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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