongly associated with neuroticism and extraversion during the expectation of emotional stimuli and compared this with brain activity correlating with anxiety and depressiveness. We hypothesized differential associations between mood and personality measures and brain activity during the cued anticipation of emotional stimuli in brain regions known to be involved in emotion processing and associated with personality traits as prefrontal, parieto-occipital, insular, cingulate and subcortical regions.

Methods

Subjects

Sixteen healthy subjects (all right-handed, 10 female) without any history of neurological or psychiatric illness (determined with a semistructured interview based on clinical routine screening and the Mini Neuropsychiatric Interview (Ackenheil et al. 1999)) and without current medication gave written informed consent to take part in this study, which was approved by the local ethics committee and performed in accordance with the Declaration of Helsinki. Basic data of this sample have been reported previously (Herwig et al. 2007). Two subjects were excluded due to drowsiness during scanning and reported lack of concentration (included: 8 females, mean age 27.8 years, range 23–36). All analyses were done with the remaining 14 subjects.

Psychometric measures

The participants completed German versions of the Eysenck self rating questionnaire of personality (Eysenck personality inventory (EPI), Eggert 1974), state depression (self-rating depression scale (SDS), Zung 1965), and trait anxiety (State trait anxiety inventory (STAI), Laux et al. 1981).

The final group of participants (n=14) had normal scores in these ratings (SDS: mean 35.4, standard deviation (SD) 6.6, range 27.5–47.5; STAI: mean 30.1, SD 4.3, range 22–35; ‘neuroticism’ (EPI-N): mean 4.86, SD 2.8, range 1–10; ‘extraversion’ (EPI-E): mean 13.6, SD 3.5, range 7–18). There were no outliers exceeding two SDs.

MRI-acquisition

Imaging was performed with a 1.5 T Siemens SonataTM whole-body scanner (Erlangen, Germany, 8-channel head coil). Anatomical volumes were acquire with a 3-D T1 weighted sequence (voxel size 1×1×1 mm) for coregistration with the functional data. Echo-planar imaging was performed for functional MR imaging (repetition-time (TR)/echo-time (TE) 1980/40 ms, 22 sequential axial slices, whole brain, slice thickness/gap 4/1 mm, voxel size 3.4×3.4×5 mm, field of view 220 mm, 908 volumes). Stimuli were projected onto a screen viewed by the subjects through a mirror attached to the head coil.

Experimental design

During fMRI, the subjects performed a cueing task (description in Herwig et al. 2007), consisting of 56 trials with the cued expectation and presentation of emotional pictures from the International Affective Picture System (IAPS, Lang et al. 2005). Within each trial, first a cue was given (duration 1000 ms), depicting either a ‘smiling’ (‘positive’, ps) ‘∪’, a ‘non-smiling’ (‘negative’, nt) ‘∩’, or a ‘neutral’ (nt) symbol ‘−’, indicating the emotional valence of the upcoming picture, or a symbol after which randomly either a pleasant or an unpleasant picture appeared: the ‘ambiguous’ or ‘unknown’ condition ‘|’ (uk). Thereafter, the respective emotional picture was presented. The highly abstract and graphically comparable symbols were easily understandable and no prominent working memory had to be used to establish their meaning. The cues were 1/20 of screen height, the pictures filled the screen. The anticipation period lasted 6920 ms (blank screen with fixation point; cue plus anticipation: 4 TR). Subsequently, emotional pictures from the International Affective Picture System (IAPS, Lang et al. 2005) were presented for 7920 ms (4 TR). During the following baseline period (15840 ms, 8 TR), the blood oxygen level dependent (BOLD-) signal could wear off before the next trial started. In the ‘unknown’ condition, positive and negative stimuli appeared (50% each, randomized order). Each condition (ng, ps, nt, uk) comprised 14 trials. Conditions and stimuli were pre-randomized. Participants were instructed to expect the emotional stimuli following the cue, to be aware of the indicated emotional valence, and thereafter to look at the following emotional picture. Before scanning, all participants performed a training session, during which they were presented a shorter version of the task with similar pictures. To avoid memory effects, those pictures did not appear during the main task. The participants thus knew timing, cues, and range of content of the pictures. The properties of the emotional pictures have been described before (Herwig et al. 2007).

Data analysis

FMRI data were analyzed using BrainVoyager™ QX 1.8.6. Preprocessing and transformation into Talairach space have been reported before (Herwig et al. 2007). Expectation period and picture presentation periods were each modeled as epochs with the standard two-gamma hemodynamic response function. Three-dimensional statistical parametric maps were computed separately for each subject using a general linear model (random-effects analysis) for the single emotion expectation (exp) contrasts versus neutral (exp negative>exp neutral, exp ambiguous>exp neutral, exp positive>exp neutral). These 'emotions versus neutral'-contrasts were chosen to achieve specificity for the respective emotion, thereby reducing non-specific, non-emotional anticipatory processes.

We sought for regions in which brain activity during the expectation contrasts correlated with the measures of personality and affectivity. Hence, the individual results of the questionnaires were implemented as primary covariates in the ANCOVA model of the emotion expectation contrast analyses. The correlation coefficients of this whole-brain analysis are given below. To find cross-correlations between factors at an exploratory level, we computed post-hoc additional correlations between the mean beta-weights in the resulting ROIs with the psychometric data of the respective other questionnaires. This represents a basically different approach compared to the previous report (Herwig et al. 2007): In this previous study, ROIs were in a first step generated using a specific contrast in which the negative and ambiguous condition were contrasted against the neutral and the positive condition in a conjunction. Thereafter correlations were computed in the ROIs applying a much lower statistical threshold than in the present study. In the current study, we aimed at uncovering areas generally involved in emotional expectation depending on personality factors with particularly high correlations: Statistical level was set at $p<0.001$ corresponding to a correlation coefficient $r>0.78$ with an additional cluster threshold of 135 mm^3. Anatomical regions were determined according to the Talairach and Tournoux system (Talairach and Tournoux 1988).

Results

Intercorrelation of psychometric measures

SDS and STAI were correlated with each other ($r=0.63$, $p<0.016$), neuroticism and STAI were correlated at a trend level ($r=0.53$, $p<0.051$). The correlation between SDS and neuroticism was weak ($r=0.38$, $p<0.18$). There were no correlations neuroticism/extraversion ($r=0.09$, $p<0.77$), and extraversion and the affective measures (extraversion/SDS: $r=0.01$, $p<0.97$, extraversion/STAI: $r=-0.23$, $p<0.44$).

Correlation of brain activity with psychometric data

Brain activity during the anticipation of negative and ambiguous stimuli was positively correlated with extraversion in prefrontal areas (bilateral superior frontal gyrus, right inferior frontal gyrus, Table 1a, Fig. 1a). Additionally, extraversion was correlated with brain activity during the anticipation of negative emotional stimuli in the left medial thalamus (Fig. 1b) and the medial prefrontal cortex (MPFC, medial frontal gyrus). During the anticipation of ambiguously announced stimuli, extraversion was further correlated with activity in visual-perceptual regions of the parieto-occipital lobes. During the anticipation of positive stimuli, only activity in the left middle frontal gyrus was positively correlated with extraversion. No regions correlating with extraversion revealed additional correlations with neuroticism and the measures of depression and anxiety (Table 1a, supplementary Table S1a).

Neuroticism (Table 1b) was positively correlated with activity in anterior parts of the caudate nucleus during the anticipation of negative and positive stimuli, and was further negatively correlated with the activity in the right supramarginal gyrus (SMG) during the anticipation of negative stimuli, (Fig. 1c), but not with brain activity during the anticipation of ambiguous stimuli. All these correlating regions showed additional correlations with both STAI and SDS (Table 1b) (Figs. 2 and 3).

The correlation of brain activity with affectivity resulted in negative correlations with the STAI in left parietal areas during the anticipation of negative and ambiguous stimuli (inferior parietal lobe, SMG, Table 2a). SDS was positively correlated with bilateral regions in the occipital lobe (inferior, middle occipital gyrus) during all emotion anticipation conditions as well as further visual perceptual regions (left pulvinar during the anticipation of negative stimuli, left cuneus and right intraparietal sulcus during the anticipation of ambiguously announced stimuli) and with activity in right caudate tail/dorsal hippocampus (anticipation of positive stimuli) and posterior cingulate cortex during the anticipation of ambiguous stimuli (Table 2b). Thalamic, temporo-occipital, dorsal caudate, and precuneus regions correlated further with the STAI. Overviews of brain regions correlating with the measures of personality and affectivity and the complete results of the cross-correlation analysis are shown in the supplementary material (supplementary Table S1, supplementary figures S1-3).

Table 1 Correlation analyses of the personality dimensions neuroticism (**a**) and extraversion (**b**) with brain activation during the emotion versus neutral conditions (p<0.001, two-tailed, Pearson's R, at least 135 mm³ contiguously). The last columns show the results of the cross-correlations of the mean beta weights in the clusters with the affective measures (**p<0.05,** *p<0.1*)

	Anatomic region (BA)	x	y	z	mm³	R/p (max)	SDS R/p (mean)	STAI R/p (mean)
a) Extraversion								
exp ng>exp nt	SFG R (6/8)	13	21	48	148	**0.876/0.00004**	−0.180/0.536	−0.314/0.275
	SFG L (9)	−8	48	35	213	**0.878/0.00004**	−0.069/0.814	−0.206/0.479
	MFG R (8)	−1	28	45	239	**0.862/0.00007**	0.066/0.822	−0.058/0.844
	IFG R (44/46)	53	31	10	325	**0.889/0.00002**	−0.151/0.605	−0.213/0.464
	Medial thalamus L	−8	−14	0	448	**0.888/0.00002**	0.149/0.612	−0.013/0.966
exp ps>exp nt	MidFG L (6)	−37	−3	47	160	**0.881/0.00003**	0.027/0.926	−0.403/0.153
exp uk>exp nt	SFG R (4)	15	−4	58	265	**0.872/0.00005**	0.179/0.541	−0.165/0.573
	SFG R (6)	15	30	51	179	**0.858/0.00009**	0.110/0.707	−0.293/0.309
	SFG L (6/8)	−3	31	53	461	**0.887/0.00002**	0.210/0.471	−0.057/0.847
	IFG R (44)	45	18	19	471	**0.878/0.00004**	0.013/0.964	−0.163/0.578
	IFG/ant. insula R (47)	41	23	−5	140	**0.884/0.00003**	−0.047/0.874	−0.230/0.429
	Precuneus L (24/31)	−5	−43	47	358	**0.895/0.00002**	0.062/0.833	−0.274/0.343
	Inf. parietal lobe R (39)	46	−57	29	178	**0.855/0.00009**	0.212/0.467	−0.035/0.904
	Fusiform gyrus R (19)	41	−69	−13	188	**0.855/0.00009**	0.246/0.396	−0.154/0.598
	SMG R (40)	54	−24	27	254	**0.846/0.00013**	0.042/0.887	−0.392/0.166
	Lingual gyrus L (19)	−18	−83	−9	615	**0.871/0.00005**	0.279/0.333	−0.100/0.733
b) Neuroticism								
exp ng>exp nt	SMG R (39)	60	−48	23	138	**−0.842/0.00015**	**−0.580/0.029**	*−0.483/0.080*
	Caudate tail L	−22	−26	23	218	**0.933/<0.00001**	0.455/0.102	0.576/0.031
exp ps>exp nt	Caudate body L	−9	10	19	218	**0.866/0.00006**	*0.517/0.058*	*0.515/0.060*
exp uk>exp nt	No regions							

exp expectation, *ng* negative, *nt* neutral, *uk* unknown, *ps* positive, *bilat* bilateral, *sup* superior, *SFG* superior frontal gyrus, *MFG* medial frontal gyrus, *IFG* inferior frontal gyrus, *MidFG* middle frontal gyrus, *SMG* supramarginal gyrus, *inf* inferior, *R* right, *L* left

Discussion

We investigated emotion processing brain regions in which activity was highly correlated with the personality traits extraversion and neuroticism. The activity was related to anxiety and depressiveness during a task comprising the anticipation of emotional stimuli, which is useful for the study of pessimistic and anxious emotion processing. Extraversion was correlated with brain activity in an extended network of several prefrontal, and also parietal and occipital regions, thus regions functionally involved in cognitive processing (prefrontal cortex), visual-perceptive (occipito-temporal cortex, Logothetis and Sheinberg 1996) and higher-order multimodal associative and attentional functions (precuneus, parietal regions, Egner et al. 2008; Phillips et al. 1998). Extraversion was also correlated with medial thalamic activity, thus functionally associated with for instance viscerosensitive gating processes (Craig 2002).

Compared to extraversion, neuroticism correlated with activity in the caudate and, negatively, in the SMG in the intersection of parietal and temporal lobe, which has as well a role in visual processing (Phillips et al. 1998). The measures of affectivity (STAI, SDS) revealed no correlations with prefrontal regions, but with activity in primarily dorsal, higher-order multi-modal associative regions, involved in perceptual and attentional processing (Egner et al. 2008; Phillips et al. 1998).

The current analysis yielded a functional pattern, in which extraversion is prominently associated with prefrontal and insular activity, whereas regions involved in various stages of visual processing are modulated in association with personality *and* affective measures. The correlation of brain activity with extraversion in prefrontal and lateral parietal regions has been shown in previous studies using emotional and cognitive paradigms (Canli et al. 2001; Eisenberger et al. 2005; Kumari et al. 2004). Our results lack correlations with extraversion in amygdalar and ventral striatal regions, whereas we used a different methodological approach which must not have led to modulations by extraversion, such that our results are of course not generalizable. These correlation have been shown before, but are far from constant in research on extraversion (DeYoung and Gray 2009; Hutcherson et al. 2008). Beyond this, our lack of finding could be caused by the very strict

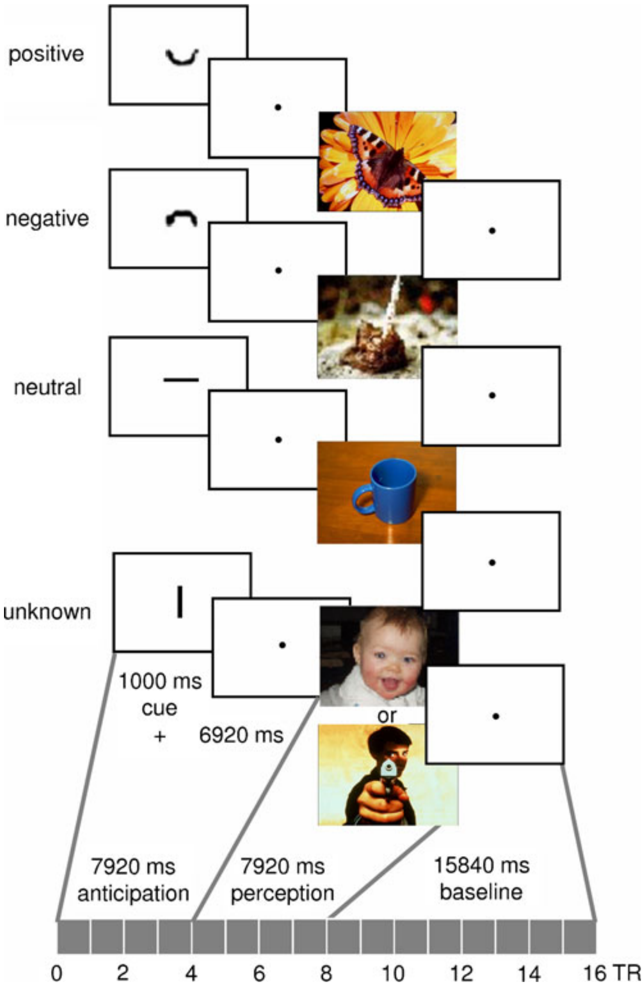

Fig. 1 Task in fMRI. Schematic summary of the paradigm for anticipation and presentation of emotional stimuli (cues here relatively enlarged for reasons of presentation)

statistical threshold for the correlations, by relatively lower arousal in the positive stimuli as inherent in the IAPS, and in the low level of arousal and social content in the total setting, which could have been insufficient to address these aspects of extraversion. However, arousal and emotional intensity in our study were intensive enough to activate extraversion-related regions, particularly during the anticipation of negative and unknown stimuli.

Neuroticism was correlated with caudate activity, which has been shown before (Kumari et al. 2007) during an anticipatory task. Additionally, that study (Kumari et al. 2007) resulted in correlations with insular, cingulate and amygdalar activity, which we did not observe in our study. Correlations between amygdalar activity and neuroticism have not consistently been found in previous studies (Britton et al. 2007; Canli et al. 2002; Canli et al. 2001; Chan et al. 2009; Deckersbach et al. 2006; Kumari et al. 2007; Simon et al. 2010), making our non-finding not so surprising. However, the lack of any correlations during the anticipation of ambiguously cued stimuli with neuroticism is to some extent unexpected, considering the known connections between neuroticism and anxiety/anxiety sensitivity (Clark et al. 1994). Our result again could be due to the strict statistical level with the intention to focus particularly on those regions with high associations between brain activity and personality factors. Another reason could be the relatively low absolute scores and the low range of neuroticism scores in our sample (mean (SD): 4.9 (2.9), range: 1–10, only 4 subjects scoring>7), as compared to the standard scores (German means: male 8.3, female 7.0, Eggert 1974).

However, the correlation between caudate activity and neuroticism is interesting, as the caudate is involved in implicit learning and processing (Seger and Cincotta 2005) and in intuition (Lieberman 2000). This relationship between caudate and neuroticism could point to a stronger implicit emotional processing in higher neuroticism and thus more pronounced automatic emotional interspersing in the processing of general information.

Regarding the subcortical level again, extraversion was on the other hand associated with medial thalamic activity. This is interesting because it implicates an early influence of this personality factor in the course of information and emotion processing. It also shows that personality related activation is located in deep brain structures, which (i) are phylogenetically old, (ii) form early in embryonal development, and (iii) might also be rather difficult to modify for instance by psychotherapy.

The correlation of state depression with brain activity in brain regions involved in the processing of and attention to visual stimuli (temporo-occipito junction, pulvinar, medial occipito-temporal gyrus, Egner et al. 2008) during all emotion anticipation conditions could indicate an increase of general preparatory activation to emotional stimuli with increasing depression. This anticipatory preparation might be a correlate of the general distress factor of the tripartite model (Clark and Watson 1991).

The lack of correlation between activity in the amygdalar region and trait anxiety is unexpected, given the known involvement of the amygdala in anxiety disorders (Uliaszek et al. 2010) and a recent finding of a correlation between trait anxiety and amygdalar activity in a fear conditioning task (Sehlmeyer et al. in press). One reason in our study could be the rather low level of threat in our setting and in the task itself, which might not have evoked a sufficient level of anxiety-related amygdalar activity.

Comparing the different patterns of correlation, our results display extraversion as modulating prefrontal regions (D/VLPFC, MPFC), where neither neuroticism

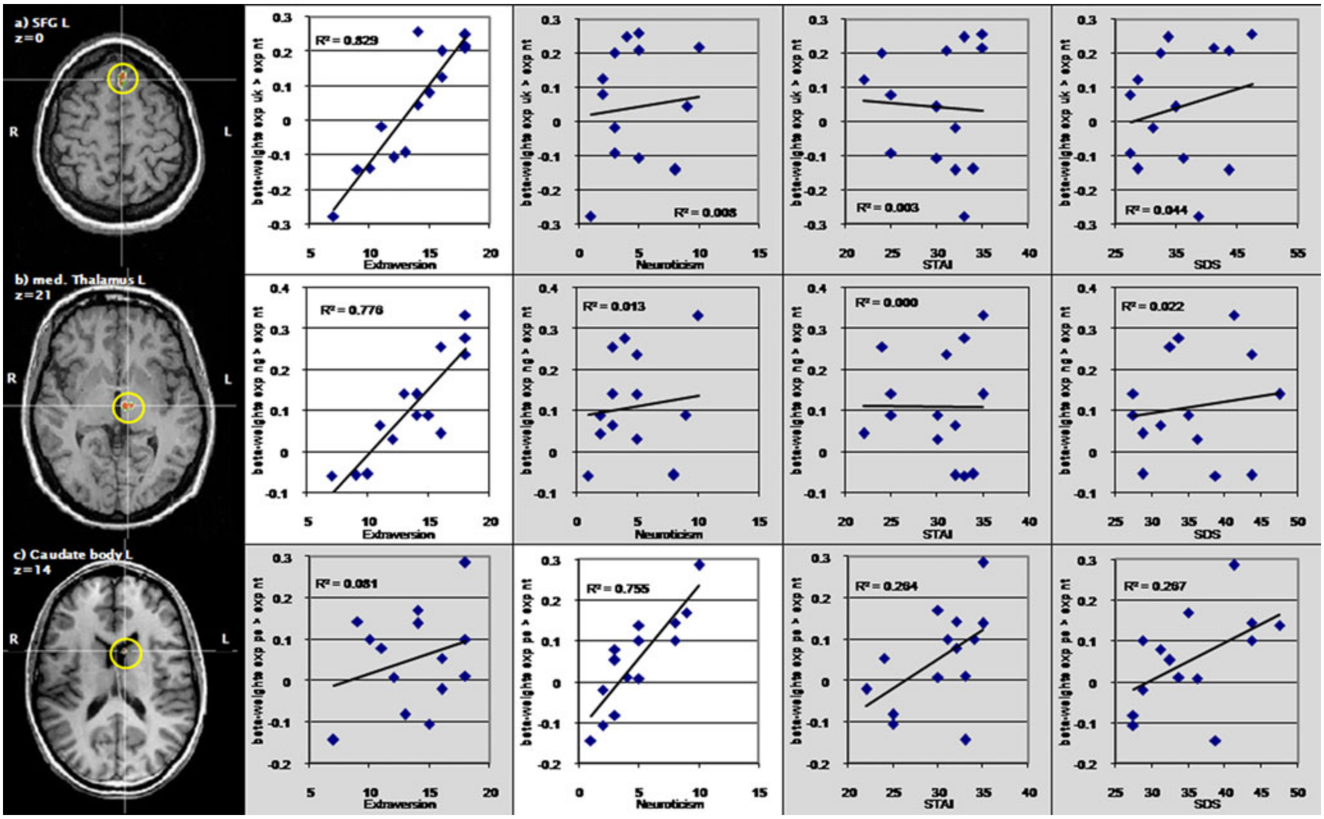

Fig. 2 Correlations between **a** extraversion and brain activity during the anticipation of unknown cued stimuli in the left superior frontal gyrus, **b** extraversion and brain activity during the anticipation of negative stimuli in the left medial thalamus, **c** neuroticism and brain activity during the anticipation of positive stimuli in the left caudate, **d** neuroticism and brain activity during the anticipation of negative stimuli in the right supramarginal gyrus. Shown are additionally the plots of the correlation with the respective other measures. Significant correlations are marked with asterisks: (*) $0.05<p<0.1$, * $p<0.05$, *** $p<0.0005$. *SFG* superior frontal gyrus, med medial, R right, L left, E_ng expectation negative, E_uk expectation unknown, E_ps expectation positive, E_nt expectation neutral

nor the affective measures revealed an influence on activity in this analysis. However, in regions defined by a specific functional contrast (‘pessimism-contrast’) a previous analysis of the data (Herwig et al. 2007) revealed correlations between depression and neuroticism and brain activity in VLPFC and insula, though at a much lower statistical level. Correlations between depression and neuroticism with medial thalamus and temporo-occipital cortex are found in both analyses (ROI-restricted in Herwig et al. 2007 vs. whole brain here).

Brain regions involved in visual processing and attention (occipital, parietal, adjacent temporal areas) showed modulated activity associated with all factors. Depressiveness was consistently associated with increasing activity in all conditions, whereas extraversion was associated with activity changes particularly during the ambiguous anticipation. Interestingly, the right SMG was modulated in opposite directions by extraversion (increase) and neuroticism (decrease), similar to the left SMG with anxiety (decrease). The interrelations, calculated to examine the specificity of the correlations, revealed no interrelations between extraversion and the other measures, whereas in certain regions neuroticism and the affective measures were intertwined. This differential pattern suggests differences in the underlying neurobiology of extraversion opposite to neuroticism and affective measures. The correlation between brain activity associated with neuroticism and the affective factors is in line with previous models and findings revealing an interrelation between these factors (Clark et al. 1994; Enns and Cox 1997). Basically, neuroticism related information biases here also seems to be implemented in earlier cortical stages of associative perception processing.

Neuroticism is supposed to be a predisposing vulnerability factor, and not simply a dimensional precursor of depression and anxiety. The interrelation of extraversion and affective disorders is less clear with mixed and contradictory results (Enns and Cox 1997; Jylha and Isometsa 2006), pointing rather to a relation between low extraversion and anxiety disorders (Trull and Sher 1994). In the current study, the modulation of perceptual and prefrontal regions by extraversion could fit with a “higher”,

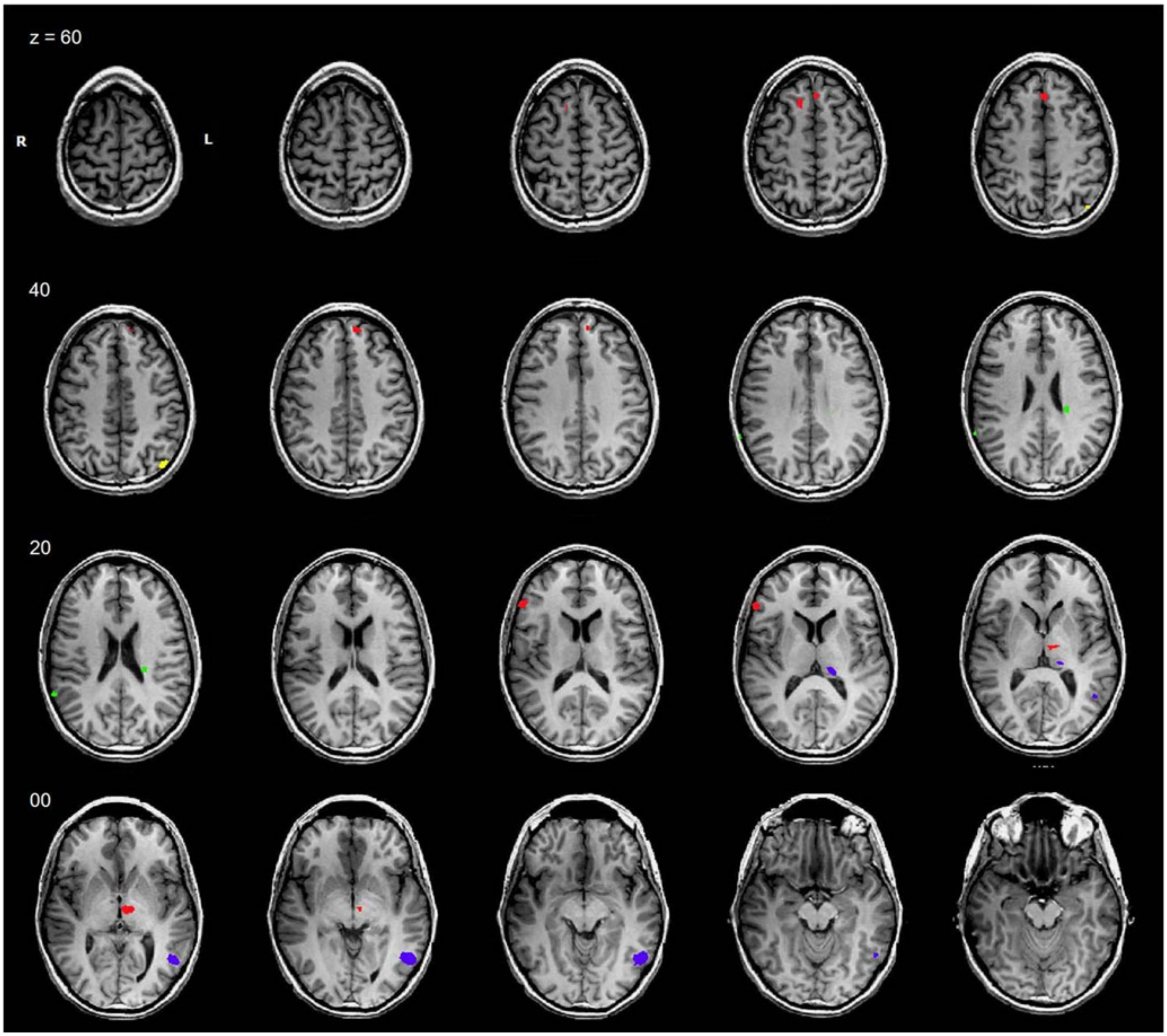

Fig. 3 Overview of the regions correlating with personality measures during the anticipation of negative stimuli. Color-coding: red = extraversion, green = neuroticism, blue = depression (SDS), yellow = anxiety (STAI). Shown are sequential transversal sections with a distance of 4 mm ranging from z=60 to z=-16. Significance level of the correlation p<0.001, r>0.78. Abbreviations: R right, L left

more complex structure of extraversion. Furthermore, the supposed correlation of extraversion and the dopamine system (DeYoung and Gray 2009) points to a divergent neurobiology as compared to the affective disorders and neuroticism, which have been linked rather to the serotonin system (Flint 2004). Additionally, the correlation with prefrontal regions in our emotional task could implicate higher cognitive emotion regulation abilities (Ochsner et al. 2004). This could explain the at least partially protective effect of high extraversion concerning the development of anxiety disorders (Trull and Sher 1994) and the remission of depression (Andrews et al. 1990), though there are till now no studies examining emotion regulation in correlation with personality dimensions.

Limitations

Considering limitations, we already mentioned the low level of neuroticism in our study sample. This could have lead to a reduced sensitivity to detect correlations with brain activity and also the low correlation between neuroticism and state depression. Nevertheless, the measures of neuroticism in our sample are within the normal range and the correlations between neuroticism and brain

Table 2 Correlation analyses of the measures of trait anxiety and state depression with brain activation during the emotion versus neutral conditions (Pearson's R, two-tailed, p<0.001, at least 135 mm^3 contiguously). The last columns show the cross-correlations of the mean beta-weights of the cluster with the personality measures (**p<0.05,** *p<0.1*)

	Anatomic region (BA)	x	y	Z	mm^3	R/p (max)	Extra R/p (mean)	Neuro R/p (mean)
a) STAI								
exp ng>exp nt	Inferior parietal lobe L (19)	−39	−72	41	211	**−0.865/0.00065**	0.273/0.3451	*−0.475/0.086*
exp ps>exp nt	No regions							
exp uk>exp nt	SMG L (40/42)	−57	−19	17	196	**−0.900/0.00001**	0.135/0.6447	−0.449/0.107
b) SDS								
exp ng>exp nt	TOC L (19/37)	−50	−58	−5	1435	**0.893/0.00002**	0.082/0.7793	0.287/0.320
	Thalamus/pulvinar L	−15	−28	8	286	**0.897/0.00001**	0.079/0.7868	*0.500/0.069*
exp ps>exp nt	Med. occipito-temp. gyrus R (17)	1	−55	6	187	**0.867/0.00006**	0.074/0.8005	0.227/0.436
	Caudate tail/dorsal hippocampus R	30	−32	7	188	**0.876/0.00004**	−0.056/0.8481	*0.461/0.097*
exp uk>exp nt	TOC R (19/39)	31	−58	24	250	**0.880/0.00003**	0.032/0.912	0.108/0.713
	TOC L (19/37)	−46	−57	−3	390	**0.890/0.00002**	0.081/0.781	0.295/0.306
	Posterior cingulate gyrus R (31)	2	−38	29	292	**0.865/0.00006**	0.323/0.260	0.409/0.147
	Cuneus L (17)	−25	−59	14	1103	**0.942/<0.00001**	0.182/0.533	0.372/0.191
	Intraparietal sulcus R (7)	32	−32	43	159	**0.870/0.00005**	0.110/0.708	0.277/0.338

exp expectation, *ng* negative, *nt* neutral, *uk* unknown, *ps* positive, *TOC* temporo-occipital cortex, *Med* medial, *temp* temporal, *SMG* supramarginal gyrus, *R* right, *L* left

activity are highly significant. Thus, we regard our sample as of sufficient informative value.

Furthermore, the number of 14 subjects is rather low for correlational analyses, whenever we selected a very strict significance level for reporting results. We are also aware of the issue of inflating correlations by the use of relatively low numbers of subjects and of the danger of circular conclusions in the cross-correlation analysis, but when regarding the results as exploratory with respect to brain regions, we consider them valuable to be reported. Further, we here regarded the relation of basic emotion expectation contrasts with personality dimensions and affective measures on a strict statistical level in the whole brain, whereas in a previous report (Herwig et al. 2007) solely ROIs from a single specific contrast ('pessimism-contrast') were regarded on a low statistical level. Thus, the in part differing results are to be regarded as adding to each other. There could additionally be influences of gender, where regularly higher scores in neuroticism in women are known (Lynn and Martin 1997). However, the sample size was too small to analyze subgroups. The theory behind personality factors is complex and of course difficult to assess with simple experimental tasks suitable for neuroimaging. In our task, we decided to not use behavioral control measures. The preparation and execution of an answer in any form would have been a distractor interfering with the addressed brain activities, increasing cognitive demands and reducing emotional reactions. Participants confirmed their attention to the task in the interview after scanning and this was verified by controlling individual brain activation in visual areas. Finally, the used contrasts focusing on the anticipation period could miss for instance perception related regions involved in emotional processing. This was, however, intended.

Conclusion

In conclusion, our findings confirm the relationship between neuroticism and affective markers on the neurobiological level, underlining the role of neuroticism in the research on biomarkers and endophenotypes for instance for depression. Extraversion, however, correlated with more widespread brain regions including frontal, occipital and subcortical areas, but lacked cross-correlations with the other measures, and thus seems to represent a distinct system as shown before in the correlation with psychopathology and here concerning neurobiology. A different involvement of subcortical structures, caudate for neuroticism, thalamus for extraversion, points to influences of these dimensions in the early course of information processing. Furthermore, the relation between personality and affectivity measures, and brain activity in visual perceptual and attention related regions apart limbic and prefrontal regions, also points to a general involvement of these factors in widespread and basic domains of emotion processing networks.

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References

Ackenheil, M., Stotz, G., Dietz-Bauer, R., & Vossen, A. (1999) Mini-International Neuropsychiatric Interview - German Version 5.0.0. München, Psychiatrische Universitätsklinik München.

Amin, Z., Constable, R. T., & Canli, T. (2004). Attentional bias for valenced stimuli as a function of personality in the dot-probe task. *Journal of Research in Personality, 38*(1), 15–23.

Andrews, G., Neilson, M., Hunt, C., Stewart, G., & Kiloh, L. G. (1990). Diagnosis, personality and the long-term outcome of depression. *The British Journal of Psychiatry, 157*(1), 13–18.

Banich, M. T., Mackiewicz, K. L., Depue, B. E., Whitmer, A. J., Miller, G. A., & Heller, W. (2009). Cognitive control mechanisms, emotion and memory: A neural perspective with implications for psychopathology. *Neuroscience and Biobehavioral Reviews, 33*(5), 613–630.

Barlow, D. H. (2000). Unraveling the mysteries of anxiety and its disorders from the perspective of emotion theory. *The American Psychologist, 55*(11), 1247–1263.

Beck, A. T. (1967). *Depression: Clinical, experimental, and theoretical aspects*. New York: Harper & Row.

Britton, J. C., Ho, S. H., Taylor, S. F., & Liberzon, I. (2007). Neuroticism associated with neural activation patterns to positive stimuli. *Psychiatry Research, 156*(3), 263–267.

Canli, T., Zhao, Z., Desmond, J. E., Kang, E., Gross, J., & Gabrieli, J. D. (2001). An fMRI study of personality influences on brain reactivity to emotional stimuli. *Behavioral Neuroscience, 115*(1), 33–42.

Canli, T., Sivers, H., Whitfield, S. L., Gotlib, I. H., & Gabrieli, J. D. (2002). Amygdala response to happy faces as a function of extraversion. *Science, 296*(5576), 2191.

Canli, T., Amin, Z., Haas, B., Omura, K., & Constable, R. T. (2004). A double dissociation between mood states and personality traits in the anterior cingulate. *Behavioral Neuroscience, 118*(5), 897–904.

Carver, C. S., & Connor-Smith, J. (2010). Personality and coping. *Annual Review of Psychology, 61*, 679–704.

Chan, S. W., Norbury, R., Goodwin, G. M., & Harmer, C. J. (2009). Risk for depression and neural responses to fearful facial expressions of emotion. *The British Journal of Psychiatry, 194* (2), 139–145.

Clark, L. A., & Watson, D. (1991). Tripartite model of anxiety and depression: psychometric evidence and taxonomic implications. *Journal of Abnormal Psychology, 100*(3), 316–336.

Clark, L. A., Watson, D., & Mineka, S. (1994). Temperament, personality, and the mood and anxiety disorders. *Journal of Abnormal Psychology, 103*(1), 103–116.

Costa, P. T., Jr., & McCrae, R. R. (1980). Influence of extraversion and neuroticism on subjective well-being: happy and unhappy people. *Journal of Personality and Social Psychology, 38*(4), 668–678.

Craig, A. D. (2002). How do you feel? Interoception: the sense of the physiological condition of the body. *Nature Reviews. Neuroscience, 3*(8), 655–666.

Cunningham, W. A., Arbuckle, N. L., Jahn, A., Mowrer, S. M., & Abduljalil, A. M. (2010). Aspects of neuroticism and the amygdala: chronic tuning from motivational styles. *Neuropsychologia, 48*(12), 3399–3404.

Deckersbach, T., et al. (2006). Regional cerebral brain metabolism correlates of neuroticism and extraversion. *Depression and Anxiety, 23*(3), 133–138.

DeYoung, C. G., & Gray, J. R. (2009). Personality neuroscience: explaining individual differences in affect, behaviour and cognition. In P. J. Corr & G. Matthews (Eds.), *The Cambridge handbook of personality psychology* (pp. 323–346). Cambridge: Cambridge University Press.

Eggert, D. (1974). *Eysenck-Persönlichkeits-Inventar EPI.* Göttingen: Verlag für Psychologie, Dr. C. J. Hogrefe.

Egner, T., Monti, J. M., Trittschuh, E. H., Wieneke, C. A., Hirsch, J., & Mesulam, M. M. (2008). Neural integration of top-down spatial and feature-based information in visual search. *The Journal of Neuroscience, 28*(24), 6141–6151.

Eisenberger, N. I., Lieberman, M. D., & Satpute, A. B. (2005). Personality from a controlled processing perspective: an fMRI study of neuroticism, extraversion, and self-consciousness. *Cognitive, Affective & Behavioral Neuroscience, 5*(2), 169–181.

Enns, M. W., & Cox, B. J. (1997). Personality dimensions and depression: review and commentary. *Canadian Journal of Psychiatry, 42*(3), 274–284.

Flint, J. (2004). The genetic basis of neuroticism. *Neuroscience and Biobehavioral Reviews, 28*(3), 307–316.

Foster, J. A., & MacQueen, G. (2008). Neurobiological factors linking personality traits and major depression. *Canadian Journal of Psychiatry, 53*(1), 6–13.

Haas, B. W., Omura, K., Constable, R. T., & Canli, T. (2007). Emotional conflict and neuroticism: personality-dependent activation in the amygdala and subgenual anterior cingulate. *Behavioral Neuroscience, 121*(2), 249–256.

Herwig, U., Kaffenberger, T., Baumgartner, T., & Jancke, L. (2007). Neural correlates of a 'pessimistic' attitude when anticipating events of unknown emotional valence. *Neuroimage, 34*(2), 848–858.

Herwig, U., Bruhl, A. B., Kaffenberger, T., Baumgartner, T., Boeker, H., & Jancke, L. (2010). Neural correlates of 'pessimistic' attitude in depression. *Psychological Medicine, 40*(5), 789–800.

Hutcherson, C. A., Goldin, P. R., Ramel, W., McRae, K., & Gross, J. J. (2008). Attention and emotion influence the relationship between extraversion and neural response. *Social Cognitive and Affective Neuroscience, 3*(1), 71–79.

Jylha, P., & Isometsa, E. (2006). The relationship of neuroticism and extraversion to symptoms of anxiety and depression in the general population. *Depression and Anxiety, 23*(5), 281–289.

Keightley, M. L., Seminowicz, D. A., Bagby, R. M., Costa, P. T., Fossati, P., & Mayberg, H. S. (2003). Personality influences limbic-cortical interactions during sad mood induction. *Neuroimage, 20*(4), 2031–2039.

Klein, D. N., Durbin, E., & Shankman, S. A. (2009). Personality and Mood Disorders. In I. H. Gotlib & C. L. Hammen (Eds.), *Handbook of depression* (pp. 93–112). New York: The Guilford Press.

Kotov, R., Gamez, W., Schmidt, F., & Watson, D. (2010). Linking "big" personality traits to anxiety, depressive, and substance use disorders: a meta-analysis. *Psychological Bulletin, 136*(5), 768–821.

Kumari, V., Ffytche, D. H., Williams, S. C., & Gray, J. A. (2004). Personality predicts brain responses to cognitive demands. *The Journal of Neuroscience, 24*(47), 10636–10641.

Kumari, V., Ffytche, D. H., Das, M., Wilson, G. D., Goswami, S., & Sharma, T. (2007). Neuroticism and brain responses to anticipatory fear. *Behavioral Neuroscience, 121*(4), 643–652.

Lang, P. J., Bradley, M.M., Cuthbert, B.N. (2005). *International Affective Picture System (IAPS): Affective ratings of pictures and instruction manual. Technical Report A-6.* Gainesville, FL: Center for Research in Psychophysiology, University of Florida.

Laux, L., Glanzmann, P., Schaffner, P., & Spielberger, C. D. (1981). *Das State-Trait-Angstinventar*. Beltz: Weinheim.

Lavender, A., & Watkins, E. (2004). Rumination and future thinking in depression. *The British Journal of Clinical Psychology, 43*(Pt 2), 129–142.

Lieberman, M. D. (2000). Intuition: a social cognitive neuroscience approach. *Psychological Bulletin, 126*(1), 109–137.

Logothetis, N. K., & Sheinberg, D. L. (1996). Visual object recognition. *Annual Review of Neuroscience, 19*, 577–621.

Lucas, R. E., & Diener, E. (2001). Understanding extraverts' enjoyment of social situations: The importance of pleasantness. *Journal of Personality and Social Psychology, 81*(2), 343–356.

Lynn, R., & Martin, T. (1997). Gender Differences in Extraversion, Neuroticism, and Psychoticism in 37 Nations. *The Journal of Social Psychology, 137*(3), 369–373.

Malouff, J. M., Thorsteinsson, E. B., & Schutte, N. S. (2005). The relationship between the five-factor model of personality and symptoms of clinical disorders: A meta-analysis. *Journal of Psychopathology and Behavioral Assessment, 27*(2), 101–114.

Marshall, G. N., Wortman, C. B., Kusulas, J. W., Hervig, L. K., & Vickers, R. R. Jr. (1992) Distinguishing optimism from pessimism: relations to fundamental dimensions of mood and personality. *Journal of Personality and Social Psychology, 62*(6), 1067–1074.

Martin, M. (1985). Neuroticism as predisposition toward depression: A cognitive mechanism. *Personality and Individual Differences, 6*(3), 353–365.

Mathews, A., & MacLeod, C. (1994). Cognitive approaches to emotion and emotional disorders. *Annual Review of Psychology, 45*, 25–50.

Ochsner, K. N., et al. (2004). For better or for worse: neural systems supporting the cognitive down- and up-regulation of negative emotion. *Neuroimage, 23*(2), 483–499.

Oquendo, M. A., et al. (2004). Prospective study of clinical predictors of suicidal acts after a major depressive episode in patients with major depressive disorder or bipolar disorder. *The American Journal of Psychiatry, 161*(8), 1433–1441.

Phillips, M. L., et al. (1998). Neural responses to facial and vocal expressions of fear and disgust. *Proceedings of the Biological Sciences, 265*(1408), 1809–1817.

Pyszczynski, T., Holt, K., & Greenberg, J. (1987). Depression, self-focused attention, and expectancies for positive and negative future life events for self and others. *Journal of Personality and Social Psychology, 52*(5), 994–1001.

Scheier, M. F., & Bridges, M. W. (1995). Person variables and health: personality predispositions and acute psychological states as shared determinants for disease. *Psychosomatic Medicine, 57*(3), 255–268.

Seger, C. A., & Cincotta, C. M. (2005). The roles of the caudate nucleus in human classification learning. *The Journal of Neuroscience, 25*(11), 2941–2951.

Sehlmeyer, C., et al. (in press). Neural correlates of trait anxiety in fear extinction. *Psychological Medicine*, 1–10. doi:10.1017/S003329171000125X.

Simmons, A., Stein, M. B., Matthews, S. C., Feinstein, J. S., & Paulus, M. P. (2006). Affective ambiguity for a group recruits ventromedial prefrontal cortex. *Neuroimage, 29*(2), 655–661.

Simon, J., et al. (2010). Neural reward processing is modulated by approach- and avoidance-related personality traits. *Neuroimage, 49*(2), 1868–1874.

Smith, T. W., Pope, M. K., Rhodewalt, F., & Poulton, J. L. (1989). Optimism, neuroticism, coping, and symptom reports: an alternative interpretation of the Life Orientation Test. *Journal of Personality and Social Psychology, 56*(4), 640–648.

Talairach, J., & Tournoux, P. (1988). *Co-planar stereotaxic atlas of the human brain: Three-dimensional proportional system*. New York: Thieme Medical.

Trull, T. J., & Sher, K. J. (1994). Relationship between the five-factor model of personality and Axis I disorders in a nonclinical sample. *Journal of Abnormal Psychology, 103*, 350–360.

Uliaszek, A. A., et al. (2010). The role of neuroticism and extraversion in the stress-anxiety and stress-depression relationships. *Anxiety, Stress, and Coping, 23*(4), 363–381.

Vaidya, J. G., Paradiso, S., Andreasen, N. C., Johnson, D. L., Boles Ponto, L. L., & Hichwa, R. D. (2007). Correlation between extraversion and regional cerebral blood flow in response to olfactory stimuli. *The American Journal of Psychiatry, 164*(2), 339–341.

Winter, K. A., & Kuiper, N. A. (1997). Individual differences in the experience of emotions. *Clinical Psychology Review, 17*(7), 791–821.

Zung, W. W. (1965). A self-rating depression scale. *Archives of General Psychiatry, 12*, 63–70.