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Decrease of prefrontal–posterior EEG coherence: Loose control during social–emotional stimulation

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ABSTRACT

In two experiments we aimed to investigate if individual differences in state-dependent decreases or increases of EEG coherence between prefrontal and posterior cortical regions may be indicative of a mechanism modulating the impact social–emotional information has on an individual. Two independent samples were exposed to an emotional stimulation paradigm in which the participants were invited to get involved and sympathize with the persons they were watching (study 1) or listening to (study 2), and who were expressing sadness or anxiety. The two studies yielded consistent results. Higher scores in trait absorption and in the propensity to ruminate were associated with decreased EEG beta coherence during the stimulation, whereas coherence increased in individuals low in absorption or rumination. Coherence changes did not predict to which degree the participants felt infected by the displayed emotions, but in individuals showing decreased prefrontal–posterior coupling during the stimulation, feelings of sadness and anxiety had a greater tendency to persist. The findings suggest that more loose prefrontal–posterior coupling may be related to loosening of control of the prefrontal cortex over incoming social–emotional information and, consequently, to deeper emotional involvement and absorption, whereas increased prefrontal–posterior coupling may be related to strong control, dampening of emotional experience, and not letting oneself become emotionally affected.

1. Introduction

The vital involvement of prefrontal cortical regions in emotion regulation and relevant inhibitory processes such as the suppression of habitual or prepotent responses or the adaptation of working memory content is well established (e.g., Eippert et al., 2007; Jahanshani, Dirnberger, Fuller, & Frith, 2000; Jonides & Nee, 2006; Levesque et al., 2003; Ochsner, Bunge, Gross, & Gabrieli, 2002; Phan et al., 2005). Neuroscientific models on affect regulation and affective disturbances implicate pathways originating from the prefrontal cortex that modulate the activity of other brain structures, above all the amygdala (Davidson, 2002; Johnstone, van Reekum, Urry, Kalin, & Davidson, 2007; Phillips, Ladouceur, & Drevets, 2008). Sudden interruption of neural synchrony between the prefrontal cortex and the amygdala, indicating functional decoupling, has been related to emotional outbursts, for instance, in the context of epileptic seizures (Bartolomei et al., 2005). But not only cortical–subcortical, but also cortico-cortical circuits may play an important role in affective processing. Remote brain regions may influence perceptual processing and awareness mediated by posterior sensory and association cortices (Vuilleumier & Driver, 2007). More specifically, there is evidence that the prefrontal cortex receives highly processed sensory information and in turn exerts feedback control on posterior association cortices, in order to further modulate representations of affectively relevant information (Miskovic & Schmidt, 2010; Rudrauf et al., 2008).

Similar mechanisms also seem at play when individuals are confronted with social–emotional information, for instance, displays of the emotional state of others. Current models of the processes involved in sharing others' emotions assume the contribution of both a bottom-up and a top-down component: The bottom-up process which is automatically activated by perceptual input is supposed to be modulated in a top-down fashion through an executive control component implemented in the prefrontal cortex (see Decety & Moriguchi, 2007 for review). The automatic adoption of others' emotions has been impressingly demonstrated with neuroimaging and electromyographic methods, both in response to facial expressions (Botvinick et al., 2005; Dimberg, Thunberg, & Elmehed, 2000; Hennenlotter et al., 2005; Hess & Blairy, 2001; Wicker et al., 2003) and nonverbal vocal affect expressions (Hietanen, Surakka, & Linnankoski, 1998; Meyer, Zysser, von Cramon, & Alter, 2005; Warren et al., 2006). However, to date little is known about neurophysiological correlates of individual differences in the top-down processes modulating the impact of social–emotional input, which may make individuals either more or less dependent on external emotional cues (Decety & Moriguchi, 2007).

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The functional connectivity during affective processing may represent a significant factor in this context. It has been proposed that the coupling of prefrontal and posterior cortical regions may help to regulate negative affect during the perception of emotion-eliciting events. Apart from individual differences, functional connectivity between cortical regions is modulated in support of dynamically changing processing demands (Sepulcre et al., 2010). A recent study using magnetic resonance imaging methods, for instance, suggested that anticipatory mental imagery of a mildly fearful facial emotional expression proactively altered the subjective experience of highly fearful faces by state-dependent top-down regulatory influences of the prefrontal cortex on the temporoparietal cortex (Diekhof et al., 2011). During the exposure to highly emotionally arousing (threatening) images, EEG coherence between the prefrontal and the posterior association cortex has been shown to increase compared to neutral images, which may be related to rejection or downregulation and was also interpreted as activation of a top-down mechanism (Miskovic & Schmidt, 2010). Similar observations were reported for prefrontal–temporal EEG coherence while participants were watching stressful versus enjoyable film sequences (Schellberg, Besthorn, Klos, & Gasser, 1990). Moreover, it has been proposed that a fronto-parietal control system may integrate information from the external environment with stored internal representations and may adjudicate between potentially competing inner- versus outer-oriented processes (Vincent, Kahn, Snyder, Raichle, & Buckner, 2008). It may, therefore, also be involved in how much emotionally affected one gets when confronted with, for instance, emotional expressions of others. Greater EEG coherence was observed in individuals with poorer recognition of emotions from speech (Kislova & Rusalova, 2009). This may also suggest that increases in prefrontal–posterior coherence may be indicative of regulatory processes related to not letting oneself become emotionally affected, whereas little prefrontal–posterior coupling may support emotional contagion and sympathizing.

Thus, there is some evidence that state-dependent increases or decreases in the functional connectivity between prefrontal and posterior cortical regions may be related to the activity of a top-down modulatory mechanism that may be relevant to the affective impact of emotional information on the individual. Increases of EEG coherence are considered to indicate increased connectivity and functional communication between two neuronal populations (Fries, 2005; Srinivasan, Winter, Ding, & Nunez, 2007). State-dependent changes of prefrontal–posterior EEG coherence, therefore, may reveal relevant coupling and de-coupling of cortical networks related to regulatory processes in the context of affect (Miskovic & Schmidt, 2010). However, not much direct empirical evidence on the significance of prefrontal–posterior EEG coherence in the context of affective processing is available to date. This especially holds for state-dependent coupling or decoupling during the exposure to emotional information. Therefore, the present project aimed at investigating whether individual differences in state-dependent decreases or increases of EEG coherence between prefrontal and posterior cortical regions may be indicative of a mechanism modulating the impact social–emotional information has on the individual.

Some preliminary evidence supporting this assumption may be found in research dealing with states of increased susceptibility to and reduced evaluation of sensory information such as hypnosis or schizotypy (Fingelkurts, Fingelkurts, Kallio, & Revonsuo, 2007; Higashima et al., 2007; Lawrie et al., 2002; Terhune, Cardena, & Lindgren, 2011; Vercammen, Knegtering, den Boer, Liemburg, & Aleman, 2010; Winterer, Coppola, Egan, Goldberg, & Weinberger, 2003). The study of Miskovic and Schmidt (2010) recently provided relevant evidence in the context of affective processing. With the present experiments we aimed to broaden our understanding on the validity of state-dependent changes in prefrontal–temporoparietal EEG coherence in the context of affective processing. As opposed to Miskovic and Schmidt's study, in which threatening images were used and, thus, the most natural response was rejection and downregulation, in the present project an emotional provocation was applied in which the participants were invited to get involved and sympathize with the displayed persons. In addition, we focused on individual differences in state-dependent (de)coupling during the affective provocation. On the basis of the existing literature it was assumed that decreases of coherence during affective provocation may indicate absorption and loose control, whereas increases of coherence may indicate rigidity and strong control. Two individual differences variables that are theoretically linked to the proposed processes are trait absorption and the propensity to ruminate. Both traits should be related to a strong impact and weak control of emotional events.

The personality trait of absorption is conceptualized as an openness to "self-altering" experiences that is related to a reduction or suspension of reality testing. The definition includes a readiness for experiences of deep involvement and a heightened sense of the reality of the attentional object, so that perceptions may acquire a temporary self-like quality (Roche & McConkey, 1990; Tellegen & Atkinson, 1974; Wild, Kuiken, & Schopflocher, 1995). These features implicate a weak control of representations of perceptual input, presumably by reduced prefrontal executive control. Absorption is strongly related to immersion in environments or events portrayed by media such as movies or books; the personality trait of absorption has been shown to predict sensations of presence in mediated environments (Weibel, Wissmath, & Mast, 2010). It has also been proposed that absorption phenomena experienced by healthy individuals may represent a mild form of pathological positive schizophrenic symptoms, sharing a common biological basis (Ott, Reuter, Henning, & Vaitl, 2005). Positive schizophrenic symptoms, in turn, have been linked to decreased frontal–temporoparietal connectivity (Higashima et al., 2007; Lawrie et al., 2002; Vercammen et al., 2010; Winterer et al., 2003). Also in line with its theoretical conceptualization, absorption has been shown to be positively correlated with a measure of hallucination proneness in healthy individuals (van Kampen, 2012). As for the location of absorption in established personality models, substantial overlaps have been found with openness to experience in the Big Five and HEXACO models of personality, and moderate positive correlations with neuroticism (van Kampen, 2012). Therefore, in the context of affective processing, absorption should be linked with little control and little dampening of social–emotional input, and a strong tendency to adopt portrayed feelings as one's own.

Rumination is characterized by a typically unintentional, persistent focus on the internal emotional state and the circumstances surrounding it, and is linked with increased associative thinking along similar lines (Koster, DeLissnyder, Derakshan, & DeRaedt, 2011; Nolen-Hoeksema, 1991). Rumination as a trait has been related to deficits in elementary inhibitory processes regulating the processing of negative emotional material (Joormann, 2006; Joormann & Gotlib, 2008). More specifically, the tendency to ruminate seems to be based on the tendency to not disengage attention from self-generated thoughts once it is captured (Koster et al., 2011). These features suggest lower regulatory activity of the prefrontal cortex in individuals with a higher tendency to ruminate (Koster et al., 2011). Evidence that absorption may facilitate rumination suggests that the two personality traits may share some basic mechanisms (Carleton, Abrams, & Asmundson, 2010). However, while there are some similarities between absorption and rumination, absorption is related to the "online" modulation of representations of perceptual input, whereas rumination is more related to the modulation of self-generated representations (e.g., imaginations or memories). Like absorption, rumination as a trait should be linked with a strong and persistent personal involvement when individuals are confronted with social–emotional information.

In the first experiment we tested (a) whether trait absorption and the propensity to ruminate may predict individual differences in state-dependent coherence changes during affective stimulation. In addition, it was tested (b) whether individual differences in state-dependent coherence changes may predict the self-reported affective impact of the social–emotional stimulation. In the second experiment we tested whether individual differences in coherence reactivity during the provocation may predict effects that go beyond the stimulation, that is, affective recovery. In addition, we aimed at replicating findings of Experiment 1 with a more common measure of rumination. As opposed to the first experiment in which the participants were exposed to films showing a female poser, we used mixed-gender auditory material in Experiment 2.

We hypothesized that in individuals high in the trait absorption and in individuals high in rumination, prefrontal–posterior coherence would decrease during the stimulation, whereas it would increase in individuals low in absorption and in those low in rumination. In addition, it was expected that individuals showing a decrease of prefrontal–temporoparietal coupling during the stimulation would get more emotionally affected and recover less efficiently than individuals showing coherence increases or no changes.

2. Experiment 1

2.1. Method

2.1.1. Participants

The sample was comprised of 35 right-handed university students aged 18–30 years ($M = 21.7$, $SD = 3.3$; 16 women, 19 men). All participants were healthy volunteers with no history of substance abuse or other medical, psychiatric, or neurological disorders which could affect the measures. Handedness was assessed by a standardized handedness test (performance test; Papousek & Schulter, 1999; Steingrüber & Lienert, 1971). Participants were requested to refrain from alcohol for 12 h and from coffee and other stimulating beverages for 4 h prior to their lab appointment, and to come to the session well rested. The study was performed in accordance with the 1964 Declaration of Helsinki and was approved by the local ethics committee.

2.1.2. Social–emotional stimulation

Three films from the set of "Emotionally Contagious Films" (Papousek, Schulter, & Lang, 2009) were presented on a computer screen: sadness (ECOF-S), anxiety (ECOF-X), and neutral (ECOF-N). The films (80 s each) show head and shoulders of a woman standing in front of a black background. In the sadness film, the actress is weeping intensely. In the anxiety film, her facial expression, posture, and movements are expressing intense fear. In the neutral film, her facial expression and posture are expressing concentration on a task (task not visible). The films were presented without sound. Previous studies had confirmed the efficiency of the films to evoke the respective affective states in the observer. As very strong emotions are displayed, healthy participants have no difficulties identifying and differentiating the displayed affective states (Papousek, Schulter et al., 2009; see also Papousek, Freudenthaler, & Schulter, 2008; Papousek, Ruch et al., 2009).

2.1.3. Individual differences variables

The Tellegen Absorption Scale (Tellegen & Atkinson, 1974; German version by Ritz and Dahme (1995)) is comprised of 34 items, each scored on a five-point Likert scale ($\alpha = .95$). In addition, the German Coping Questionnaire was applied (Erdmann & Janke, 2008). It is a commonly used scale in German-speaking Europe, of which the rumination subscale was used as a measure of the propensity to ruminate. Participants rated the likelihood of coping responses on a five-point Likert scale. The rumination subscale was comprised of six items ($\alpha = .92$; e.g., "When I am disturbed, irritated, or upset by something or someone ... the situation rushes into my mind over and over again").

2.1.4. Rating scales

Affect ratings were used to evaluate to which extent the films evoked the respective affective states. The participants were instructed as follows: Please indicate what effect the film had *on you personally*: "The film infected me with sadness (anxiety)". Ratings included seven further emotions (cheerfulness, disgust, hatred, desire, envy, pride, joy). The rating "The film aroused a feeling of excitement in me" was used to check for the evoked amount of emotional arousal. Participants indicated their judgements on 10 cm horizontal visual analogue scales presented on the computer screen. The responses were scored in millimetres from 0 ("do not agree at all") to 100 ("strongly agree"). Previous studies provided evidence for the validity of these ratings. For instance, groups showing higher cardiovascular responses to a particular film also showed higher scores on the respective affect rating (Papousek et al., 2008). Findings for the ratings also matched results that were obtained with other methods (Papousek, Ruch et al., 2009).

2.1.5. Procedure

Participants were seated in an acoustically and electrically shielded examination chamber, and electrodes were attached. Participants were told that they would now see some short films to which they should direct their whole attention, and that they should let the film sink in and try to feel with the person in the film. EEG was recorded during presentation of the films. After each film the participants completed the rating scales and a 2 min break was given before the next film was presented. The order of films was counterbalanced. The technical equipment and the experimenter were located outside the chamber, and the participants were monitored through a one-way window and an intercom. Data on the individual differences variables, handedness, demographic data, and informed consent were collected in separate individual test sessions 1–7 days before the laboratory sessions[1].

2.1.6. EEG recording and quantification

EEG was recorded from 19 channels according to the international 10–20 system, using a Brainvision BrainAmp Research Amplifier (Brain Products; sampling rate 500 Hz, resolution 0.1 μV) and a stretchable electrode cap, and was re-referenced to a mathematically averaged ears reference (Essl & Rappelsberger, 1998; Hagemann, 2004). Impedance was kept below 5 kΩ for all electrodes. Horizontal and vertical EOG measures were obtained for identification of ocular artifacts. All data were inspected visually, in order to eliminate intervals in which ocular or muscle artifacts occurred. Only participants who had at least 30 s of artifact free data in each of two conditions and in each of the included electrode positions were included in the final sample ($n = 35$). The average number of artifact free seconds per participant was $M = 55.1$ ($SD = 11.2$), $M = 52.3$ ($SD = 13.2$), and $M = 52.1$ ($SD = 12.8$) for the neutral, the anxiety, and the sadness film,

[1] Additional data were obtained for purposes not relevant to the present research question.

respectively. Artifact-free EEG data were submitted to Fast Fourier Analysis using a Hanning window (epoch length 1 s, overlapping 10%; low-cut filter 0.016 Hz). Spectral coherence (Fisher's *z*-transformed) was obtained in each frequency band using the quotient of the cross spectrum and the auto spectra according to the following equation: $Coh(c_1,c_2)(f) = |CS(c_1,c_2)(f)|^2/(|CS(c_1,c_1)(f)||CS(c_2,c_2)(f)|)$, with $CS(c_1,c_2)(f) = \sum c_{1,i}(f)\ c_{2,i}(f)$. $Coh(c_1,c_2)(f)$ denotes the coherence at frequency *f* between electrodes 1 and 2, which can vary between 0 and 1.

In the study of Miskovic and Schmidt (2010) which also focused on EEG coherence in the context of affective processing, changes in cross-regional coherent brain activity during affective viewing were observed primarily in the beta frequency band. This is in accordance with research suggesting that beta-band oscillations are particularly important for mediating long distance coupling (Gross et al., 2004; Kopell, Ermentrout, Whittington, & Traub, 2000; Schnitzler & Gross, 2005). Schellberg et al. (1990) found differences in prefrontal–temporal coherence in the beta band when participants were watching stressful versus enjoyable film sequences (which also showed up in the high alpha range). Other studies also observed connectivity changes primarily in the beta range during evoked emotions (Aftanas, Lotova, Koshkarov, & Popov, 1998). Consequently, in the present study we focused on coherence in the beta frequency range (13–30 Hz). In order to avoid an unnecessary great number of statistical comparisons, we do not report other frequency bands.

Following Miskovic and Schmidt (2010), coherence pairs were grouped into anatomically valid clusters corresponding to the left and right, prefrontal and posterior association cortex regions. Coherence scores of nine electrode pairs each were averaged to summarize interaction within the left and the right hemisphere, respectively (left: Fp1-T7, Fp1-P3, Fp1-P7, F3-T7, F3-P3, F3-P7, F7-T7, F7-P3, F7-P7; right: Fp2-T8, Fp2-P4, Fp2-P8, F4-T8, F4-P4, F4-P8, F8-T8, F8-P4, F8-P8). By using these clusters we avoided a hardly manageable inflation of the number of statistical tests. By confining the analysis to electrode pairs spanning larger distances, volume conduction artifacts should not have been an issue. All distances between two electrodes in the used pairs exceeded the estimated spatial resolution of EEG of approximately 5 cm (Lachaux, Rodriguez, Martinerie, & Varela, 1999; Nunez, 1995; Srinivasan et al., 2007). The selection of the posterior electrodes was in accordance with evidence of involvement of the posterior part of the temporal lobe and the inferior parietal lobe in the visual perception of socially relevant information, imitation, and mental simulation of the actions of another person (Decety & Sommerville, 2003).

As an index of state-dependent decreases or increases of intrahemispheric coherence in response to the emotional provocation, change scores were computed, derived from subtracting coherence during the neutral (reference) film from coherence during viewing the emotionally arousing film (reactivity scores). Negative scores indicate a decrease in prefrontal to posterior coherence, positive scores indicate an increase. Linear regressions were conducted using the reference film scores to predict the reactivity scores, in order to calculate residualized change scores. This was done to ensure that the analyzed residual variability was due to the experimental manipulation, and not to individual differences in baseline levels (Linden, Earle, Gerin, & Christenfeld, 1997). In the following, the abbreviation "Δcoh" will be used for these change-of-coherence scores.

2.1.7. Statistical analysis

To evaluate whether individual differences in trait absorption and the propensity to ruminate may predict individual differences in coherence changes during emotional provocation, hierarchical multiple regression analyses were performed, with coherence changes (Δcoh) from the neutral to the sadness film or from the neutral to the anxiety film as the dependent variable. Entering sex in Step 1 allowed to determine how much variance the two individual differences variables could explain independently of variance that might be explained by sex (R^2_{inc}). In Step 2, trait absorption and rumination were simultaneously entered to determine the unique contribution of each. A significant F_{inc} test indicates that the traits absorption and rumination explained a significant amount of variance, independently of potential influences of sex. A significant semipartial correlation (*sr*) indicates that the predictor explained a significant amount of variance of coherence changes, independently of sex and the other predictor variable. Sr^2 directly indicates the amount of unique variance and, thus, the size of the unique effect of a predictor. Sex was included in the analyses, because research suggested that there may be sex differences in coherence reactivity (Flores-Gutierrez et al., 2009; Volf & Razumnikova, 1999). Studies also reported sex differences in the tendency to ruminate and in correlates of absorption (Kremen & Block, 2002; Nolen-Hoeksema, Larson, & Grayson, 1999). Moreover, there is evidence that women tend to show stronger responses to emotional stimuli in general and may be more susceptible to experiencing others' emotions in particular (Kring & Gordon, 1998; Sonnby-Borgström, Jönsson, & Svensson, 2008).

In order to test whether individual differences in coherence changes during the emotional provocation may predict its subjective impact, multiple regression analyses were performed with sex and coherence changes (Δcoh) from the neutral to the sadness film or from the neutral to the anxiety film as predictors, and the sadness rating (*S*–*N*) or the anxiety rating (*X*–*N*) as the dependent variable. A significant F_{inc} test/a significant semipartial correlation indicates that changes of coherence could explain how much emotionally affected participants felt after watching the film.

Instead of collapsing across hemispheres, coherence changes were analyzed separately for the left and the right hemisphere, because previous research showed lateralized effects (Moratti, Keil, & Stolarova, 2004; Schellberg et al., 1990). Different findings in the left and in the right hemisphere could be important for their integration into current laterality models of affect (Harmon-Jones, Gable, & Peterson, 2010).

Effectiveness of the emotional provocation was tested using oneway multivariate analysis of variance (MANOVA) with condition (ECOF-N, ECOF-S, ECOF-X; within-subjects factor) as the independent variable and the subjective ratings (sadness, anxiety, arousal) as the dependent variables. Possible main effects of the emotional films on coherence were tested using MANOVAs with condition as the independent variable and coherence of the right and the left hemisphere as the dependent variables. There was no violation of the sphericity assumption. Estimates of effect size are reported using partial eta-squared (η_p^2), which gives the proportion of variance a factor explains of the overall (effect + error) variance.

3. Results

The MANOVA with the subjective ratings as the dependent variables confirmed effectiveness of the emotional contagion provocation ($F(6,132) = 57.1$, $p < .001$). Subsequently conducted univariate *F*-Tests showed significant effects for all three ratings: Sadness $F(2,68) = 73.5$ ($p < .001$, $\eta_p^2 = .68$); anxiety $F(2,68) = 103.8$ ($p < .001$, $\eta_p^2 = .75$); arousal $F(2,68) = 9.4$ ($p < .001$, $\eta_p^2 = .22$). Means are shown in Table 1. They indicate that, on average, both emotional films evoked the respective affective states. Emotional arousal was rated higher for the emotional films than for the neu-

Table 1
Mean scores of subjective ratings (Experiment 1).

	ECOF-N	ECOF-S	ECOF-X
Sadness	8.9 (15.25)	68.5 (20.9)	27.8 (24.5)
Anxiety	3.3 (4.9)	20.1 (18.2)	60.0 (23.0)
Arousal	16.5 (20.2)	30.7 (23.3)	38.7 (26.2)

Note: ECOF-N, ECOF-S, ECOF-X: neutral, sadness, and anxiety films, respectively. Standard deviations are given in parentheses. Critical differences Tukey's HSD: sadness $HSD = 12.1$, anxiety $HSD = 9.7$, arousal $HSD = 12.5$.

tral film, but the arousal ratings did not differ between the two emotional films.

3.1. Film infecting with sadness

3.1.1. Effects of trait absorption and rumination on coherence changes during emotional provocation

The regression analysis with Δcoh in the right hemisphere as the dependent variable showed that individual differences in absorption ($sr = -.36$, $p < .05$) and rumination ($sr = -.34$, $p < .05$) predicted to which extent coherence increased or decreased during the sadness film ($F_{inc}(2,31) = 3.5$, $p < .05$, $R^2_{inc} = .18$). In individuals high in the trait absorption and in individuals high in rumination, coherence decreased during watching the emotionally contagious film, whereas it increased in individuals with low absorption or rumination scores. The analogous analysis with coherence changes in the left hemisphere yielded no significant results ($F_{inc}(2,31) = 1.9$, ns., $R^2_{inc} = .10$; absorption $sr = -.30$, $p < .10$; rumination $sr = -.22$, ns.).

3.1.2. Effects of coherence changes during emotional provocation on subjective mood

Coherence changes (Δcoh) did not predict how contagious the participants experienced the film (right hemisphere $F_{inc}(1,31) = .03$, ns., $R^2_{inc} = .00$; Δcoh $sr = .03$, ns., left hemisphere $F_{inc}(1,31) = 1.6$, ns., $R^2_{inc} = .05$; Δcoh $sr = -.21$, ns.).

Coherence differences between the sadness and the neutral film ranged from $-.04$ to .07. There were no average trends towards decreases or increases of coherence from the neutral to the emotional film ($F(2,33) = .8$, ns., right $M = .01$, $SD = .02$, left $M = .00$, $SD = .02$). That is, in some participants coherence decreased, whereas it increased in others.

3.2. Film infecting with anxiety

3.2.1. Effects of trait absorption and rumination on coherence changes during emotional provocation

Individual differences in absorption predicted right-hemisphere Δcoh ($sr = -.35$, $p < .05$). Only a nonsignificant trend was observed for rumination ($sr = -.30$, $p < .10$; $F_{inc}(2,31) = 2.6$, $p < .10$, $R^2_{inc} = .14$). Neither of the two individual differences variables showed an association with Δcoh in the left hemisphere ($F_{inc}(2,31) = .1$, ns., $R^2_{inc} = .01$; absorption $sr = -.01$, ns., rumination $sr = -.07$, ns.).

3.2.2. Effects of coherence changes during emotional provocation on subjective mood

Δcoh did not predict how contagious the participants experienced the film (right hemisphere $F_{inc}(1,32) = 3.0$, ns., Δcoh $sr = .24$, ns., $R^2_{inc} = .08$, left hemisphere $F_{inc}(1,32) = .7$, ns., Δcoh $sr = .14$, ns.).

Coherence differences between the anxiety and the neutral film ranged from $-.04$ to .09. Similar to the sadness film, no average trends towards decreases or increases of coherence from the neutral to the anxiety film were observed ($F(2,33) = .8$, ns., right $M = .01$, $SD = .02$, left $M = .00$, $SD = .02$).

Table 2
Effects of individual differences in absorption and rumination on coherence changes from neutral to emotionally contagious films (Experiment 1).

	Left hemisphere		Right hemisphere	
	ECOF-S	ECOF-X	ECOF-S	ECOF-X
Absorption	$-.30^{**}$	$-.01$	$-.36^{*}$	$-.35^{*}$
Rumination	$-.22$	$-.07$	$-.34^{*}$	$-.30^{**}$

Note: Semipartial correlations controlling for rumination/absorption and sex. ECOF-S: film infecting with sadness, ECOF-X: film infecting with anxiety. Positive coherence scores indicate an increase in prefrontal to posterior coherence.
* $p < .05$.
** $p < .10$.

Semipartial correlations are shown in Table 2. The correlation between absorption and rumination was $r = -.32$ (ns.). Sex was not a significant predictor in any of the analyses[2].

4. Discussion

Experiment 1 showed that during the social–emotional stimulation prefrontal–posterior coherence decreased in some individuals, whereas it increased in others. In line with our hypothesis, higher absorption and rumination scores were associated with a decrease of prefrontal–posterior EEG coherence during the emotional provocation, indicating a reduced control and a deeper emotional involvement. On the other hand, the observed increases of coherence in some individuals may be indicative of a stronger control and more rigidity or downregulation. The effect of trait absorption was equally observed during stimulation with sadness and anxiety, whereas the contribution of rumination seemed to be somewhat weaker during the anxiety than during the sadness stimulation.

Correlations were found in the right hemisphere only. This may be in line with the predominant role of the right hemisphere in emotion processing, in particular in terms of the intensity of emotional arousal (Gainotti, 2000; Hagemann, Hewig, Naumann, Seifert, & Bartussek, 2005; Papousek, Schulter et al., 2009). The use of exclusively visual material, which may be preferentially processed in the right hemisphere, may also play a role.

According to our interpretation of the correlations with trait absorption and rumination, individuals showing coherence decreases during the emotional contagion provocation should have adopted the displayed affect to a greater degree than individuals showing coherence increases. This, however, could not be demonstrated with the subjective ratings of emotional contagion. Several possible reasons may account for this discrepancy. For instance, demand characteristics may have influenced the ratings, thereby introducing error variance. Alternatively, little prefrontal–posterior coupling may support involvement and emotional contagion. But at the same time, the regulatory top-down mechanism may become more activated if the person is more affected, and, thus, the effects might in a way neutralize each other.

Proceeding from these results, a second experiment was done in order to corroborate and extend the main findings observed in Experiment 1 in three important ways. First, in order to be better able to evaluate the finding that the correlation with rumination was stronger with coherence changes during watching the sadness film as compared to the anxiety film, we aimed at replicating this finding with another, internationally more common measure of trait rumination. (No difference between the films was observed

[2] Analyses in other frequency bands did not reach the significance level. A trend ($p < .10$) in the same direction as the result in the beta frequency band was observed for the effects of the personality traits on coherence changes in the alpha frequency band in the right hemisphere during the anxiety film ($F_{inc}(2,31) = 3.1$, $p = .06$, $R^2_{inc} = .16$).

for the trait absorption.) Second, in order to evaluate the generalizability of the interpretation of state-dependent changes of prefrontal–temporoparietal coherences across different stimulus modalities, an auditory stimulation was used in the second experiment. Additionally, the auditory stimulation material is comprised of the affective expressions of mixed groups of men and women, whereas the material that was used in the first experiment had shown a female poser, which might have influenced the results. Third, in order to learn more about potential direct effects of prefrontal–posterior coherence changes during social–emotional stimulation, we tested whether the expected effect might perhaps only become apparent after the end of the stimulation. To this end, the experimental design was changed in a manner that each emotional condition was preceded and followed by a neutral one, in order to be able to also evaluate affective recovery. Demand characteristics should be negligible in the rating after the neutral condition following the affective stimulation, and it should not suffer from potential ceiling effects.

5. Experiment 2

5.1. Methods

5.1.1. Participants

The sample was comprised of 53 right-handed university students aged 18–52 years ($M = 23.8$, $SD = 5.7$; 24 women, 29 men). The same inclusion criteria and general instructions were used as in Experiment 1. The study was performed in accordance with the 1964 Declaration of Helsinki and was approved by the local ethics committee.

5.1.2. Social–emotional stimulation

In the ''Emotionally Contagious Sound Clips'' (ECOS; Papousek, Reiser, Weber, Freudenthaler, & Schulter, 2012; Weber, Papousek, & Schulter, 2011) a small group of people audibly expresses the respective affect without using language (i.e., words or parts of words). ECOS-S (sadness; bitter weeping and sobbing), ECOS-X (anxiety; panic-fuelled screaming, rumbling noises), and ECOS-N (neutral; soft murmurs and trivial everyday sounds without understandable language) were used (90 s each). The clips were matched for peak sound intensity and sound level range and were presented over headphones. Previous studies had confirmed the efficiency of the sound clips to evoke the respective affective states in the listener. As very strong emotions are displayed, healthy participants have no difficulties identifying and differentiating the displayed affective states (Papousek, Freudenthaler, & Schulter, 2011; Papousek et al., 2012).

5.1.3. Rumination and rating scales

The symptom-focused rumination subscale from the German version of the Response Styles Questionnaire was used to assess the propensity to ruminate about one's affective state (Kuehner, Huffziger, & Nolen-Hoeksema, 2007; original version by Nolen-Hoeksema and Morrow (1991)). The scale is comprised of eight items that assess responses to sad mood that are passively focused on one's dysphoric symptoms (e.g., ''When I feel sad or depressed, I think about how passive and unmotivated I am''), rated on a four-point Likert scale ($\alpha = .69$)[3].

Affect ratings as in the first experiment were used to evaluate to which extent listening to the sound clips evoked the respective affective states, and to which extent they persisted during listening to the neutral sound afterwards. The number of affect ratings was restricted to four (sadness, anxiety, cheerfulness, anger), in order to minimize the time lags between the emotional clips and the neutral clips following them and, consequently, to be better able to assess recovery. Only the sadness and anxiety ratings were used in the statistical analyses. According to standards in psychophysiological research, *affective responsivity scores* were calculated by subtracting the rating of the neutral sound preceding the emotional sound from the rating of the emotional sound ($S–N_S$ and $X–N_X$), and *affective recovery scores* were calculated by subtracting the rating of the neutral sound preceding the emotional sound from the rating of the neutral sound following the emotional sound (${}_SN–N_S$ and ${}_XN–N_X$). Positive values indicate strong responsivity and poor recovery, respectively.

5.1.4. Procedure

After informed consent had been obtained and the participants had performed the hand dominance test, they were seated in an acoustically and electrically shielded examination chamber, and electrodes were attached. The participants were instructed via headphones that in each of the following short sound clips they would hear a group of people, to close their eyes, direct their whole attention to what they would hear, and to imagine that they were part of the group. EEG was recorded during each sound clip. Emotionally arousing and neutral sound clips were presented alternating, so that each emotional sound was preceded and followed by ECOS-N (e.g., *N–S–N–X–N*). Order of emotional sounds was counterbalanced. Ratings were applied after presentation of each ECOS and were presented on a computer monitor. The technical equipment and the experimenter were located outside the chamber, and the participants were monitored through a one-way window and an intercom. Rumination was assessed in a separate individual test session 1–10 days after the laboratory session[1].

5.1.5. EEG recording and quantification

The same methods of EEG recording and quantification were applied as in Experiment 1. In analyses of the sadness stimulation the sample is reduced to $n = 50$, because three participants did not reach the criterion of at least 30 s of artifact free data at all electrodes. The average numbers of artifact free seconds per participant in the different conditions ranged from $M = 51.4$ ($SD = 14.8$) and $M = 55.6$ ($SD = 16.8$). ECOS-N preceding the sadness or anxiety sound was used as a reference for calculating Δcoh.

5.1.6. Statistical analysis

Statistical methods were analogous to those applied in Experiment 1. To evaluate whether individual differences in the propensity to ruminate may predict individual differences in coherence changes during the emotional provocation, hierarchical multiple regression analyses were performed, with sex (Step 1) and rumination (Step 2) as predictors, and coherence changes (Δcoh) from the neutral sound preceding the sadness sound to the sadness sound or the change from the neutral sound preceding the anxiety sound to the anxiety sound as the dependent variable. A significant F_{inc} test indicates that rumination explained a significant amount of variance, independently of potential influences of sex. The semipartial correlation (*sr*) indicates the size of a predictor's unique effect. In order to test whether individual differences in coherence changes during the emotional contagion provocation may predict its subjective impact, multiple regression analyses were performed with sex and coherence changes (Δcoh) as predictors, and affective responsivity (sadness or anxiety) as the dependent variable. An analogous set of analyses was performed with affective recovery.

[3] Symptom-focused rumination is the theoretically most relevant aspect to the research question of the present study. Analyses using the total score including also the subscales self-focused rumination (related to self-analysis/introspection and self-isolation, e.g., ''analyse my personality and try to understand why I am depressed'' and distraction yielded highly similar results. The three subscales could not be analysed simultaneously in one equation, because they shared great amounts of variance (RSQ_SYM $\times$ RSQ_SELF $r = .61$). Separate analyses would have produced an unnecessary threefold number of statistical tests.

Table 3
Mean scores of subjective ratings (Experiment 2).

	ECOS-N	ECOS-S	ECOS-X
Sadness	12.3 (14.2)	73.4 (27.7)	51.3 (28.1)
Anxiety	18.0 (17.9)	39.2 (32.3)	68.1 (25.5)
Arousal	42.5 (24.2)	51.0 (25.9)	69.7 (23.8)

Note: ECOS-N, ECOS-S, ECOS-X: neutral, sadness, and anxiety sound clips, respectively. Standard deviations are given in parantheses. Critical differences Tukey's HSD: sadness $HSD = 10.4$, anxiety $HSD = 9.9$, arousal $HSD = 9.0$.

As in the first experiment, the effectiveness of the emotional provocation was tested using a MANOVA with condition (ECOS-N, ECOS-S, ECOS-X; within-subjects factor) as the independent variable and the subjective ratings as the dependent variables. Ratings of ECOS-N preceding ECOS-S and ECOS-X were averaged for this analysis. Possible main effects of the emotional sound clips on coherence were tested in MANOVAs analogous to those in Experiment 1. There was no violation of the sphericity assumption.

6. Results

The emotional sound clips had the expected emotionally contagious effects ($F(6,204) = 59.3$, $p < .001$). Subsequently conducted univariate *F*-Tests showed significant effects for all three self-report ratings: Sadness $F(2,104) = 103.3$ ($p < .001$, $\eta_p^2 = .67$); anxiety $F(2,104) = 75.2$ ($p < .001$, $\eta_p^2 = .59$); arousal $F(2,104) = 27.4$ ($p < .001$, $\eta_p^2 = .35$). Emotional arousal was rated higher for ECOS-X than for ECOS-S (Table 3).

6.1. Sound clip infecting with sadness

6.1.1. Effects of trait rumination on coherence changes during emotional provocation

The regression analysis with Δcoh in the right hemisphere as the dependent variable showed that individual differences in the propensity to ruminate predicted to which extent coherence increased or decreased during listening to the sadness sound ($F_{inc}(1,47) = 4.6$, $p < .05$, $R^2_{inc} = .09$; rumination $sr = -.29$, $p < .05$). In individuals high in rumination, coherence decreased during listening to the sadness sound, whereas it increased in individuals with low rumination scores. The analogous analysis with Δcoh in the left hemisphere showed similar results ($F_{inc}(1,47) = 4.8$, $p < .05$, $R^2_{inc} = .09$; rumination $sr = -.30$, $p<.05$). Semipartial correlations are shown in Table 4.

6.1.2. Effects of coherence changes during emotional provocation on subjective mood

As in Experiment 1, Δcoh did not predict affective responsivity to the provocation (right hemisphere $F_{inc}(1,47) = 1.1$, ns., $R^2_{inc} = .02$, Δcoh $sr = -.15$, ns., left hemisphere $F_{inc}(1,47) = .2$, ns., $R^2_{inc} = .00$, Δcoh $sr = .07$, ns.). However, the regression analysis with affective recovery scores as the dependent variable showed that feelings of sadness had a greater tendency to persist when coherence in the right hemisphere decreased during listening to the sadness sound than when it increased ($F_{inc}(1,47) = 4.8$, $p< .05$, $R^2_{inc} = .09$; Δcoh $sr = -.30$, $p < .05$). The analogous analysis with coherence changes in the left hemisphere yielded no significant result ($F_{inc}(1,47) = 1.3$, ns., $R^2_{inc} = .03$; Δcoh $sr = -.17$, ns., Table 5).

Table 4
Effects of individual differences in rumination on coherence changes from neutral to emotionally contagious sound clips (Experiment 2).

	Left hemisphere		Right hemisphere	
	ECOS-S	ECOS-X	ECOS-S	ECOS-X
Rumination	−.30*	−.02	−.29*	.08

Note: Semipartial correlations controlling for sex. ECOS-S: sound clip infecting with sadness, ECOS-X: sound clip infecting with anxiety. Positive coherence scores indicate an increase in prefrontal to posterior coherence.
* $p < .05$.

Table 5
Effects of coherence changes from neutral to emotionally contagious sound clips on affective recovery (Experiment 2).

	Left hemisphere		Right hemisphere	
	ECOS-S	ECOS-X	ECOS-S	ECOS-X
Affective recovery	−.17	−.21	−.30*	−.28*

Note: Semipartial correlations controlling for sex. ECOF-S: sound clip infecting with sadness, ECOF-X: sound clip infecting with anxiety. Positive coherence scores indicate an increase in prefrontal to posterior coherence. Positive recovery scores indicate poor recovery.
* $p < .05$.

Coherence differences between the sadness and the neutral sound clip ranged from −.05 to .05. There were no average trends towards decreases or increases of coherence from the neutral to the sadness condition ($F(2,48) = .8$, ns., right $M = .00$, $SD = .02$, left $M = .00$, $SD = .02$).

6.2. Sound clip infecting with anxiety

6.2.1. Effects of trait rumination on coherence changes during emotional provocation

Rumination did not predict to which extent coherence increased or decreased during listening to the anxiety sound (right hemisphere $F_{inc}(1,50) = .3$, ns., $R^2_{inc} = .01$; rumination $sr = .08$, ns., left hemisphere $F_{inc}(1,50) = .0$, ns., $R^2_{inc} = .00$; rumination $sr = -.02$, ns.).

6.2.2. Effects of coherence changes during emotional provocation on subjective mood

Again, Δcoh did not predict how contagious the participants experienced the sound clip ($F_{inc}(1,50) = .0$, ns., $R^2_{inc} = .00$; right hemisphere Δcoh $sr = .00$, ns., left hemisphere $F_{inc}(1,50) = .2$, ns., $R^2_{inc} = .00$; Δcoh $sr = .06$, ns.). But feelings of anxiety had a greater tendency to persist when coherence in the right hemisphere decreased during listening to the anxiety sound as compared to when it increased ($F_{inc}(1,50) = 4.2$, $p < .05$, $R^2_{inc} = .08$, Δcoh $sr = -.28$, $p < .05$). This effect was not significant in the left hemisphere ($F_{inc}(1,50) = 2.3$, ns., $R^2_{inc} = .04$; Δcoh $sr = -.21$, ns.).

Coherence differences between the anxiety and the neutral condition ranged from −.06 to .09, with no average trends towards decreases or increases of coherence from the neutral to the anxiety sound ($F(2,51) = .14$, ns., right $M = .00$, $SD = .02$, left $M = .00$, $SD = .02$).[4] Sex was not a significant predictor in any of the analyses.

7. Discussion

The present study aimed to investigate if state-dependent decreases or increases of EEG coherence between prefrontal and posterior cortical regions may be indicative of a mechanism modulating the impact emotional information has on an individual. On the basis of relevant literature in the field it was assumed that decreases of prefrontal–posterior coherence during processing of social–emotional information may be related to loosening of control, deep involvement, absorption, and increased susceptibility to catch the perceived emotions, whereas coherence increases would be related to strong control, dampening of emotional experience, and not letting oneself become emotionally affected.

Our findings showed a functional de-coupling during the emotional contagion provocation in some individuals, whereas others

[4] Analyses in other frequency bands did not reach the significance level. A trend ($p < .10$) in the same direction as the result in the beta frequency band was observed for the effect of rumination on coherence changes in the alpha frequency band in the right hemisphere during the sadness film ($F_{inc}(1,47) = 3.6$, $p = .07$, $R^2_{inc} = .07$).

showed an increased coupling of prefrontal and posterior cortical regions. The observed individual differences in state-dependent EEG coherence may be related to differences in the capacity or the readiness to adopt the feelings of the persons one is watching or listening to. This interpretation is supported by correlations with trait absorption indicating that individuals with a greater readiness for experiences of deep involvement and a greater openness to experience emotional alterations as a trait (i.e., trait absorption) were more likely to show state-dependent decreases of coherence during the emotional contagion provocation. This association became apparent during both the sadness and the anxiety stimulation.

Correlations were also expected for rumination, a trait that has been linked to difficulties to disengage from negative content and deficient regulation of negative affect (Koster et al., 2011; Mikolajczak, Nelis, Hansenne, & Quoidbach, 2008). In the current study, a higher propensity to ruminate predicted greater decreases of prefrontal–posterior coherence during the emotional contagion provocation with sad stimulus material. It appears to be particularly worth mentioning that we were able to demonstrate this in two independent studies, using different stimulation material and different instruments for the assessment of rumination. However, the difference between the sadness and the anxiety condition was more prominent in Experiment 2, in which the RSQ was applied. This seems plausible, because in line with Nolen-Hoeksema's (1991) Response Styles Theory, the RSQ is focusing on depressed mood (participants are required to indicate their responses when feeling sad or depressed). Apparently, rumination as assessed by the RSQ may be relatively specific for conditions associated with sadness and, therefore, only limited transferable to anxiety provoking situations. The questionnaire used in the first experiment can only be partially related to sadness ("when I am disturbed, irritated, or upset by something or someone"). Nevertheless, the scale also seemed to be more relevant to sadness than to anxiety, although the difference between the sadness and anxiety films was only relatively small. Therefore, the stronger correlation during the sadness provocation found in the current study is in line with the proposition that the concept of rumination may generally be more closely related to sadness and past events and feelings, whereas anxiety may be more closely related to worry which typically involves perseverative thinking about future uncertainties and potential threats (Watkins, 2008).

In neither of the two experiments did state-dependent changes of prefrontal–posterior coherence explain to which degree the participants felt infected by the displayed emotions in the films and sound clips. However, in Experiment 2, which allowed to examine also the efficiency of recovery, it was found that feelings of sadness and anxiety had a greater tendency to persist when coherence decreased during listening to the emotional sounds as compared to when it increased. This finding is in line with the idea that there may be direct effects of prefrontal–posterior coupling on the experience of affect after all. The present study does not allow any firm conclusions whether the failure to predict affective reactivity may be due to shortcomings of the self-report ratings (e.g., demand characteristics or ceiling effects) or to the eventuality that the coherence changes may indeed be more important for the duration of the contagion effect than for the intensity of the emotional response itself. A recent fMRI study suggested that the coupling of prefrontal and posterior cortical regions may reflect a process related to shutting off an emotional response. In that study, in which changes in connectivity during recording periods at rest after watching a fearful movie and a neutral movie were compared, connectivity was enhanced only after watching the emotionally arousing film (Eryilmaz, Van De Ville, Schwartz, & Vuilleumier, 2011). These findings might also be interpreted in a manner that emotional provocation may initialize a state of heightened internal engagement in the processing of emotion-related information that is only weakly apparent at stimulus onset but becomes increasingly relevant with increasing time. In this vein we may speculate that the presented emotional stimuli induced a state of heightened internally focused attention which could be characterized by intense search and retrieval of emotion-related memory contents (as it is typically the case in trait absorption or in rumination). However, it should also be pointed out that due to the modest sample sizes the statistical power was limited, so that small effects might not have been detected.

Some correlations were stronger for coherence measures in the right than in the left hemisphere, whereas other associations appeared to be bilateral. An fMRI study investigating the functional connectivity between the prefrontal and parietal cortices found that seed regions in the prefrontal cortex were most correlated with the parietal cortex in the ipsilateral hemisphere of the seed, suggesting that the functionality of the frontal–posterior system is hemisphere-specific (Vincent et al., 2008). But to date, there is only little literature available on potential hemispheric differences in state-dependent coherence changes in the context of affective processing. In Schellberg et al.'s study (1990) increased prefrontal–posterior EEG beta coherence during stressful as compared to enjoyable films was observed in the right hemisphere only. Miskovic and Schmidt (2010) found no different effects for the two hemispheres in the beta frequency band, but only average effects of affective stimulus presentation but no relationships to individual differences variables or subjective effects of the stimulation were investigated in that study. As the lateralization of effects was not consistent in the present studies either, no final conclusion on it can be made so far. Further research will be required to gain more information.

Since deficient inhibitory processes and associated sustained processing are common to negative affective dispositions including anxiety and depression (Chida & Hamer, 2008; Davidson, 2002; Goeleven, De Raedt, Baert, & Koster, 2006; Siegle, Granholm, Ingram, & Matt, 2001; Thayer & Friedman, 2002), the relevance of prefrontal–posterior EEG coherence during emotional events may go beyond the demonstrated effects. On the other hand, the capacity to produce distinct affective responses and to maintain affective states when it is appropriate is also considered essential for successful functioning (Demaree, Schmeichel, Robinson, & Everhart, 2004; Eisner, Johnson, & Carver, 2009; Keltner & Gross, 1999; McEwen, 1998). In addition, the related modulatory processes may not only influence the experience of affect but also the encoding and later recall of emotional content (Miskovic & Schmidt, 2010). It has been shown, for instance, that the attempt to suppress emotional memories was associated with the activation of a right-lateralized fronto-parietal network (Butler & James, 2010). In line with the postulated top-down modulatory process, activation of prefrontal and concurrent deactivation of posterior cortical regions have been observed during hypnotically induced suppression of memory (Mendelsohn, Chalamish, Solomonovich, & Dudai, 2008). This evidence may suggest that individual differences in prefrontal–posterior EEG coherence may to some extent underlie the contribution of absorption, rumination, and related traits to the development of clinical disorders such as posttraumatic stress disorder (Berenbaum, Thompson, Milanak, Boden, & Bredemeier, 2008; Ehring, Ehlers, & Glucksman, 2008; McLaughlin & Nolen-Hoeksema, 2011; Simeon, Giesbrecht, Knutelska, Smith, & Smith, 2009; Watkins, 2008; Wessa, Jatzko, & Flor, 2006; Zetsche, Ehring, & Ehlers, 2009). However, the potential relevance of prefrontal–posterior coupling and decoupling in the context of emotional memories remains an issue for future research.

Apart from the narrower emotion-related context, the proposed interpretation of a more loose coupling of prefrontal and posterior cortical functions during social–emotional stimulation can be integrated into research dealing with states of increased susceptibility to and reduced evaluation of sensory information such as hypnosis or schizotypy. Scientific evidence suggests that hypnotic susceptibility may depend on the ability or tendency to disconnect brain regions and on associated dissociations between certain cognitive processes, which may underpin the suspension of reality testing and critical evaluation (Crawford, 1989; Gruzelier, 2006; Woody & Bowers, 1994). In susceptible individuals, functional decoupling of prefrontal and temporoparietal cortical regions has been observed after hypnotic induction, indicating reduced communication and reduced control by the prefrontal cortex. This may predispose for misrepresentation of suggestions as real and associated altered representation of available information (Fingelkurts et al., 2007; Terhune et al., 2011). Hypnotizability is also positively related to emotional contagion susceptibility (Cardena, Terhune, Lööf, & Buratti, 2009).

In schizophrenic patients with positive schizophrenic symptoms, a similar picture of disrupted functional connectivity has been found (Lawrie et al., 2002; Vercammen et al., 2010). EEG studies showed a correlation between decreases of frontal–temporal coherence and increases of the severity of positive symptoms, and reduced task-related inhibitory connectivity between frontal and temporoparietal cortices in schizophrenia as compared to healthy controls (Higashima et al., 2007; Winterer et al., 2003). Moreover, reduced functional coupling between the prefrontal cortex and posterior cortex and amygdala was shown in schizophrenic patients during an emotional processing task (Ioannides, Poghosyan, Dammers, & Streit, 2004). These findings are nicely complemented by recent EEG evidence revealing abnormalities in the functional connectivity in individuals with high schizotypal personality trait scores, which have been referred to as "deficient top-down network" (Koychev, Deakin, Haenschel, & El-Deredy, 2011, p. 2866).

An important research question in future studies will be how the observed individual differences in EEG coherence changes can be integrated into established personality models and to demonstrate the failure of divergent personality constructs in predicting coherence changes. Another important issue will be to examine if some of the common variance shared by the variables in the present study may be explained by other factors such as tobacco smoking (see, e.g., Fisher et al., 2012).

The explanatory power of the present findings is limited by the modest size of the effects. On the other hand, large effects are generally not to be expected in brain research, because each cortical region is always involved in several other processes too, and all processes always concurrently involve several brain structures. Effect size estimates may also be reduced by the potentially increased unreliability of difference scores (Cronbach & Furby, 1970; Hunter & Schmidt, 2004). Apart from that, the findings may nevertheless be impressive, particularly in view of the fact that parts of the findings have been replicated in an independent sample, using different psychometric instruments and different stimulation material.

Taken together, the findings of the present study provide some evidence of the validity of state-dependent changes in EEG coherence between prefrontal and temporoparietal regions in the context of affective processing. More loose coupling of prefrontal and posterior cortical functions during social–emotional stimulation seems to be related to loosening of control over incoming information and, consequently, to a greater or longer lasting emotional impact on the observer. The associated level of dependence on emotional cues may have some relevance to clinical disorders.

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