



Spontaneous EEG activity and spontaneous emotion regulation



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ABSTRACT

Variability in both frontal and parietal spontaneous EEG activity, using α and β band power and θ/β and δ/β ratios, was explored in a sample of 96 healthy volunteers as a potential correlate of individual differences in spontaneous emotion regulation (SER). Following a baseline EEG recording, participants were asked to continuously rate their discomfort while looking at affective pictures, as well as for a period of time after exposure. Greater spontaneous β band power in parietal locations, lower frontal and parietal δ/β ratios, and lower parietal θ/β ratio were associated with lower ratings of discomfort after the offset of unpleasant pictures. Moreover, lower parietal δ/β ratio was also related to less time needed to recover from discomfort after exposure to aversive pictures, while only a greater frontal and parietal α band power appeared to be associated with faster recovery from discomfort induced by normative-neutral pictures. However, parietal δ/β ratio was the only predictor of both minimum discomfort ratings and time needed to downregulate following exposure to unpleasant pictures, and frontal α band power the only spontaneous EEG index that predicted variability in spontaneous down-regulation after the exposure to normative-neutral pictures. Results are discussed focusing on the utility of diverse spontaneous EEG measures in several cortical regions when capturing trait-like individual differences in emotion regulation capabilities and processes.

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1. Introduction

Several measures of the spontaneous EEG activity (i.e. recorded in baseline conditions) have been linked to individual differences in spontaneous (i.e. automatic, uninstructed) emotion regulation (SER) capabilities (e.g. Jackson et al., 2003; Knyazev, 2007; Putman et al., 2010). Individuals regularly engage in SER to downregulate affect when experiencing disturbing emotions or facing aversive stimuli (e.g. Gyurak et al., 2011), and difficulties in SER have often been associated with increased negative affect and emotional disorders (e.g. Egloff et al., 2006; Ehling et al., 2010; Etkin et al., 2010).

In laboratory settings SER has been evaluated by means of several indices, mainly: (a) attenuated eyeblink startle magnitude after the onset of unpleasant pictures or after being exposed to stressful conditions (e.g. Jackson et al., 2003; Goodman et al., 2013), (b) time needed to decrease heart rate or other physiological responses to baseline levels after stress-inducing tasks (e.g. Hannesdottir et al., 2010), (c) performance-based measures in conflicting tasks following emotionally distracting stimuli or after unpleasant emotional induction (e.g. Dennis and Solomon, 2010; Etkin et al., 2010; Zhang and Lu,

2012), and/or (d) discrete self-reports comparing emotional states prior to and a time after emotional induction (e.g. Aldao et al., 2013; Egloff et al., 2006; Ehling et al., 2010; Volokhov and Demaree, 2010). These measures differ from the assessment of general affective responsiveness (i.e. reactivity) as they are also taken for a time after the offset of unpleasant stimuli/stressful conditions, and not only rely on the magnitude of immediate emotional reactivity when facing affective stimuli but emphasise the duration of and recovery from the emotional response.

The relationships between spontaneous EEG activity and SER have not received a great deal of attention as they have been relegated in favour of phasic measures during emotional tasks performance in the search of neural correlates of emotion regulation (e.g. Coan et al., 2006; Goodman et al., 2013; Harmon-Jones et al., 2010).

In studies that have reported on the associations between spontaneous EEG activity and SER, increased spontaneous left frontal (Jackson et al., 2003; Larson et al., 1998) or bilateral (Dennis and Solomon, 2010) frontal activity, as indexed by a reduced α band power [8–13 Hz] in these sites, was related to greater or more efficient SER. These findings were interpreted as prefrontal cortex activity may act to inhibit the amygdala. This inhibitory process may be one of the neural mechanisms underlying SER emotion regulation. However, in other studies (Goodman et al., 2013) no significant associations were found between spontaneous EEG activity and SER. Moreover, Hannesdottir et al. (2010) reported that reduced spontaneous left frontal EEG activity in the 6–9 Hz frequency band (i.e. partially including α

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band frequencies) in early childhood was prospectively related to an increased parent-reported ability to regulate emotions at age 9, but not with a physiological index of SER. In brief, data from previous literature point out that reduced α band power, that it is assumed to reflect increased brain activity, relates to higher SER capabilities.

In addition to frontal α EEG activity, other EEG-based measures and cortical brain regions (i.e. parietal cortex) have been reported to be of interest in the study of emotion regulation and related processes and capabilities. In this sense, slow/fast EEG wave amplitude (SW/FW) ratios (i.e. resulting from dividing SW power density [δ or θ] by FW power density [β] in a selected brain site or sites) and coherence between narrow band amplitude (coherence refers to a positive correlation between SW and FW power densities, in a specific brain region), have also been explored as related to emotion regulation related constructs. The predominance of slow (θ ; 4–7 Hz, δ ; 1–3 Hz) over fast (β ; 13–30 Hz) brain activity is recognized to be strongly associated with psychological disorders, mainly related to lower attentional capabilities (Arns et al., 2013; Schutter and Van Honk, 2005). This relationship between SW and FW activity may reflect cortical-subcortical interactions involved in affective processes, such as emotion regulation (Knyazev, 2007). Following this rationale, Putman et al. (2010) found that spontaneous θ/β ratio in frontal areas was inversely correlated with self-reported attentional control (AC) and with inhibitory control functioning (i.e. fearful modulation of response inhibition in an emotional go/no-go task). In subsequent studies, the same research group found that individuals with stronger δ/β coherence showed reduced attentional avoidance of threat (Putman, 2011) and lower interference effects during an emotional Stroop task (Putman et al., 2012).

In summary, previous research has pointed out that the relative predominance of SW over FW relates to attentional and inhibitory control difficulties that, in turn, have been related to problems in effective emotion regulation (e.g. Armstrong et al., 2011; Rothbart and Rueda, 2005; Sulik et al., 2010).

Self-reported AC has also been found to be negatively correlated with spontaneous EEG α and β band power in the right parietal cortex, while no significant relationships were found between the AC and spontaneous EEG activity in the prefrontal cortex (Morillas-Romero et al., 2013). The fact that both α and β band powers were associated in the same way with attentional control individual differences seems to be at odds with traditional views of α band interpretations and in accordance with alternative perspectives (Knyazev, 2007), which are largely ignored in affective research (Uusberg et al., 2013) and consider alpha a watchful or preparedness rhythm with important inhibitory functions. In a subsequent study conducted by the same research group (Balle et al., 2013), only right-sided parietal activity in the β_2 (13–30 Hz) frequency range was a significant predictor of decreased AC. In any case, in both studies (Balle et al., 2013; Morillas-Romero et al., 2013), results regarding the role of the parietal cortex fit with previous literature claiming that this brain area is critically involved in attentional capabilities (Kanai et al., 2011; Mevorach et al., 2009; Ochner et al., 2009; Posner and Rothbart, 2009) and processes (Deiber et al., 2007; McRae et al., 2010; Schutter et al., 2001; Szczepanski and Kastner, 2013) which, in turn, seem to be crucial to regulate emotions.

Therefore, we consider that spontaneous EEG activity deserves to be further investigated as a potential correlate of SER capabilities from a dispositional or trait-like perspective. This approach matches the view that brain functions are mainly intrinsic, with organised functional activity in baseline conditions (Raichle, 2010), which has also been found to be associated with emotion regulation styles (e.g. Abler et al., 2008; Berman et al., 2011; Bornas et al., 2013). Moreover, taking into account the aforementioned research outcomes, spontaneous EEG activity studies would also benefit from analysing, beyond frontal α activity, other EEG band powers such as β and other cortical regions such as the parietal ones.

On a separate issue, as stated before, in previous literature SER has been evaluated by means of comparing emotional states prior to and

after emotional induction through discrete self-reports, physiological (e.g. startle response) and/or performance-based measures during emotional conflicting tasks. However, no previous studies have used continuous discomfort self-records in order to evaluate non-instructed emotional recovery after emotional induction. We consider that real-time continuous discomfort recording could provide relevant insights on the dynamics of SER while it takes place. Furthermore, this kind of assessment could offer similar advantages to electronic diaries in natural conditions (Bolger et al., 2003), overcoming some limitations of the pre-post assessment of discrete emotional states.

Additionally, it is quite well established that anxiety-prone individuals tend to exhibit elevated distress not only when facing intense stressors and/or explicit aversive cues but also, and perhaps especially, during periods of overt safety or in mild stressful conditions (e.g. Craske et al., 2009 for a review). Moreover, several authors (e.g. Davidson et al., 2007; Shackman et al., 2009) highlighted the desirability of measuring temperamental individual differences, such as the proneness to automatically downregulate negative emotions efficiently, not only using the traditional novel and unfamiliar contexts or exposing the individual to normative fear/discomfort explicit cues (e.g. exposed to normative aversive pictures), but also using non discomfort-normative contexts (e.g. neutral conditions). Following this rationale, SER studies would benefit from also analysing SER after the offset of neutral stimuli rather than exclusively after aversive ones.

In light of the above, the aim of the current study was to simultaneously explore, in a sample of healthy volunteers, whether frontal and parietal spontaneous EEG activity in α and β bands, and θ/β and δ/β ratios, would be associated with SER capabilities (i.e. without any specific regulatory instruction given) after the offset of aversive and neutral pictures. A continuous self-record of participants' discomfort was collected while they were exposed to aversive and neutral emotional pictures, as well as for a period of time after each picture exposure (see Method section for details).

It was hypothesised that greater spontaneous α and β band power and lower SW/FW ratios (θ/β and δ/β) in frontal areas would be associated with a more efficient SER. Taking into account that EEG indices in parietal areas have been previously associated with a directly emotional regulation related construct, such as attentional control, we also explored the role of parietal areas regarding SER. Finally, in the same exploratory fashion, we analysed which of the recorded EEG activity indices would better predict SER capabilities.

2. Method

2.1. Participants

One hundred and nineteen healthy university students and staff members (89 females and 30 males, $M_{\text{age}} = 29.54$ years; $SD = 10.16$; range 18–55) not previously selected by any psychological or sociodemographic characteristics voluntarily agreed to participate and signed an informed consent form. Participants were recruited via electronic or posted advertisements. EEG recording data from fourteen participants were excluded due to the presence of too many artifacts (changes in voltage greater than 100 μV). Finally, to maintain consistency across the data, nine left-handed participants were excluded from further analysis. Therefore, the final sample of the study was made up of 96 right-handed participants (72 females and 24 males, $M_{\text{age}} = 29.18$ years; $SD = 10.21$).

2.2. Materials and procedure

Spontaneous (i.e. baseline) EEG activity from each participant was recorded before the execution of an emotional induction/SER task. EEG recordings were conducted individually in a dimly lit and sound-attenuated room. After a three-minute adaptation period, EEG activity was recorded during an eight-minute baseline: a sequence of two

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