Biological Psychology 124 (2017) 119–132

Contents lists available at ScienceDirect

Biological Psychology

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

An electrophysiological investigation of emotional abnormalities in groups at risk for schizophrenia-spectrum personality disorders

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ARTICLE INFO

Article history:
Received 22 June 2016
Received in revised form 26 January 2017
Accepted 3 February 2017
Available online 5 February 2017

Keywords:
Late positive potential
LPP
Automatic emotion processing
Controlled emotion processing
Cognitive reappraisal
IAPS

ABSTRACT

Both extreme levels of social anhedonia (SocAnh) and perceptual aberration/magical ideation (PerMag) are associated with risk for schizophrenia-spectrum disorders and with emotional abnormalities. Yet, the nature of any psychophysiological-measured affective abnormality, including the role of automatic/controlled processes, is unclear. We examined the late positive potential (LPP) during passive viewing (to assess automatic processing) and during cognitive reappraisal (to assess controlled processing) in three groups: SocAnh, PerMag, and controls. The SocAnh group exhibited an increased LPP when viewing negative images. Further, SocAnh exhibited greater reductions in the LPP for negative images when told to use strategies to alter negative emotion. Similar to SocAnh, PerMag exhibited an increased LPP when viewing negative images. However, PerMag also exhibited an increased LPP when viewing positive images as well as an atypical decreased LPP when increasing positive emotion. Overall, these results suggest that at-risk groups are associated with shared and unique automatic and controlled abnormalities.

1. Introduction

Schizophrenia and schizophrenia-spectrum personality disorders (e.g., schizotypal personality disorder, schizoid personality disorder, paranoid personality disorder) are associated with abnormalities in emotional information processing, generation, and expression (Cohen & Minor, 2010; Kohler & Martin, 2006; Kring & Moran, 2008), and these abnormalities are associated with poor outcomes (Green, Hellemann, Horan, Lee, & Wynn, 2012; Kring, Gur, Blanchard, Horan, & Reise, 2013). Similarly, other evidence suggests that people at risk for schizophrenia-spectrum personality disorders also have abnormalities related to emotions. For example, social anhedonia (SocAnh), which is associated with increased risk of schizophrenia-spectrum personality disorders (Gooding, Tallent, & Matts, 2005; Kwapil, 1998), is characterized by diminished self-reported experience of positive emotion (e.g., Brown, Silvia, Myin-Germeys, & Kwapil, 2007; Kerns, Docherty, & Martin, 2008; Martin, Becker, Cicero, Docherty, & Kerns, 2011). Further, there is evidence that SocAnh is associated with decreased attention to emotions, including increased reports of wanting to ignore positive emotions and decreased influence of negative mood on judgment (Martin et al., 2011; Martin, Becker, Cicero, & Kerns, 2013; Martin, Cicero, Bailey, Karcher, & Kerns, 2015). Alternately, there is some evidence that individuals who report increased frequency of psychotic-like experiences, and thus are also at risk for the development of schizophrenia-spectrum disorders (e.g., extremely elevated perceptual aberrations and/or magical ideation, or PerMag; Chapman, Chapman, Kwapil, Eckblad, & Zinser, 1994), might exhibit greater reactivity to both positive and negative stimuli (e.g., Karcher & Shean, 2012). Also, when they are exposed to a stressor, they report increased psychotic-like symptoms (Collip et al., 2013). Hence, understanding the nature of specific emotion mechanisms in at-risk individuals could not only help treat functional disability in people with a schizophrenia-spectrum personality disorder, but also potentially could help prevent onset of a spectrum personality disorder. However, the nature of deficits in these emotion mechanisms in at-risk populations is still unclear (e.g., Kring & Moran, 2008). The current research used event-related potentials (ERPs) to examine whether people with elevated SocAnh or PerMag exhibit altered neural activation either when passively viewing emotional

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http://dx.doi.org/10.1016/j.biopsycho.2017.02.001
0301-0511/

images or when actively attempting to regulate their emotional responses.

Affective neuroscience theory and previous research suggests multiple neural systems are associated with more automatic, reflexive processing of affective stimuli and more controlled, reflective processing of affective stimuli (Barrett, 2006; Cunningham, Dunfield, & Stillman, 2013; Gross & Thompson, 2007; Ochsner & Gross, 2007). More automatic affective processing occurs when one is presented with an affective stimulus that elicits an implicit evaluation which is "rapid, unconscious and robust across situations" (Cunningham & Zelazo, 2007; p. 97) and occurs in the first few hundred milliseconds after stimulus presentation (Barrett, Mesquita, Ochsner, & Gross, 2007; Cunningham & Zelazo, 2007; Johnstone, van Reekum, Urry, Kalin, & Davidson, 2007; Ochsner & Gross, 2005). In contrast, more controlled affective processing refers to the deliberate control of one's emotional response (Cunningham et al., 2013; Ochsner & Gross, 2007; Phillips et al., 2008). According to the Iterative Reprocessing Model of emotion (Cunningham et al., 2013), there is a bidirectional ongoing relationship of mechanisms subserving more automatic and controlled processes. Hence, abnormalities in emotion processing associated with SocAnh or PerMag could involve either automatic and/or controlled processes.

There is evidence consistent with abnormalities of both automatic and controlled affective processing in SocAnh. For instance, decreased self-reported positive affect in SocAnh is generally consistent with a decreased automatic focus specifically on positive information and on positive emotional experience (Cohen, Callaway, Najolia, Larsen, & Strauss, 2012; Kerns et al., 2008). At the same time, increased self-reported negative affect in SocAnh is generally consistent with an increased automatic focus specifically on negative information (Cohen et al., 2012; Kerns et al., 2008). Additionally, there is also evidence consistent with increased controlled avoidance of both positive and negative affective information in SocAnh. For instance, SocAnh is associated with an increased self-reported desire to ignore positive emotions (Martin et al., 2011). This might result in increased controlled avoidance of positive emotional information and experience. Further, this increased controlled avoidance could result in a decreased habitual or automatic decreased processing of positive emotional information in SocAnh. However, in addition to increased avoidance of positive affect, some evidence also suggests decreased attention to negative information in SocAnh. In particular, despite a strong association between current negative mood and judgment of future risk in both healthy controls and PerMag individuals, there was no association between current negative mood and risk judgment in SocAnh ($r = 0.00$; Martin et al., 2011). Hence, overall, evidence suggests that SocAnh could be associated with blunted automatic processing of positive affect but also exaggerated automatic processing of negative affect as well as increased controlled avoidance of both positive and negative affect. However, there is little evidence of altered neural responses to affective stimuli in SocAnh (Hooker et al., 2014).

In contrast to SocAnh, there is some evidence suggesting elevated scores on measures of PerMag and related scales (e.g., Schizotypal Personality Questionnaire), might involve increased reactivity to both positive and negative stimuli (e.g., Karcher & Shean, 2012; Ragsdale, Mitchell, Cassisi, & Bedwell, 2013). This increased reactivity could be related to either exaggerated automatic processing or deficits in controlled regulation. For example, other positive schizotypy scales strongly correlated with PerMag have been associated with increased self-reports of positive emotions in response to pleasurable events compared to controls (Shi et al., 2012). Relatedly, PerMag scores are at least moderately positively correlated ($r = 0.43–0.49$; Eckblad & Chapman, 1986) with the Hypomanic Personality Scale which is characterized by subsyndromal mania, with both PerMag and Hypomanic Personality predictive of future onset of bipolar disorders (Chapman et al., 1994; Kwapil et al., 2000). At the same time, in response to a daily stressor, individuals with increased self-reported psychotic experiences report greater increases in negative affect than healthy controls (Myin-Germeys, van Os, Schwartz, Stone, & Delespaul, 2001). This suggests that PerMag might be associated with elevated stress reactivity, which has been consistently linked to the clinical course and functional outcome in psychotic disorders (Myin-Germeys & van Os, 2007). Overall, such an increased reactivity to emotional stimuli could potentially reflect an exaggerated automatic response or potentially a deficit in controlled regulation of emotional responses.

Hence, there is evidence that both SocAnh and PerMag may be associated with altered automatic and/or controlled processing of emotion. One way to examine automatic and controlled processing of affective stimuli and affective experience is to examine ERPs, including the late positive potential (LPP; Hajcak, MacNamara, & Olvet, 2010). Both research (e.g., Briggs & Martin, 2008; Hilgard, Weinberg, Hajcak Proudfit, & Bartholow, 2014; Schupp et al., 2000; Schupp et al., 2004; Weinberg & Hajcak, 2010) and theory (see Nieuwenhuis, Aston-Jones, & Cohen, 2005) have linked the amplitude of the LPP to the motivational significance of the eliciting stimulus. For example, studies using affective images, such as those comprising the International Affective Picture Set (IAPS; Lang, Bradley, & Cuthbert, 2005), consistently shows that both positive and negative images elicit larger LPP amplitudes than do neutral images (Schupp et al., 2000, 2004). This property of the LPP makes it particularly well suited to the aims of the current research because it allows for the covert assessment of automatic processing of affective stimuli without the reliance on self-reports. For example, if SocAnh is associated with a blunted automatic processing of positive affective stimuli, then SocAnh might be associated with a smaller increase in the LPP for passive viewing of positive affective stimuli than for neutral stimuli when compared to control or PerMag participants. In contrast, if risk for a schizophrenia-spectrum personality disorder more generally is associated with exaggerated automatic processing of negative affective stimuli, then both the SocAnh and PerMag groups might be associated with a larger increase in the LPP for passive viewing of negative affective stimuli than for neutral stimuli when compared to control participants.

In contrast to automatic processing, one way to examine the efficacy of controlled processing of affective stimuli is to examine the LPP in emotion regulation conditions (e.g., in conditions where participants are instructed to use cognitive appraisal to either increase or decrease affective response to affective stimuli) compared to the passive viewing of affective stimuli. Some previous ERP research which has utilized emotion regulation paradigms has found that the instruction to *increase* affect results in larger LPP amplitudes compared to passively viewing affective stimuli (e.g., Gardener, Carr, Macgregor, & Felmingham, 2013; Moser, Most, & Simons, 2010). In contrast, previous research has found that the instruction to *decrease* one's emotional response results in smaller LPP amplitudes compared to passively viewing affective stimuli (Gardener et al., 2013; Hajcak & Nieuwenhuis, 2006; Krompinger, Moser, & Simons, 2008; Moser, Hajcak, Bukay, & Simons, 2006; Moser et al., 2010). If SocAnh is associated with increased controlled avoidance of both positive and negative affective stimuli, then SocAnh might be associated with an altered LPP when attempting to regulate either positive or negative affect. In contrast, if risk for a schizophrenia-spectrum personality disorder more generally is associated with a deficit in controlled regulation of emotional responses, then both the SocAnh and PerMag groups might be associated with altered LPPs when attempting to regulate either positive or negative affect when compared to control participants.

In the current study, we examined automatic and controlled affective processing in SocAnh, PerMag, and control participants. An advantage to studying individuals at risk for a schizophrenia-

Table 1
Demographic information by group.

	Control (n = 18)	SocAnh (n = 20)	PerMag (n = 15)	Group comparisons
Age (mean, (SD))	18.37 (0.76)	18.57 (0.65)	18.68 (0.82)	$F(2, 49) = 0.85$, $p = 0.43$
Race (% Caucasian)	72.2	50.0	60.0	χ^2 (2, N = 53) = 1.96, $p = 0.38$
Sex (% female)	52.6	50.0	63.2	χ^2 (2, N = 53) = 0.69, $p = 0.71$

spectrum disorder (e.g., SocAnh and PerMag groups) over studying those who have crossed the diagnostic threshold is that it allows for the examination of etiological factors without some of the confounds associated with the full-blown illness, such as medication effects (Kwapil, Crump, & Pickup, 2002). At the same time, certain illness features, such as anhedonia, may occur at the same (or even greater) levels in at-risk individuals as patients (Cohen, Auster, MacAulay, & McGovern, 2014), and thus, samples can have similar severity of some symptoms, allowing for increased generalizability between at-risk and patient groups.

We used electroencephalography (EEG) to investigate how these affective processing mechanisms might exhibit similarities or dissimilarities across these three groups. In order to maximize sensitivity to individual differences in these mechanisms, we used trial blocks with a random mix of both stimulus valence (Positive, Negative, Neutral) and condition instruction (LOOK, INCREASE, DECREASE) and examined their influence on LPP amplitudes. Consistent with previous research (e.g., Dennis & Hajcak, 2009; Hajcak, Dunning, & Foti, 2007), we divided the LPP into an "early" and a "late" portion to examine whether any group differences in automatic or controlled processing varied across time. For example, it is possible that automatic deficits might be more evident at an earlier time course whereas controlled deficits might be more evident at a later time course (e.g., Schupp et al., 2007; Taylor, 2002). Based on previous self-report and behavioral data (Martin et al., 2011; Martin, Cicero, & Kerns, 2012; Martin & Kerns, 2010), we hypothesized that SocAnh would be associated with automatic processing deficits of both positive and negative stimuli resulting in decreased early LPP amplitudes to positive stimuli when passively viewing (i.e., the LOOK condition) compared to both of the other groups but increased early LPP amplitudes to negative stimuli when passively viewing compared to the control group. We did not expect a significant difference between the SocAnh and PerMag groups in LPP amplitudes of passively viewing negative stimuli. We also hypothesized that the SocAnh group would exhibit increased controlled avoidance of both positive and negative stimuli evidenced by decreased late LPP amplitudes in the cognitive reappraisal conditions (i.e., the INCREASE and DECREASE conditions) compared to the other groups. In addition, based on previous physiological evidence (Karcher & Shean, 2012), we hypothesized that PerMag would be associated with increased affective reactivity and, subsequently, more difficulty regulating their affective experiences compared to controls. Specifically, we predicted that the PerMag group would show increased early LPP amplitudes to both positive and negative stimuli when passively viewing compared to the control group as well as difficulty downregulating emotional responses in the DECREASE conditions.

2. Methods

2.1. Participants

We used an extreme-groups approach (Preacher, Rucker, MacCallum, & Nicewander, 2005) that compared (a) people with extremely elevated SocAnh, (b) people with extremely elevated PerMag scores, and (c) a control group. The current ERP study participants were Introductory to Psychology students who participated for course credit after taking part in a separate behavioral testing session (Karcher, Martin, & Kerns, 2015). As can be seen in Table 1, there were no significant between group differences on any demographic variable we assessed.[1]

In the current study, there were 23 people in the SocAnh group who scored 1.96 *SD* above the same-sex mean on the Revised Social Anhedonia Scale and 18 people in the PerMag group who scored above 1.96 *SD* above the same-sex mean on the Perceptual Aberration or Magical Ideation scales or had a summed, standardized score from the Perceptual Aberration and Magical Ideation scales above 3.0.

There were 19 people in the control group. Following previous research (e.g., Chapman et al., 1994), individuals in this group scored less than 0.5 standard deviations below the mean on the Revised Social Anhedonia Scale, Perceptual Aberration Scale, and Magical Ideation Scale. In addition, in order to more clearly distinguish elevated SocAnh from psychosis risk, to be recruited for this study both the SocAnh and control groups had to be rated less than a 2 (2 = "mild") on both lifetime Structured Interview for Prodromal Syndromes ratings of Unusual Thought Content/Delusional Ideas and Perceptual Abnormalities/Hallucinations subscales of the SIPS.[2] Further, all PerMag participants in the current study had lifetime (& current) ratings ≥ 2 on both of these subscales.

2.2. Materials

2.2.1. Psychosis-proneness scales

Participants completed the Revised Social Anhedonia Scale (Eckblad, Chapman, Chapman, & Mishlove, 1982; α in current study = 0.86; $M = 12.79$, $SD = 8.24$), which is designed to measure lack of relationships and lack of pleasure from relationships (e.g., "Having close friends is not as important as many people say."). They also completed the Perceptual Aberration Scale (Chapman, Chapman, Raulin, & Edell, 1978; α in current study = 0.87, M = 6.38, SD = 6.71) and the Magical Ideation Scale (Eckblad & Chapman, 1983; α in current study = 0.83, $M = 8.43$, $SD = 6.52$), which are designed to measure psychotic-like distortions and unusual beliefs respectively ("I have sometimes had the feeling that one of my arms or legs is disconnected from the rest of my body"; "Some people can make me aware of them by just thinking about me"). In addition, participants completed the Chapman Infrequency Scale (Chapman & Chapman, 1983) to screen for careless or invalid responses. Based on previous research (Chapman et al., 1994), those who endorsed

[1] Although the groups did not significantly different in terms of race or gender composition, there were numerical differences. Thus, we tested whether the addition of these demographic variables to the models discussed in the Results section changed any of the significant findings, and they did not.

[2] Given rates of SIPS scores in the sample of SocAnh participants recruited for current study (8% with scores ≥ 2), then it would be expected that if they had not been excluded from recruitment, only 1 or 2 people in the SocAnh group in the current study would have had scores ≥ 2. Further, there is no clear evidence that people with SocAnh who are not also elevated on PerMag scores are at increased risk for psychotic disorders (i.e., across two earlier studies at most only a single person with only extremely elevated SocAnh actually developed a psychotic disorder; Gooding et al., 2005; Kwapil, 1998). Moreover, a previous study did not find any evidence that eliminating psychosis risk in a SocAnh group reduced risk for schizophrenia-spectrum disorders, with if anything the rates of spectrum disorders increasing from 24 to 28% (for a recent review, see Debbane et al., 2015; Kwapil, 1998).

3 or more items on this 13-item, true-false scale were eliminated from analyses. The 118-items from these four scales were randomized and then presented to each participant in the same fixed order.

2.2.2. Structured interview for prodromal syndromes

The Structured Interview for Prodromal Syndromes (Miller et al., 2003) was used to assess lifetime and current psychotic-like symptoms. The SIPS is a semi-structured interview and includes assessment of both Unusual Thought Content/Delusional Ideation and Perceptual Abnormalities/Hallucinations. These two types of psychotic-like symptoms are rated on a 0–6 scale, ranging from "absent" to "severe and psychotic", with a rating of 2 indicating a "mild" psychotic-like symptom. All the SIPS interviews were videotaped and were conducted by two graduate student interviewers extensively trained in SIPS administration and scoring (EAM & NRK; inter-rater reliability between the two raters was 0.93 for the Perceptual Abnormalities/Hallucinations and 0.95 for Unusual Thought Content/Delusional Ideation). Interviewers were blind to group membership and questionnaire scores of the participants prior to the interview.

2.3. ERP paradigm

ERPs were recorded while subjects performed an emotion regulation task that used IAPS images (please see the Appendix A for a list of the images used in each valence category), and researchers who collected these data were blind to group membership at the time of collection. Emotion regulation instructions, specifically cognitive reappraisal, were modeled after the self-focused condition from Ochsner and colleagues (Ochsner et al., 2004). Previous research has shown that cognitive reappraisal is associated with activation of lateral prefrontal and other regions associated with emotional and cognitive control (Buhle et al., 2014; Etkin, Egner, & Kalisch, 2011; Ochsner, Bunge, Gross, & Gabrieli, 2002; Ochsner & Gross, 2004) and with reductions in self-reported emotional experience (Ochsner et al., 2004). In the LOOK condition, participants were told to respond naturally to the image and not to alter their natural emotional response in any way. In the INCREASE condition, participants were asked to increase the intensity of the emotion they felt in response to the image or to try to feel the emotion more strongly. They were told they could imagine themselves or a loved one in the pictured event. In the DECREASE condition, participants were asked to decrease the intensity of the emotion they felt in response to the image or to try to feel the emotion less strongly. They were told they could focus on the facts of the image in an objective, non-personal way. Participants were instructed not to focus on small, irrelevant details of the image (e.g., the floor tile) in order to encourage them to engage in an active emotional regulation strategy rather than to use attentional avoidance to down-regulate their emotions.

In each trial of the task, participants were first shown a condition instruction (LOOK, INCREASE, DECREASE) for 2000 ms, followed by a fixation cross for 250 ms and then a target image for 2000 ms. In the LOOK condition participants saw a positive, negative or neutral image; in the INCREASE and DECREASE conditions, participants saw either positive or negative image (but never a neutral image because participants were not asked to increase or decrease their emotional response to neutral images). The inter-trial interval was jittered and ranged from 1400 to 2000 ms. A total of 280 trials were presented (7 blocks of 40 trials each; with 40 trials per condition), during which positive, negative, and neutral images were pseudorandomly presented. That is, a condition was randomly selected and then, based on which condition was selected, an image was randomly selected for presentation. Thus, each positive and negative image was presented three times (once in each condition) and each neutral image was presented one time (once in the LOOK condition).

2.3.1. Image and mood ratings

After EEG recording was completed, participants were asked to rate the valence (*extremely negative* to *extremely positive*) and arousal levels (*low arousal* to *extreme arousal*) of each image they previously viewed, using 1–9 scales. Participants also completed a mood measure. For eight positive words (e.g., happy) and eight negative words (e.g., sad), participants were asked to rate their current mood on a scale ranging from 0 (*not at all*) to 6 (*extremely*).

2.4. EEG recording and processing

The EEG was recorded from 30 tin electrodes (F3, Fz, F4, FC3, FCz, FC4, C3, Cz, C4, TP7, CP3, CPz, CP4, TP8, T5/P7, P3, Pz, P4, T6/P8, PO7, PO5, PO3, POz, PO4, PO6, PO8, O1, Oz, O2, A2) fixed in an electrode cap (Electro-Cap International) and placed according to an expanded 10/20 system (American Encephalographic Society, 1994). Electrooculogram generated from horizontal and vertical eye movements was measured via two electrodes located approximately 1 cm outside the outer edge of the right and left eyes and two electrodes placed approximately 1 cm above and below the center of the right eye, respectively. All EEG electrodes were referenced online to the right mastoid; an average mastoid reference was derived offline. EEG was amplified with a Neuroscan Synamps2 amplifier (Compumedics) and bandpass filtered on-line at 0.1–30 Hz (half-amplitude) using a sampling rate of 1000 Hz. Impedance was kept below 5 kΩ at all electrodes.

All signal processing and analysis procedures were conducted through EEGlab (Delorme & Makeig, 2004) with the ERPLAB toolbox (Lopez-Calderon & Luck, 2014) for MatLab (MathWorks, 2014). Data preprocessing included the removal of large muscle artifacts or extreme offsets through a semi-automated procedure that identified voltage deflections of ±200 microvolts (μV). Data were downsampled to 500 Hz. Identification and removal of eyeblink artifacts was accomplished using an independent component analysis (ICA). After the ICA, stimulus-locked epochs of 1400 ms (including 200 ms pre-stimulus baseline) were created for each channel. Epochs containing either voltage deflections of ±100 microvolts (μV) in any of the centro-parietal channels (Pz, P3, P4, CPz, CP3, CP4) or ±75 μV in the ocular channels were rejected prior to averaging. Following previous research (e.g., Franken, Nijs, Muris, & Van Strien, 2007; Horan, Wynn, Kring, Simons, & Green, 2010), participants' data were excluded if more than 50% of the epochs contained artifacts. In the current study, all participants whose data were excluded (N = 7; SocAnh n = 3; PerMag n = 3; Control n = 1) had more than 75% of trials rejected, and of the participants maintained, all had at least 10 trials in each quantified waveform. Artifact-free EEG data were then averaged according to participant, stimulus and instruction conditions. Finally, individual subject averages were filtered with a Butterworth lowpass, half-amplitude filter of 15 Hz.

Because the LPP is maximal at centro-parietal sites (Foti & Hajcak, 2008; Hajcak et al., 2007; Keil et al., 2002; Schupp et al., 2000; Weinberg & Hajcak, 2010), LPP amplitude was measured at six centro-parietal sites (Pz, P3, P4, CPz, CP3, and CP4). Also consistent with previous research (e.g., Dennis & Hajcak, 2009; Hajcak et al., 2007), the LPP was divided into early and late portions, defined as the average voltage occurring between 400 and 700 and 700–1100 ms post-stimulus, respectively. Grand average ERP waveforms showing the LPP as a function of group, image valence and instruction condition are presented in Figs. 1–3.

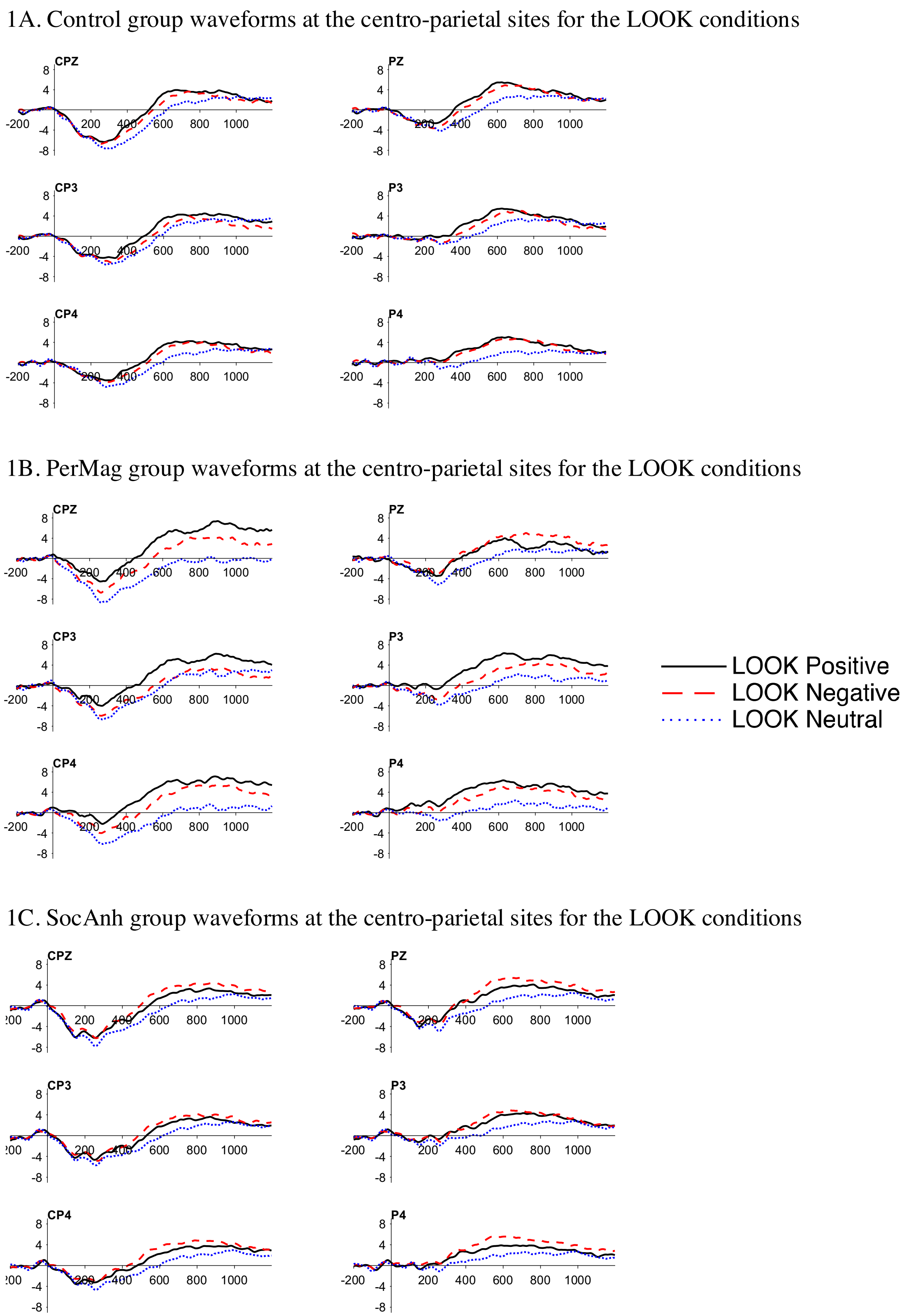

Fig. 1. (A) Control group waveforms at the centro-parietal sites for the LOOK conditions. (B) PerMag group waveforms at the centro-parietal sites for the LOOK conditions. (C) SocAnh group waveforms at the centro-parietal sites for the LOOK conditions.

2.5. Procedure

Participants were seated in a soundproof recording chamber. After electrode placement, they completed both the emotion regulation task and another, unrelated, non-emotional task not reported here in counterbalanced order. Immediately following the EEG session, participants completed current mood and image ratings.

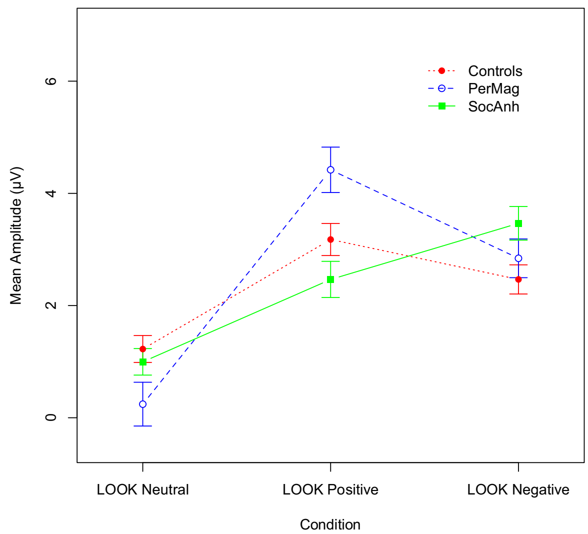

Fig. 2. Mean amplitudes averaged across the centro-parietal sites by group for the LOOK conditions.

2.6. Statistical approach for the ERP data

As in many other ERP studies (e.g., Hilgard et al., 2014; Tremblay & Newman, 2015; Wierda, van Rijn, Taatgen, & Martens, 2010), we used mixed hierarchical linear models (HLM) to test the effects of the stimulus and instruction manipulations on LPP amplitudes within and across groups. When analyzing psychophysiological data, multivariate approaches, such as HLM, have several advantages over univariate approaches (Gratton, 2007; Vasey & Thayer, 1987). First, multivariate approaches do not make the same statistical assumptions often required by univariate models (e.g., sphericity; Jennings & Wood, 1976), and therefore do not require corrections for violations of these assumptions that result in reduced statistical power. Also, the within-subject variability in EEG data is often greater than the variability associated with manipulated variables of interest (Gratton, 2007), contributing to inflated error variance in univariate models that can also reduce statistical power. The use of an intercept for each electrode within each subject, as used in the current statistical approach, reduces these error variance estimates, thereby maintaining power. In addition, multivariate approaches do not use listwise deletion for instances of missing data, and therefore are more robust to incomplete data across individuals (e.g., artifact rejection in EEG resulting in different numbers of electrodes per subject in any given condition).

All statistical analyses were conducted using R (R Core Team, 2015). Specific packages used to run HLM models in R included *nlme* (Pinheiro, Bates, DebRoy, Sarkar, & Team, 2015), *lme4* (Bates, Maechler, Bolker, & Walker, 2015), and *lmerTest* (Kuznetsova, Brockhoff, & Christensen, 2015). Because our design was not fully crossed (i.e., there was no INCREASE or DECREASE Neutral conditions), we could not conduct an omnibus test of Group (Control vs. PerMag vs. SocAnh) X Valence (Neutral vs. Positive vs. Negative) X Condition (LOOK vs. INCREASE vs. DECREASE) X Time (Early LPP vs. Late LPP). Thus, we ran one mixed model to examine LPP amplitudes of the groups only in the LOOK conditions across valence and time: Group (Control vs. PerMag vs. SocAnh) X Valence (Neutral vs. Positive vs. Negative) X Time (Early LPP vs. Late LPP). Then, we ran another mixed model to examine LPP amplitudes of the groups only in response to positive stimuli across conditions and time: Group (Control vs. PerMag vs. SocAnh) X Condition (LOOK vs. INCREASE vs. DECREASE) X Time (Early LPP vs. Late LPP). Then the same model was conducted only for negative stimuli. We ran these last two analyses separately for positive stimuli and negative stimuli because in HLM models, one condition in each factor is the reference condition (e.g., LOOK Positive or LOOK Negative), and it did not seem reasonable to use the same reference condition in all analyses (i.e., using LOOK Positive as the reference condition in comparison to INCREASE Negative and DECREASE Negative and vice versa). Thus, we ran separate models for positive and negative stimuli with each respective LOOK condition as the reference condition (i.e., LOOK Positive for INCREASE and DECREASE Positive; and LOOK Negative for INCREASE and DECREASE Negative). All models included random intercepts of subject and of electrodes within subjects.

After the processing of the ERP data as explained above, three individuals in the SocAnh group, three individuals in the PerMag group, and one individual in the control group were excluded due to excessive EEG artifact. Thus, in each of the model, there were 20 individuals in the SocAnh group, 15 in the PerMag group, and 18 in the Control group.

3. Results

3.1. Exaggerated automatic responses to positive stimuli in PerMag and to negative stimuli in both at-risk groups

First, we tested whether the amplitudes of LPP in the passive viewing conditions (i.e., LOOK conditions) varied by group (Control vs. PerMag vs. SocAnh), valence of the stimuli (Neutral vs. Positive vs. Negative), or time (early LPP vs. late LPP) in a mixed effects model. Because the 3-way interactions between group, valence, and time were not significant (all $ps > 0.14$; AIC = 10,174, BIC = 10,296, log likelihood = −5065.1) and because a χ^2 difference test indicated that the full model (i.e., with 3-way interactions) and a reduced model (i.e., with only 2-way interactions) were not significantly different (χ^2 (4) = 4.01, p > 0.41), the reduced model was used for analyses (AIC = 10,170, BIC = 10,270, log likelihood = −5067.1). As can be seen in Figs. 1 and 2, there were significant 2-way interactions between group and valence.

Specifically, although as expected the LPP was significantly larger when looking at positive images than when looking at neutral images for all groups, all $ps < 0.001$, the PerMag group exhibited significantly greater increases in amplitudes when passively looking at positive images than when looking at neutral images compared to both the SocAnh and control groups: PerMag vs. SocAnh: $t(1839) = 5.91$, $p < 0.001$, B = 2.71, 95% CI [1.81–3.61]; PerMag vs. Controls: $t(1839) = 4.74$, $p < 0.001$, B = 2.22, 95% CI [1.3–3.14]. Although the increase from LOOK Neutral to LOOK Positive was smaller for the SocAnh group than the control group, these groups did not significantly differ from each other, $t(1839) = -1.11$, $p = 0.27$, B = −0.48, 95% CI [−1.34–0.37 [although note that this includes both early and late LPP; in an exploratory analysis, if we restricted our analyses to only the early LPP then there was a significant difference between SocAnh and the other two groups for positive stimuli, e.g., versus controls $t(315) = -1.66$, $p = 0.049$, B = −0.92, 95% CI [−2.01 – 0.17], however, this difference with controls would not be significant when corrected for multiple comparisons]. Thus, as can be seen in Tables 2 and 3, these results indicate that although all of the groups showed increased LPP amplitudes in response to positive stimuli compared to neutral stimuli, there is evidence of an exaggerated automatic response to positive images in PerMag compared to the other groups.

In contrast to the results for passively viewing positive images, the results for passively viewing negative images were very different. Although as expected, the LPP was significantly larger when looking at negative images than when looking at neutral images for all groups, all $ps < 0.001$, both the PerMag and SocAnh groups exhibited significantly greater increases in LPP amplitude

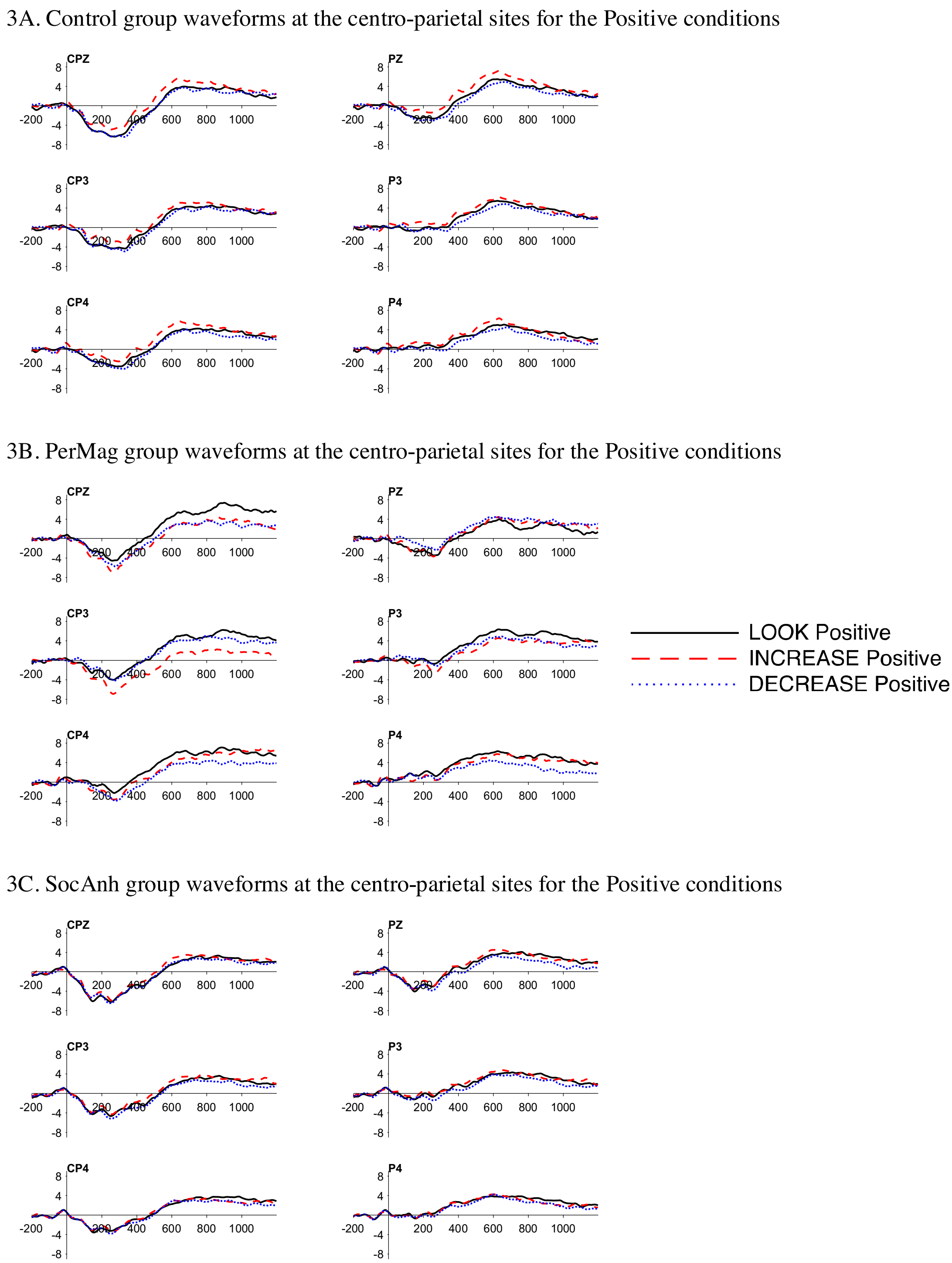

Fig. 3. (A) Control group waveforms at the centro-parietal sites for the Positive conditions. (B) PerMag group waveforms at the centro-parietal sites for the Positive conditions. (C) SocAnh group waveforms at the centro-parietal sites for the Positive conditions.

when passively looking at negative images than when looking at neutral images compared to the control group [PerMag vs. Controls: $t(1839) = 2.89$, $p = 0.004$, B = 1.36, 95% CI [0.44–2.28]; SocAnh vs. Controls: $t(1839) = 2.82$, $p = 0.005$, B = 1.23, 95% CI [0.37–2.08]]. The PerMag and SocAnh groups did not differ from each other, $t(1839) = -0.29$, $p = 0.77$, B = −0.13, 95% CI [−1.03 – 0.77]. Thus, these results indicate that although all of the groups showed increased LPP amplitudes in response to negative stimuli compared to neutral stimuli, the at-risk groups show exaggerated automatic responses to negative stimuli.

Finally, when comparing passive viewing of positive vs. negative stimuli in this model, the groups showed a different pattern of responses. Whereas the PerMag and control groups showed the same pattern—significantly larger LPPs in response to positive images compared to negative images, in contrast the SocAnh group showed the opposite pattern with significantly larger LPPs in response to negative images compared to positive images. Also, the SocAnh group significantly differed from the other two groups on this relative difference in LPP amplitude for positive versus negative images (SocAnh vs. Controls, $t(1839) = 3.93$, $p < 0.001$,

Table 2
Mean Early LPP (400–700 ms) Amplitudes (μV) Across the Centro-Parietal Electrodes for Each Image Type in Each Condition.

	Control group (n = 18)	SocAnh group (n = 20)	PerMag group (n = 15)
Neutral Images			
Look condition	−0.05 (3.22)	−0.09 (3.66)	−0.77 (4.29)
Positive Images			
Look condition	2.74 (4.02)	1.70 (5.25)	3.79 (4.55)
Increase condition	3.89 (4.24)	2.32 (4.92)	2.30 (4.84)
Decrease condition	2.19 (4.08)	1.49 (4.14)	2.73 (3.18)
Negative Images			
Look condition	1.83 (3.69)	2.97 (4.67)	1.78 (4.77)
Increase condition	4.45 (5.62)	2.70 (4.24)	4.69 (7.31)
Decrease condition	2.85 (4.50)	1.90 (4.54)	2.88 (3.87)

Note: Values in parentheses are *SDs*.

Table 3
Mean Late LPP (700–1100 ms) Amplitudes (μV) Across the Centro-Parietal Electrodes for Each Image Type in Each Condition.

	Control group (n = 18)	SocAnh group (n = 20)	PerMag group (n = 15)
Neutral Images			
Look condition	2.50 (2.57)	2.08 (2.71)	1.23 (4.83)
Positive Images			
Look condition	3.61 (3.76)	3.15 (4.46)	5.04 (3.67)
Increase condition	4.01 (4.02)	2.95 (3.68)	3.81 (3.33)
Decrease condition	3.02 (4.19)	2.33 (3.13)	3.56 (1.93)
Negative Images			
Look condition	3.09 (3.12)	3.96 (4.12)	3.91 (3.09)
Increase condition	5.42 (4.69)	4.06 (3.57)	6.59 (6.04)
Decrease condition	4.14 (3.59)	3.10 (3.60)	3.14 (2.67)

Note: Values in parentheses are *SDs*.

B = 1.71, 95% CI [−0.86 – 2.57]; SocAnh vs. PerMag, $t(1839) = 5.62$, $p < 0.001$, B = 2.58, 95% CI [1.68–3.48]; in contrast, PerMag vs. Controls, $t(1839) = -1.84$, $p = 0.08$, B = 0.96, 95% CI [−0.05 – 1.78]).

As expected, there were significant valence by time interactions (all *ps* < 0.02), which indicate that in response to valenced stimuli compared to neutral stimuli, the LPP shows larger decreases over time. That is, because LPP amplitudes are bigger for valenced images compared to neutral images, the LPP decreases more over time for the valenced conditions than the LPP for the neutral condition. There were no significant group by time interactions (all *ps* > 0.53), which indicates that the differences in amplitude of the LPP for each group did not vary with time.

3.2. PerMag shows atypical decreases in cognitive reappraisal conditions involving positive stimuli

Next, we examined whether the amplitudes of LPP in response to positive stimuli varied by group (Control vs. PerMag vs. SocAnh), condition (LOOK vs. INCREASE vs. DECREASE), or time (early LPP vs. late LPP) in a mixed effects model. Because the 3-way interactions between group, condition, and time were not significant (all *ps* > 0.22, AIC = 9838.2, BIC = 9960.4, log likelihood = −4897.1) and because a χ^2 difference test indicated that the full model (i.e., with 3-way interactions) and a reduced model (i.e., with only 2-way interactions) were not significantly different (χ^2 (4) = 3.47, p > 0.48), the reduced model was used for analyses (AIC = 9833.7, BIC = 9933.6, log likelihood = −4898.8). There were significant 2-way interactions between group and condition. As can been seen in Fig. 3 for the cognitive reappraisal INCREASE condition, the PerMag group actually exhibited a significant decrease in the LPP from the LOOK condition compared to the other groups (PerMag vs. Controls, $t(1579) = -5.11$, $p < 0.001$, B = −2.14, 95% CI [−2.96 – −1.32]; PerMag vs. SocAnh, $t(1579) = -3.75$, $p < 0.001$, B = −1.53, 95% CI [−2.34 – 0.73]). That is, although the control group showed a larger LPP in the INCREASE condition (compared to the LOOK condition; $p < 0.01$) and the SocAnh group showed no significant difference in LPP amplitude in the INCREASE condition (compared to the LOOK condition; $p = 0.47$), the PerMag group showed smaller LPPs in the INCREASE compared to the LOOK condition ($p < 0.001$). Further, it is not just that the PerMag group exhibited less of an increase in the LPP for the INCREASE Positive condition, as the PerMag group also exhibited a significantly smaller LPP than the other two groups when considering the INCREASE Positive condition by itself. In addition, although the SocAnh group showed a non-significant increase between the LOOK Positive and INCREASE Positive conditions, the SocAnh and Control groups did not significantly differ from each other, $t(1579) = -1.55$, p =0.12, B = −0.60, 95% CI [−1.37 – 0.16].

All groups showed the expected pattern of smaller LPP amplitudes in the DECREASE condition compared to the LOOK condition (control group, $p < 0.01$; PerMag, $p < 0.001$,; SocAnh, $p = 0.02$), and there were no significant differences between the groups in changes in LPP amplitudes from the LOOK Positive to DECREASE Positive condition (all *ps* > 0.08). In addition, there were no significant group by time or condition by time interactions (all *ps* > 0.1). Thus, there was evidence that the LPP in response to positive stimuli atypically decreased for PerMag in the INCREASE condition.

3.3. SocAnh shows a decrease in cognitive reappraisal conditions involving negative stimuli

Last, we examined whether the amplitudes of LPP in response to negative stimuli varied by group (Control vs. PerMag vs. SocAnh), condition (LOOK vs. INCREASE vs. DECREASE), or time (early LPP vs. late LPP) in a mixed effects model. Because the 3-way interactions between group, condition, and time were not significant (all *ps* >0.1, AIC = 9999.9, BIC = 10,122, log likelihood = −4977.7) and because a χ^2 difference test indicated that the full model (i.e., with 3-way interactions) and a reduced model (i.e., with only 2-way interactions) were not significantly different (χ^2 (4) = 8.45, p > 0.08), the reduced model was used for analyses (AIC = 9,999.9, BIC = 10,100,

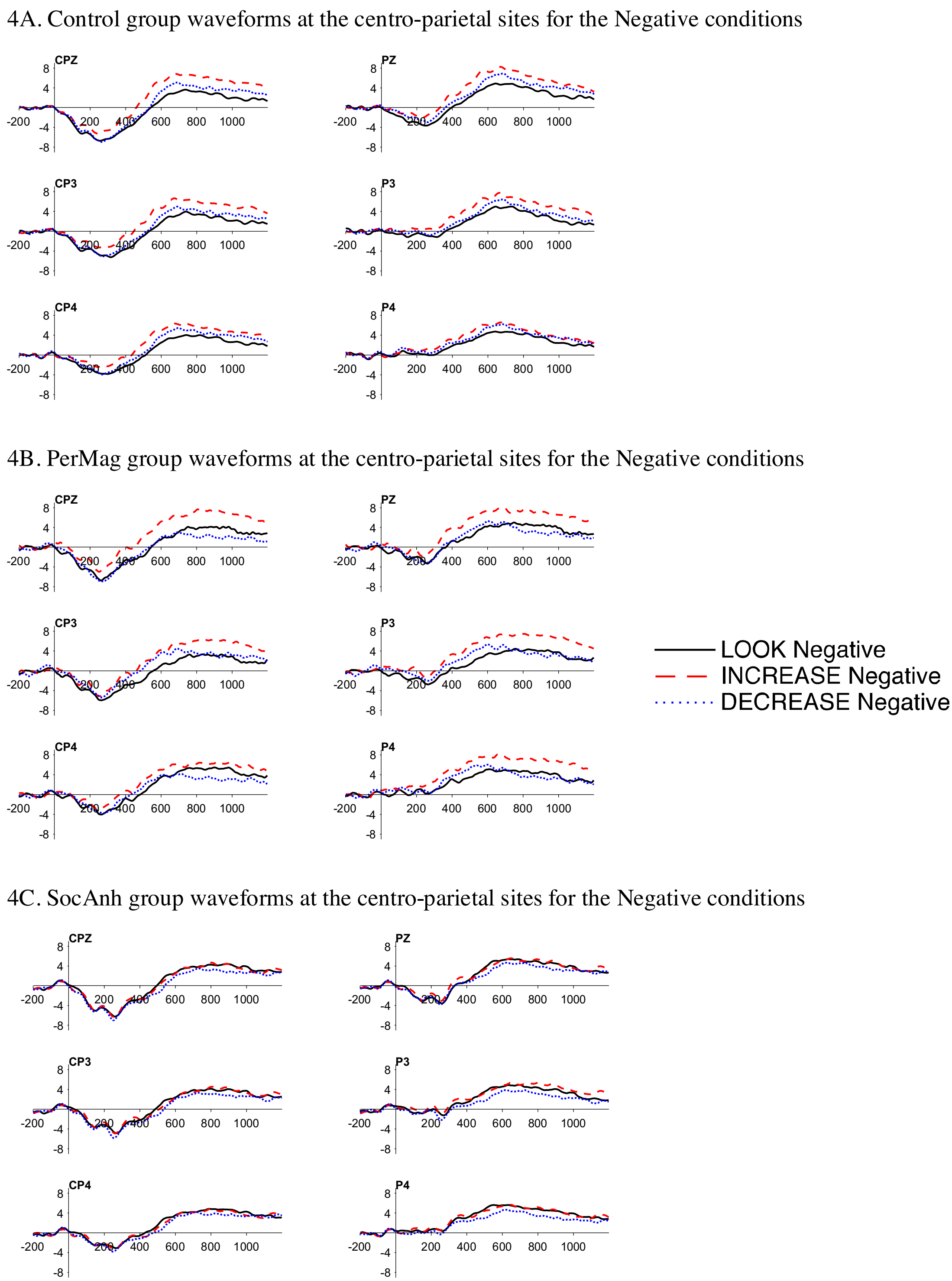

Fig. 4. (A) Control group waveforms at the centro-parietal sites for the Negative conditions. (B) PerMag group waveforms at the centro-parietal sites for the Negative conditions. (C) SocAnh group waveforms at the centro-parietal sites for the Negative conditions.

log likelihood = −4981.9). There were significant 2-way interactions between group and condition. In contrast to the results for the cognitive reappraisal conditions for positive stimuli, the results for the cognitive reappraisal conditions for negative stimuli were very different.

As can been seen in Fig. 4, the SocAnh group exhibited a smaller LPP in all of the cognitive reappraisal conditions group comparisons containing negative images [INCREASE compared to LOOK: SocAnh vs. Controls, $t(1579) = -6.16$, $p < 0.001$, B = −2.55, 95% CI [−3.36 – −1.74]; SocAnh vs. PerMag, $t(1579) = -6.62$, $p < 0.001$, B = −2.88, 95% CI [−3.73 – −2.03]; DECREASE compared to LOOK: SocAnh vs. Controls, $t(1579) = -4.81$, $p < 0.001$, B = −1.99, 95% CI [−2.80 – −1.18]; SocAnh vs. PerMag, $t(1579) = -2.59$, $p < 0.001$, B = −1.13, 95% CI [−1.98 – −0.28]]. In contrast, the PerMag and control groups did not significantly differ from each other in these emotional regulation condition comparisons, both *ps* > 0.08. That is, while the control and PerMag groups showed significantly larger LPPs in three of the four cognitive reappraisal conditions involving

Table 4
Means (Standard Deviation) of Image Ratings and Mood Measure by Group.

	Control group (n = 18)	SocAnh group (n = 20)	PerMag group (n = 15)
Positive Images			
Valence Rating	7.23 (.69)	7.25 (.67)	7.37 (.71)
Arousal Rating	5.95 (1.34)	5.79 (1.41)	6.30 (1.05)
Negative Images			
Valence Rating	1.91 (.43)	2.16 (.49)	1.89 (.49)
Arousal Rating	6.15 (1.04)	5.85 (1.36)	6.14 (1.76)
Neutral Images			
Valence Rating	4.89 (.44)	5.08 (.54)	4.86 (.63)
Arousal Rating	2.97 (1.17)	3.09 (.94)	3.47 (.91)
Positive Mood Rating	19.78 (7.58)	16.30 (6.96)	20.27 (5.78)
Negative Mood Rating	8.72 (4.81)	12.80 (9.66)	10.33 (4.82)

negative stimuli compared to the LOOK condition (all $ps < 0.001$, except for DECREASE vs. LOOK for the PerMag, $p = 0.69$), the SocAnh group exhibited no significant difference in LPP amplitude from the LOOK condition to INCREASE condition ($p = 0.72$) and a significant decrease from the LOOK condition to the DECREASE condition ($p < 0.001$). Further, it is not just that the SocAnh group exhibited less of an increase in the LPP for the INCREASE Negative condition, as the SocAnh group also exhibited a significantly smaller LPP than the other two groups when considering the INCREASE Negative condition by itself. Also, there were no significant group by time or condition by time interactions, all $ps > 0.2$. Hence, although the SocAnh group exhibited a significantly larger LPP when passively viewing negative images compared to the control group, they exhibited less of an increase and more of a decrease in the LPP during INCREASE/DECREASE the cognitive reappraisal conditions for negative stimuli compared to both the control and PerMag groups.

3.4. Image and current mood ratings

We examined whether groups differed in their valence or arousal ratings of the images (made at the end of the study). Overall, we found no group differences in ratings of images. As can be seen in Table 4, all groups rated the positive images significantly more positive than the negative images (all $ps < 0.001$), but they did not differ in their ratings of arousal levels between positive and negative images, all $ps > 0.49$. In addition, all groups rated the positive images significantly more positive and the negative images significantly more negative than the neutral images, all $ps > 0.001$, as well as significantly more arousing, all $ps > 0.001$. Also, a series of one-way ANOVAs with group as a factor revealed that the groups did not differ in their valence or arousal ratings for positive, negative or neutral images, all $ps > 0.19$. We also examined whether there were any group differences in overall current mood. Similar to results for the image ratings, we did not find any group differences in either current positive or negative mood, both $ps > 0.18$. Finally, to ensure that mood was not related to electrophysiological responses to emotional stimuli, we tested for these relationships. We found no significant relationships between positive mood and LPP amplitude for any positive stimuli condition or negative mood and LPP amplitude for any negative stimuli condition, all $ps > 0.18$.

4. Discussion

In the current study, we found evidence suggesting both shared and unique automatic and controlled emotion processing abnormalities in SocAnh and PerMag. Both the SocAnh and the PerMag groups exhibited evidence of a larger LPP when passively viewing negative pictures compared to controls. However, other results were specific to just the SocAnh or PerMag group. For SocAnh, there was evidence of a greater neural response to negative than to positive stimuli during passive viewing. Further, there was also some evidence of altered controlled processing of negative stimuli specifically in SocAnh. In contrast, the PerMag group differed from both SocAnh and control groups by exhibiting a larger LPP for passively viewing positive pictures, suggesting an overall increase in affective reactivity for both positive and negative stimuli in PerMag. There was also some evidence of altered controlled processing of positive stimuli in PerMag. Overall, these results suggest that SocAnh and PerMag are associated with both shared and unique automatic and controlled emotion processing abnormalities.

Before discussing the results for the SocAnh and PerMag groups further, we will first review the results for the control participants in this study. The current results for the control group were largely as expected based on previous LPP research (e.g., Hajcak et al., 2010; Hilgard et al., 2014). The control participants exhibited a larger LPP when passively viewing emotional pictures than neutral pictures. They also exhibited an increase in the LPP when instructed to INCREASE their emotions, with the LPP for the INCREASE conditions being larger than the LPP for both the LOOK and the DECREASE conditions. However, there were also two unexpected results for control participants. First, they exhibited a larger LPP in the LOOK Positive condition than in the LOOK Negative condition. Second, and perhaps related to the previous result, the LPP for LOOK Negative condition was smaller than the LPP for DECREASE Negative condition. Previous research of valence effects on LPP amplitude in unselected samples has been mixed with some reporting a negativity bias (i.e., larger amplitudes in response to negative stimuli compared to positive stimuli; Foti, Hajcak, & Dien, 2009) whereas others reporting no differential effects of valence (e.g., Schupp et al., 2000). A recent investigation reported that the types of images used (e.g., thrilling vs. affiliative images), as well as the paradigm in which they are displayed (e.g., blocked vs. oddball vs. random), may be related to these mixed findings (Hilgard et al., 2014). Thus, it is possible that the current finding of larger amplitudes for positive stimuli compared to negative stimuli is related to both the images used[3] and the random display of condition within each block (i.e., passive viewing vs. increasing emotional experience vs. decreasing emotional experience). Previous non-affective ERP research has also found that instructions that increase attention to task relevant stimuli increase later ERP positive going waves (e.g., Hajcak, MacNamara, & Olvet, 2010). Hence, this suggests that controls paid relatively less attention to the negative pictures in the LOOK condition than to either positive pictures in the LOOK condition or negative pictures in the DECREASE condition. One possibility in the current study is that controls followed the explicitly

[3] Given the way in which image presentation was recorded during the experiment (i.e., the valence of the image was recorded but not the specific image number), we are not able to examine the effects of different subtypes of images within each valence. Future research should track this information so that analyses on ERP amplitudes associated with image subtypes can be performed.

given instructions in the DECREASE Negative condition (i.e., focus on the facts of the image in an objective, non-personal way), but that they naturally used a different and for them more successful attentional deployment strategy in the LOOK Negative condition (when they were told to respond naturally to the content and not to alter their natural emotional response in any way). Note also that at least some other research has found evidence that relatively better adjusted control participants might automatically carry out strategies to decrease negative affect even in passive viewing conditions (Drabant, McRae, Manuck, Hariri, & Gross, 2009). Overall, again, the control group results as a whole were largely in line with results from previous research. However, again, there was also some evidence that controls devoted less attention to negative images in the LOOK condition compared to LOOK Positive or even DECREASE Negative conditions.

With respect to the SocAnh and PerMag groups, the evidence that both of these groups exhibited a greater automatic response when passively viewing negative pictures suggests that this might reflect general increased current distress (e.g., Richards, Holmes, Pell, & Bethell, 2013) and/or psychopathology risk (e.g., Dennis & Hajcak, 2011) in these two groups. The current results are also consistent with other evidence that both SocAnh and PerMag are associated with increased negative affect, including increased stress reactivity (Gooding, Davidson, Putnam, & Tallent, 2002; Kerns et al., 2008).

However, for a number of other conditions, the results for SocAnh and PerMag groups were quite different. For the SocAnh group, in contrast to the other two groups, they exhibited a larger LPP for passively viewing negative than positive images. Further, in SocAnh there was also evidence of a decreased early LPP for passively viewing positive images (although this result would not survive a multiple comparison correction). Hence, overall, the clearest most distinctive result for SocAnh when passively viewing affective images is that they displayed a larger neural response to negative stimuli than to positive stimuli. This result is consistent with self-reported decreased positive and increased negative trait affect in SocAnh (e.g., Gooding et al., 2002).

Therefore, the current study has found novel evidence of a greater neural response to negative than to positive stimuli in SocAnh. Our result has some similarities to a previous fMRI study that reported decreased neural activation in SocAnh compared to controls for positive stimuli (facial expressions; Hooker et al., 2014). In contrast, some previous SocAnh research did not find any alteration of blink magnitude in a startle probe response paradigm using both positive and negative stimuli (Gooding et al., 2002). Importantly, blink magnitude reflects a defensive reflex (Lang, Bradley, & Cuthbert, 1990) that is mediated by direct projections from the amygdala to the nucleus reticularis pontis caudalis, a structure in the brainstem (e.g., Davis, 1989; Hitchcock & Davis, 1987; Miserendino & Davis, 1993). Thus, the startle probe is thought to reflect the influence of primarily subcortical brain regions. In contrast, given that a previous fMRI study found evidence of cortical deficits in SocAnh (Hooker et al., 2014) and that the LPP is thought to reflect predominantly cortical influences, this suggests that affective deficits in SocAnh related to greater neural response to negative than to positive stimuli might reflect primarily cortical influences. This suggests that the different results for SocAnh between paradigms and physiological measures might indicate something important about the nature of affective deficits in SocAnh. Thus, future research could use both measures of cortical and subcortical functioning in a single study to replicate and extend the findings of differential performance on such measures.

Potentially consistent with altered cortical processing of affective stimuli in SocAnh, the SocAnh group also exhibited atypically smaller LPPs when asked to use cognitive reappraisal strategies for negative pictures, both in the INCREASE and DECREASE conditions. For instance, even though the SocAnh group exhibited a greater LPP in the LOOK Negative condition than controls, the LPP was smaller for SocAnh than controls (or PerMag participants) when told to INCREASE or DECREASE Negative emotion. Moreover, the SocAnh group did not exhibit a significantly increased LPP for negative pictures in the INCREASE condition compared to the LOOK condition. However, the SocAnh group did exhibit a significantly decreased LPP for negative pictures in the DECREASE condition compared to the LOOK condition. Hence, it appears that SocAnh did exhibit an intact ability to down-regulate negative affect in the DECREASE condition.

For the INCREASE Negative condition, it is unclear whether the lack of increase in the LPP in SocAnh reflects an unwillingness or inability to increase negative affect in those conditions. However, these SocAnh results do appear consistent with previous research finding that SocAnh is associated with decreased attention to emotion (Martin et al., 2011). Hence, overall, the SocAnh group exhibited a greater neural response to passively viewing negative than positive images as well as possibly evidence of increased avoidance of negative information. Future research could examine whether a specific subtype of negative image (e.g., disgust vs. mutilation vs. threat) drives increased response to negative images in SocAnh. Specifically, Weinberg and Hajcak (2010) found that LPP amplitude varied by the motivational significance within positive and negative images. Thus, it is possible that, for example, social threat images elicit the strongest negative motivational significance in SocAnh and thus largest LPP amplitudes.

Similar to the SocAnh group, the PerMag group also differed from controls by exhibiting a relatively larger LPP in the LOOK Negative condition. However, the results in the positive image conditions were quite different in the PerMag group compared to the other two groups. For instance, in the LOOK Positive condition, the PerMag group exhibited a larger LPP than both of the other groups. The increased LPP in the PerMag group in both the LOOK Positive and Negative conditions is generally consistent with some other research on PerMag and related positive schizotypy measures. For instance, measures of PerMag are moderately correlated with measures of hypomanic personality, with both PerMag and hypomanic personality predicting future manic episodes (Chapman et al., 1994; Kwapil et al., 2000). In addition, positive schizotypy measures have been associated with increased self-reports of positive emotions in response to pleasurable events compared to controls (Shi et al., 2012). Further, extreme levels of magical ideation have been associated with greater skin conductance to both positive and negative stimuli (Karcher & Shean, 2012). Hence, the current study provides further evidence of an increased automatic response to both positive and negative stimuli in PerMag, suggesting that PerMag might be associated with an overall increase in affective reactivity.

In addition to a greater LPP in the LOOK Positive condition, the PerMag group also differed from the other two groups for the INCREASE Positive condition. In the current study, only the PerMag group exhibited an atypical significantly decreased LPP in the INCREASE Positive condition. Hence, not only did the PerMag group fail to exhibit a larger LPP in the INCREASE Positive condition but they actually exhibited a decreased LPP in the INCREASE Positive condition ($p < 0.001$). Overall, the results for the PerMag group in the INCREASE Positive condition were unexpected and are certainly in need of replication. We offer the speculation that one possible explanation of these results is that PerMag, like bipolar disorder (Fulford, Johnson, Llabre, & Carver, 2010), might be associated with a decreased inhibition or control of positive affect. That is, perhaps the PerMag group is relatively unpracticed or unskilled at attempting to intentionally increase positive affect. Hence, when the PerMag group did explicitly attempt to increase positive affect in a controlled manner in this study, this might have then reduced their positive affect in comparison to their natural response to positive stimuli. The current results also have a general similarity to the role of dopamine in increasing responses to positive stimuli, with some evidence that this could result in impaired top-down control (Cools & D'Esposito, 2011). Last, the results for the PerMag group are consistent with the PRotective Inhibition of Self-regulation and Motivation model (PRISM; Tops, Montero Marín, & Quirin, 2016), which relates personality characteristics to dynamics within neural systems. For example, the PRISM model argues that "absorption", which is akin to magical ideation (Lange, Thalbourne, Houran, & Storm, 2000; Parker, 1999), is related to greater physiological and emotional reactivity to both positive and negative stimuli and to increased aberrant experiences when exposed to stressors. However, increasing intensity of stimuli, and subsequent neural responses, will protectively increase PRISM, thereby decreasing responses. In addition, the "threshold of protective inhibition" is modulated by motivational intensity—that is, urgent stimuli, which are more often negative in valence, shift the threshold up relative to less urgent stimuli, which are more often positive. This is consistent with the findings of larger LPP amplitudes in the PerMag group to both positive and negative stimuli compared to controls, and also the decrease in LPP in the INCREASE Positive condition, which may have shifted already high responding past the threshold of protective inhibition.

Overall, these results suggest that SocAnh and PerMag are associated with both shared and unique automatic and controlled information processing abnormalities and highlight emotional nuances of the schizophrenia-spectrum. Specifically, the schizophrenia-spectrum has varied emotional abnormalities and therefore a "one-size-fits-all" approach to prevention or treatments may not be effective (Bobo & Meltzer, 2010). For example, based on the current results, individuals experiencing elevated perceptual aberrations or magical ideation might benefit from emotional regulation strategies aimed at downregulating both positive and negative emotions (e.g., cognitive reappraisal), whereas individuals reporting elevated social anhedonia might additionally benefit from strategies aimed specifically at increasing positive emotions (e.g., Positive Emotions Program for Schizophrenia; Favrod et al., 2015).

Although this study provides novel findings regarding the nature of emotional deficits in at-risk groups, it is not without limitations. One limitation is that the sample sizes for each group were not large, and it is possible that the study lacked sufficient power to detect some small effects. Thus, future research is needed to replicate these findings. In addition, because we used an extreme groups approach, the between-group effects we found between the at-risk groups and the control group might be larger than if we had used an unselected sample and treated self-reports of the personality measures associated with risk of schizophrenia-spectrum personality disorders continuously (Preacher et al., 2005). However, given the labor intensity of EEG data collection, the extreme groups approach was more realistic as the first step to investigate objective automatic and controlled emotion processing abnormalities in these groups (DeCoster, Iselin, & Gallucci, 2009; Preacher et al., 2005). Furthermore, the current study could not assess the frequency with which at-risk groups spontaneously attempt to regulate their emotional experience or whether they are more adept at using other emotion regulation strategies than cognitive reappraisal (e.g., suppression). Future research could examine EEG gamma band activity, previously associated with elaborative processing of emotional information (e.g., Siegle, Condray, Thase, Keshavan, & Steinhauer, 2010), after exposure to an emotional stimulus for several seconds without explicit task instructions to examine whether these groups spontaneously engage in elaborative processing. Despite these limitations, the current paper provides potentially very important information regarding the emotional functioning in SocAnh and PerMag.

Acknowledgement

This work was partially supported by a National Research Service Award awarded to Elizabeth A. Martin (F31 MH 090669).

Appendix A.

IAPS images used in the current study

Positive	Negative	Neutral
1463	1050	1616
1811	1220	1935
2040	1300	2214
2057	1525	2385
2071	2141	2393
2080	2205	2487
2150	2206	2495
2208	2375.1	2514
2303	2399	2516
2340	2455	2635
2352	2900	2749
2550	3160	2840
4250	3550	2850
4599	6230	2880
4608	6243	5532
4641	6244	5740
5270	6260	5920
5470	6300	6150
5629	6360	7000
5830	6370	7002
5910	6560	7004
5982	6838	7035
7200	7380	7036
7250	9000	7041
7270	9007	7050
7400	9008	7090
7460	9046	7100
7502	9110	7160
8080	9140	7161
8090	9301	7170
8162	9320	7175
8170	9331	7179
8180	9342	7182
8186	9435	7187
8190	9500	7207
8200	9560	7233
8370	9600	7640
8420	9800	8160
8461	9810	8475
8500	9830	9070

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