International Journal of Psychophysiology 96 (2015) 38–48

Contents lists available at ScienceDirect

International Journal of Psychophysiology

journal homepage: www.elsevier.com/locate/ijpsycho

Spontaneous emotion regulation: Differential effects on evoked brain potentials and facial muscle activity

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ARTICLE INFO

Article history:
Received 9 September 2014
Received in revised form 13 February 2015
Accepted 16 February 2015
Available online 22 February 2015

Keywords:
Late positive potentials
Emotion regulation
Event-Related Potentials
Facial muscle activity

ABSTRACT

Late positive potentials (LPPs) were found to be decreased during down-regulation and increased during up-regulation of positive and negative emotions. However, previous studies lack ecological validity, since they explicitly instructed their participants to use certain regulation strategies. The goal of our study was to test an ecologically more valid paradigm of emotion regulation. We therefore investigated the effects of freely chosen emotion regulation strategies on LPPs and additionally assessed facial EMG responses and valence and arousal ratings as control variables. Responses to positive IAPS pictures were marked by pleasant valence ratings and high activations of M. zygomaticus major, negative pictures elicited unpleasant valence ratings and high activations of M. corrugator supercilii, and both, positive and negative pictures, went along with increased arousal ratings and LPPs. Importantly, ratings and EMG activity were intensified through up-regulation and attenuated through down-regulation of emotions, while LPPs were increased through both up-and down-regulation. We conclude that LPPs in paradigms with free choice of emotion regulation strategies might be a marker of attentional resources required for the selection of adequate emotion up- and down-regulation strategies, while LPP effects following emotion regulation with specific, instructed strategies reflect modulated arousal processes.

1. Introduction

Emotion regulation is essential for an adaptive functioning in social interactions. Numerous psychological disorders go along with deficits in emotion regulation (Aldao et al., 2010; Berking and Wupperman, 2012; Cole and Deater-Deckard, 2009; Gross and Levenson, 1997). According to a process model of emotion regulation (Gross, 1998, 2002), emotional reactions may be influenced at different steps of the emotion generation process. As antecedent-focused strategies, Gross (1998, 2002) identified situation selection, attentional deployment, and reappraisal. Attentional deployment and reappraisal have mostly been investigated in experimental studies (Foti and Hajcak, 2008; Hajcak and Nieuwenhuis, 2006; Hajcak et al., 2006; Johnson, 2009; Krompinger et al., 2008; McRae et al., 2012; Shiota and Levenson, 2012; Wu et al., 2012). The last step in this model is the response-focused suppression of an emotional reaction. These studies revealed that antecedent-focused emotion regulation strategies are more effective than response-focused emotion regulation (Gross and John, 2003; Gross and Levenson, 1997) and are a crucial part of many psychotherapeutic programs (Aldao and Mennin, 2012; Barlow, 2008; Clark and Beck, 2012; Herbert and Forman, 2011; Philipsen et al., 2007; Price et al., 2012; Smits et al., 2012; Totterdell et al., 2012; Linehan, 1993).

The neural correlates of emotion regulation have been investigated through the modulation of late positive potentials (LPPs; Dennis and Hajcak, 2009; Hajcak and Nieuwenhuis, 2006; Hajcak et al., 2010; Langeslag and van Strien, 2010), a special component of event-related brain potentials (ERPs). LPPs are positive electrophysiological deflections which appear relatively late after stimulus onset (from 400 ms up to several seconds after stimulus onset). The LPP amplitude was found to be modulated by emotional stimuli (Hajcak et al., 2010; Lang and Bradley, 2010) with larger amplitudes related to an increase in arousal. Thus, a broad range of empirical work revealed larger LPP amplitudes up to 2000 ms, in one study even up to 6 s after stimulus onset, mostly in centro-parietal brain regions after the presentation of pleasant or unpleasant, compared to neutral pictures (Amrhein et al., 2004; Cuthbert et al., 2000; Hajcak et al., 2007; Pastor et al., 2008; Schupp et al., 2000). In addition, up-regulation of emotions went along with an amplification of LPP amplitudes, while down-regulation led to diminished LPPs in studies where participants were trained to apply certain emotion regulation strategies according to Gross's (Gross, 1998, 2002) model of emotion regulation, such as attention allocation (Dunning and Hajcak, 2009; Hajcak et al., 2006) or reappraisal strategies (Dennis and Hajcak, 2009; Foti and Hajcak, 2008; Hajcak and Nieuwenhuis, 2006; MacNamara et al., 2011a, 2011b; Moser et al.,

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http://dx.doi.org/10.1016/j.ijpsycho.2015.02.022
0167-8760/

2009). Therefore, it was concluded that changes in LPP amplitude due to emotion regulation reflect modulations in the elicited arousal.

However, because nearly all previous studies provided instructions of specific emotion regulation strategies, there is little knowledge about naturalistic emotion regulation when participants are free to choose and develop individual regulation strategies. To our knowledge the only emotion regulation study measuring LPP amplitudes without specific strategy instructions so far (Langeslag and van Strien, 2010) found increased LPP amplitudes in both up- and down-regulation conditions, compared to a non-regulation condition (still, the LPP increase in the up-regulation condition was larger than in the down-regulation condition). Since this pattern of results contrasts the majority of LPP effects related to emotion regulation, a replication of the Langeslag and van Strien (2010) study with improved methodology is warrant to decide whether a spontaneously applied emotion regulation strategy indeed has unique effects on LPPs. Accordingly, we intended to investigate emotion regulation effects on LPP amplitudes under a free strategy choice (without training in advance) with the following methodological improvements. In contrast to Langeslag and van Strien who used a block design with varying orders across participants, we realized a completely randomized trial order. Moreover, to gain a complete picture of naturalistic emotion regulation, we considered it important to investigate regulation of both positive and negative emotions, at central and parietal brain regions and different time frames, and also with various biopsychological measures. Whereas Langeslag and van Strien (2010) assessed modulations of LPPs only up to 1000 ms after stimulus onset, we investigated LPP modulations up to 4000 ms after stimulus onset and also measured EMG modulations as a manipulation check.

This approach to further investigate emotion regulation without specific strategy instructions seems important to increase the ecological validity of such studies. In everyday life, we continuously have to regulate our emotions without being trained to do so in a specific way beforehand. Additionally, it is known that patients with psychiatric disorders often suffer from emotion regulation deficits (Aldao and Dixon-Gordon, 2014; Gross, 2002). A straightforward assessment of their deficient emotion regulation capabilities requires a paradigm without strategy training because such strategy training would already function as some sort of psychotherapeutic intervention.

Our research question was whether emotion regulation also works under free choice of regulation strategies in healthy subjects. We therefore investigated emotion regulation effects on ratings of affect, LPPs and facial EMG responses during free strategy choice. Facial EMG of M. zygomaticus major and of M. corrugator supercilii as indicator of pleasant and unpleasant affective valence, respectively, has been found to be a good marker of emotion regulation as those muscles' activity increases from down-, to not-, to up-regulation during the corresponding emotions (Jackson et al., 2000; Wu et al., 2012). As a matter of fact, the present study is to our knowledge the first combining EEG and EMG measurements during emotion regulation. The assessment of EEG, EMG, and valence and arousal ratings during emotion regulation allows a direct comparison of different implicit and explicit emotion and regulation effects and allows further conclusions about the interpretation of changes in LPPs. In addition, we planned to study emotion regulation after both pleasant and unpleasant pictures, while most previous studies concentrated on the investigation of either positive or negative emotions compared to neutral affective states (Dunning and Hajcak, 2009; Foti and Hajcak, 2008; Hajcak and Nieuwenhuis, 2006; Krompinger et al., 2008; MacNamara et al., 2011a, 2011b; Paul et al., 2013).

Recent research (Poole and Gable, 2014) has also shown that approach vs. avoidance related emotional motivation influences the amplitude of the left vs. right frontal LPP differentially. In this study, frontal LPPs elicited by approach-positive and approach-negative pictures were larger in left vs. right frontal regions. LPPs elicited by withdrawal-negative pictures, however, did not differ between left and right frontal regions.

For the mere emotion induction by simply watching affective pictures, we expected higher respectively lower valence ratings for pleasant respectively unpleasant, compared to neutral pictures. Moreover, we hypothesized that arousal ratings and LPP amplitudes would be comparably high for pleasant and unpleasant pictures and higher than for neutral pictures. M. zygomaticus major activation should be higher for pleasant than for unpleasant and neutral images, whereas M. corrugator supercilii activation should be higher for unpleasant compared to pleasant and neutral images. Concerning the regulation of emotions, we expected valence and arousal ratings as well as M. zygomaticus major respectively M. corrugator supercilii activations to be intensified by the up-regulation and attenuated by the down-regulation conditions. In line with the findings of several classical LPP-studies on emotion regulation where participants used specifically instructed and trained regulation strategies, we also expected LPP amplitudes to be intensified by up- and attenuated by down-regulation of both positive and negative emotions. Alternatively, in line with the only other previous study investigating spontaneously applied emotion regulation strategies and LPPs (Langeslag and van Strien, 2010), it would be also possible to detect increased LPPs during both up- and down-regulation conditions.

2. Methods

2.1. Participants

In total, data from 47 undergraduate psychology students from the University of Würzburg were collected. However, data of six subjects had to be excluded because of problems with data recording and study dropout, so that a total of 41 subjects remained for statistical analysis of ratings and EMG data. Among those, there were 32 women and 9 men with an age range from 18 to 31 years ($M = 21.05$, $SD = 2.58$ years). For the statistical analysis of EEG data, another 8 subjects had to be excluded because after artifact rejection, there remained less than 50% of all trials for averaging. Therefore, EEG data of 33 participants (24 women and 9 men) remained to be statistically analyzed. Their age range was from 18 to 31 years (mean age $\pm$ standard deviation: 21.18 ± 2.72 years). These two samples did not differ in age or gender distribution ($ps < .60$).[2] For taking part in this study, participants received course credit. The study design was approved by the local ethics committee. All participants gave their written informed consent.

2.2. Stimulus material

For the induction of positive, negative, and neutral emotions, a total of 222 pictures of the International Affective Picture System (Lang et al., 2005) were presented.[3] Thereof, 12 pictures were used for training trials

[2] All emotion induction and emotion regulation effects in rating and EMG data reported in the results section for the whole sample of 41 participants could also be found in the smaller sample of the 33 participants used for the EEG analysis. Results are available in the supplementary material (supplement 3).

[3] IAPS picture numbers: Training pictures: 2000, 4603, 4631, 8350, 8461, 7004, 7950, 1050, 3063, 6350, 9050, 9410; Test pictures: 5621, 8370, 5460, 5623, 8034, 5626, 4810, 4664, 4652, 4653, 4601, 4599, 4680, 4607, 1731, 1590, 1463, 1440, 1720, 1722, 5660, 7580, 7570, 5660, 2080, 2160, 2150, 8500, 8380, 8190, 8021, 8400, 5623, 8040, 8080, 8250, 4607, 4611, 4680, 4658, 4640, 4608, 4641, 4670, 1610, 1710, 1721, 1811, 1510, 1600, 5260, 5982, 5700, 5830, 5600, 2070, 2391, 2057, 8502, 8090, 8030, 8210, 8490, 8031, 8200, 8496, 4653, 4651, 4610, 4650, 4660, 4599, 4690, 4606, 5831, 1460, 1650, 1750, 1920, 1540, 5890, 5990, 5270, 5628, 2165, 2050, 2550, 8501, 8540, 8120, 7550, 2840, 2570, 2890, 2381, 2210, 4000, 2200, 2020, 2580, 2600, 2720, 8311, 2221, 2880, 7233, 7090, 5740, 5731, 7006, 5500, 7700, 7190, 7183, 7285, 5390, 7205, 5120, 7234, 7224, 9420, 6571, 9400, 9415, 9433, 9520, 3150, 3140, 9452, 6242, 6250, 6410, 6510, 2110, 6200, 6210, 3160, 9042, 3190, 9220, 9290, 9280, 9611, 9470, 9000, 9571, 1111, 1274, 9340, 9622, 3051, 3181, 6312, 9006, 4621, 9250, 9050, 6821, 6230, 6244, 6300, 6241, 6610, 6370, 3500, 6560, 2100, 9430, 2205, 2751, 9102, 9280, 9920, 2692, 9140, 9180, 7380, 9041, 9320, 9621, 3062, 3350, 3400, 9420, 3550, 6831, 9421, 2900, 2691, 6216, 6243, 6540, 6314, 6360, 2120, 6550, 9911, 9102, 2710, 2750, 9912, 6020, 9007, 9480, 1220, 9008, 9300, 9620, 9561, 9182.