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Emotion Regulation Abnormalities in Schizophrenia: Directed Attention Strategies Fail to Decrease the Neurophysiological Response to Unpleasant Stimuli

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Previous research provides evidence that individuals with schizophrenia (SZ) have emotion regulation abnormalities, particularly when attempting to use reappraisal to decrease negative emotion. The current study extended this literature by examining the effectiveness of a different form of emotion regulation, directed attention, which has been shown to be effective at reducing negative emotion in healthy individuals. Participants included outpatients with SZ ($n = 28$) and healthy controls (CN: $n = 25$), who viewed unpleasant and neutral images during separate event-related potential and eye-movement tasks. Trials included both passive viewing and directed attention segments. During directed attention, gaze was directed toward highly arousing aspects of an unpleasant image, less arousing aspects of an unpleasant image, or a nonarousing aspect of a neutral image. The late positive potential (LPP) event-related potential component indexed emotion regulation success. Directing attention to nonarousing aspects of unpleasant images decreased the LPP in CN; however, SZ showed similar LPP amplitude when attention was directed toward more or less arousing aspects of unpleasant scenes. Eye tracking indicated that SZ were more likely than CN to attend to arousing portions of unpleasant scenes when attention was directed toward less arousing scene regions. Furthermore, pupilary data suggested that SZ patients failed to engage effortful cognitive processes needed to inhibit the prepotent response of attending to arousing aspects of unpleasant scenes when attention was directed toward nonarousing scene regions. Findings add to the growing literature indicating that individuals with SZ display emotion regulation abnormalities and provide novel evidence that dysfunctional emotion-attention interactions and generalized cognitive control deficits are associated with ineffective use of directed attention strategies to regulate negative emotion.

Keywords: emotion regulation, affect, attention, cognitive control, psychosis

In the past decade, there has been increased interest in incorporating theories of emotion regulation into models of psychopathology, particularly for anxiety, mood, eating, and substance use disorders (Aldao, Nolen-Hoeksema, & Schweizer, 2010). In his widely accepted conceptual framework, James Gross (2002) posits that emotion regulation involves a dynamic interplay between emotion generation processes and attempts to control emotion through the use of various strategies. The emotion generation sequence is thought to involve four stages, beginning with the occurrence of an external (i.e., environmental) or internal (i.e., thought or emotion) stimulus that is attended to, which gives rise to an appraisal of the situation's valence and motivational relevance, and a subsequent cascade of experiential, behavioral, and neurophysiological response changes (Gross, 2002). Importantly,

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at any one of these stages of the emotion generation process, strategies can be implemented to regulate emotions (i.e., increase or decrease the frequency or intensity of negative or positive affect). Strategies used to regulate emotions are typically divided into those that are antecedent-focused (situation selection, situation modification, attentional deployment, reappraisal) or response-focused (expressive suppression), with some evidence for greater effectiveness of antecedent than response focused strategies (Gross, 1998).

Although schizophrenia (SZ) has long been considered a disorder characterized by affective disturbance (Bleuler, 1911/1950; Kraepelin, 1919), there have been few empirical investigations of whether individuals with SZ evidence emotion regulation abnormalities. The majority of studies conducted to date have used self-report questionnaires to explore dispositional tendencies toward implementing reappraisal and expressive suppression. Findings have been mixed, with the majority of studies indicating that people with SZ report less frequent use of reappraisal and greater use of suppression than healthy controls (CN; Horan, Hajcak, Wynn, & Green, 2013; Kimhy et al., 2012; Livingstone, Harper, & Gillanders, 2009; Rowland et al., 2012; van der Meer, van't Wout, & Aleman, 2009), and others reporting no group differences in self-reported use of reappraisal and suppression (Badcock, Paulik, & Maybery, 2011; Henry, Rendell, Green, McDonald, & O'Donnell, 2008; Perry, Henry, & Grisham, 2011; van der Meer et al., 2014). Despite these inconsistencies, there is reliable evidence that individual differences in self-reported frequency of reappraisal and suppression are associated with community-based functional outcome and symptoms (Badcock et al., 2011; Horan et al., 2013; Kimhy et al., 2012; Perry et al., 2011; van der Meer et al., 2009).

Studies using self-report measures provide valuable information about patients' perceptions of how often they implement different emotion regulation strategies during everyday life; however, they do not provide an indication of how *effective* different strategies are at decreasing or increasing emotional response. To examine the effectiveness of various emotion regulation strategies in SZ, a small number of studies have used experimental paradigms from the field of affective neuroscience in conjunction with psychophysiological recording or neuroimaging methods. In an early study, Henry et al. (2007) used an expressive suppression paradigm that asked participants to view film clips and either increase outward expression of emotion, decrease outward expression of emotion, or respond naturally. Using behavioral facial affect coding ratings, they found that people with SZ were less effective at increasing facial expressions in response to positive stimuli. Perry, Henry, Nangle, and Grisham (2012) extended these findings using facial electromyography in a paradigm that exposed participants to unpleasant or neutral film clips and asked them to perform passive viewing or down-regulate negative emotion using expressive suppression, reappraisal, or acceptance strategies. They found that SZ patients showed greater facial electromyography response than CN to unpleasant stimuli across all conditions; however, there was no evidence for an interaction effect, suggesting that patients demonstrated some ability to decrease outward displays of negative affect using various regulation strategies.

Using an event-related potential (ERP) paradigm modeled after Foti and Hajcak (2008); Strauss et al. (2013) examined whether a cognitive change strategy was effective at reducing the neural response to unpleasant stimuli in SZ patients and CN. The electroencephalogram was recorded while participants passively viewed neutral and unpleasant photographs, which were each preceded by an audio file that described the upcoming image. Neutral images were preceded by a neutral description of the upcoming image, whereas unpleasant images were preceded by a sound file that either described the upcoming image as more negative or more neutral. In this paradigm, the audio file served as a preappraisal of the photograph, which provided a purer test of emotion regulation success, independent of reappraisal ability (i.e., how well subjects could generate reinterpretations of unpleasant stimuli). Analyses in Strauss et al. (2013) focused primarily on the late positive potential (LPP), an ERP component that is often used as an objective, neurophysiological index of emotion regulation (Hajcak, MacNamara, & Olvet, 2010). The LPP is a centroparietal midline component that typically becomes evident around 300 ms after stimulus onset and persists throughout stimulus duration (Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Schupp et al., 2000). It is sensitive to emotionally arousing content and is thought to reflect sustained attention to emotional stimuli and appraisal of emotional significance (Hajcak et al., 2010). Behavioral self-report results of Strauss et al. (2013) indicated that the preappraisal manipulation was equally effective at decreasing negative emotional experience in SZ patients and CN. However, patients with SZ displayed a deficit in down-regulating the neural response to unpleasant stimuli. Specifically, whereas CN participants evidenced decreased LPP amplitude for the unpleasant stimuli preceded by a neutral audio file relative to unpleasant stimuli preceded by a negative audio file, individuals with SZ showed similar LPP amplitude between these conditions. Furthermore, lower LPP difference scores (reflecting poorer emotion regulation) were associated with higher self-reported state experience of negative emotion to unpleasant stimuli and higher trait negative affect. In a separate study by Horan et al. (2013), nearly identical LPP results were found using the same ERP paradigm. When one considers additional evidence for comparable LPP amplitude between patients and CN for both unpleasant and pleasant stimuli during passive viewing tasks (Horan, Foti, Hajcak, Wynn, & Green, 2012; Horan, Wynn, Kring, Simons, & Green, 2010), these findings suggest that individuals with SZ may primarily have a problem with emotion regulation, rather than emotional reactivity.

Results from two published functional MRI (fMRI) studies provide preliminary insight into the neural circuitry underlying emotion regulation abnormalities in SZ. Similar to a large body of literature examining neural processes involved in emotion regulation in healthy individuals (for review see Ochsner, Silvers, & Buhle, 2012), Morris, Sparks, Mitchell, Weickert, and Green (2012) found that effective use of reappraisal in CN was associated with increased activation of the prefrontal cortex and decreased amygdala activation. In contrast, individuals with SZ exhibited decreased activation of the right ventrolateral prefrontal cortex (but comparable amygdala response). Van der Meer et al. (2014) also reported hypoactivation of the ventrolateral prefrontal cortex in SZ patients relative to controls during a reappraisal task, as well as reduced activation of the insula, middle temporal gyrus, caudate, and thalamus. Thus, when one considers evidence accumulated across studies using self-report, psychophysiological, and neuroimaging methods, there is increasing evidence for an emotion regulation abnormality in SZ.

However, studies to date have primarily focused on reappraisal and expressive suppression. It is currently unclear whether people with SZ are also ineffective at using strategies other than reappraisal and suppression that have been proposed in Gross' (2002) model. Attentional deployment is one such strategy that would be particularly important to explore in SZ. This strategy involves directing attention toward or away from affective content in the service of up- or down-regulating emotion (Ferri et al., 2013). Several novel paradigms have been developed to study attentional deployment using electrophysiological, neuroimaging, and eye-tracking methods (Bebko, Franconeri, Ochsner, & Chiao, 2014; Dunning & Hajcak, 2009; Urry, 2010). For example, Dunning and Hajcak (2009) developed an attentional deployment paradigm where participants are presented with unpleasant or neutral images from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2001) for 6 s. For 3 s, images are overlaid with a colored circle directing attention to either a nonarousing aspect of a neutral image, a highly arousing area of an unpleasant image, or a nonarousing portion of an unpleasant image. Participants are asked to attend to the portion of the image within the circle for the entire duration that it appears on screen. For the other 3 s of stimulus presentation, participants view the image freely without the circle superimposed. After the trial, participants provide self-reports of emotional experience in relation to the entire trial. EEG was recorded throughout the task and the LPP was used to index emotion regulation and attentional deployment. Results of Dunning and Hajcak (2009) indicated that directing attention toward less arousing aspects of unpleasant scenes effectively reduced the amplitude of the LPP relative to when attention was directed toward more arousing aspects of the unpleasant scene. These ERP findings have been replicated in subsequent studies examining healthy individuals (Hajcak, Dunning, & Foti, 2009; Hajcak, MacNamara, Foti, Ferri, & Keil, 2013), and extended to fMRI, where it was found that directing attention toward less arousing aspects of unpleasant scenes results in increased activation of the prefrontal cortex and decreased activation of the amygdala (Ferri et al., 2013).

In the current study, we administered a paradigm modeled after Dunning and Hajcak (2009) to a sample of SZ patients and CNs to examine the effectiveness of a directed attention manipulation at reducing the LPP and self reported experience of negative emotion. We hypothesized that CN would evidence intact neural response to unpleasant stimuli, as indicated by more positive LPP amplitude to unpleasant than neutral stimuli during the passive viewing portion of the trial. Additionally, CN were expected to display successful emotion regulation as indicated by less positive LPP amplitude for unpleasant stimuli with a nonarousing focus condition compared to unpleasant stimuli with an arousing focus in the directed attention portion of the trial. Similar to CN, SZ patients were predicted to display larger LPP amplitude for unpleasant than neutral images during the passive viewing portion of the trial, indicating intact reactivity to unpleasant stimuli; however, SZ patients were expected to display similar LPP amplitudes for unpleasant stimuli with an arousing focus and unpleasant stimuli with a nonarousing focus during the directed attention portion of the trial.

Several prior findings led to the hypothesis that directing attention toward nonarousing aspects of unpleasant scenes would fail to decrease the LPP in SZ. First, there is evidence for dysfunctional interactions between bottom-up attention and unpleasant stimuli in SZ, such that patients display more automatic orienting to aversive content than controls (Besnier et al., 2011; Kinderman, 1994; Kinderman, Prince, Waller, & Peters, 2003; Park, Park, Chun, Kim, & Kim, 2008). Greater bottom-up capture for unpleasant stimuli might be expected to cause SZ patients to more rapidly fixate on arousing scene regions, even when attention is cued toward less arousing content. Second, there is also evidence for dysfunctional interactions between unpleasant stimuli and top-down attention in SZ (Strauss et al., 2008; Strauss et al., 2011). For example, people with SZ have greater difficulty than controls at disengaging attention from unpleasant images presented in foveal vision to rapidly identify nonaffective targets located in the periphery (Strauss et al., 2011). Given that SZ patients also display a greater propensity to have bottom-up attention captured by unpleasant stimuli, difficulty disengaging attention from unpleasant content may make it especially hard for patients to shift attention away from arousing scene regions toward more neutral ones in the unpleasant image, nonarousing focus condition. Finally, SZ patients reliably evidence impairments on measures of cognitive control (Lesh, Niendam, Minzenberg, & Carter, 2011). Cognitive control refers to processes that allow information processing and behavior to vary adaptively in the service of current goals (Braver & Cohen, 1999). The prefrontal cortex, which is known to be affected in SZ (Glahn et al., 2005), plays a key role in facilitating cognitive control (MacDonald, Cohen, Stenger, & Carter, 2000). In the context of the current paradigm, cognitive control deficits might be expected to make the goal-directed task of attending to the target window more difficult across all three conditions.

To more precisely evaluate the role of visual attention and cognitive control in this paradigm, we also administered a separate eye-tracking task that recorded gaze fixation and pupil dilation while participants performed the directed attention task. Prior eye-tracking studies in healthy individuals indicate that visual attention plays a critical role in emotion regulation success. For example, van Reekum et al. (2007) found that when attempting to decrease negative emotion using reappraisal, participants shifted gaze away from more arousing aspects of the scene, which predicted a substantial proportion of variance in brain activation in the amygdala and prefrontal cortex. In the current paradigm, fixations within the target window would indicate how effectively a participant could engage cognitive control processes needed to maintain focus within the cued scene region. Fixation data also provide valuable insight as to where participants are looking when they fixate on areas outside of the target window. For example, in the unpleasant stimulus, nonarousing focus condition, it is possible for participants to attend to either arousing aspects of the unpleasant scene or other nonarousing regions that are not highlighted by the target window. If participants were to simply attend to other nonarousing scene regions in the unpleasant stimulus with a nonarousing focus condition, this might imply a general cognitive control deficit is at play, especially if patients also had difficulty maintaining fixation in the target window in the other two conditions. However, if in the unpleasant stimulus with a nonarousing focus condition, patients were in fact attending to arousing aspects of the unpleasant scene located outside of the target window more than controls, this would suggest that dysfunctional emotion-attention interactions are impacting task performance. Eye-tracking data therefore extends the ERP measurements by providing a means of evaluating competing hypotheses related to why patients might evidence different LPP results than controls. In addition to fixation data, several eye-tracking studies have also examined pupil dilation in emotion regulation paradigms (Urry et al., 2006; van Reekum, et al., 2007). It is well-established that greater pupil dilation is associated with increased emotional arousal and sympathetic nervous system activity (Bradley, Miccoli, Escrig, & Lang, 2008). However, studies have also demonstrated that pupilary response is sensitive to effort and level of cognitive demand (Beatty, 1982; Granholm, Asarnow, Sarkin, & Dykes, 1996), as well as changes in cognitive control dynamics (Chatham, Frank, & Munakata, 2009; Chiew & Braver, 2013; Satterthwaite et al., 2007). Emotion regulation studies conducted in healthy individuals have indicated that attempts to increase and decrease negative emotion via reappraisal results in significant increases in pupil dilation relative to an unpleasant passive viewing condition (van Reekum et al., 2007; Urry et al., 2006), suggesting that pupil dilation is sensitive to increases in cognitive control above and beyond sympathetic nervous system changes resulting from emotional reactivity. Pupil dilation therefore serves as another index of emotion regulation. Given these prior findings, the following hypotheses were made in relation to fixation and pupil dilation data. Hypothesis 1: SZ patients would evidence a lower total proportion of fixations within the target window than CN for all three conditions. Hypothesis 2: SZ patients would evidence a longer first fixation time (i.e., the time in ms, at which the first fixation occurs within the target window) than CN for unpleasant images with a nonarousing focus. Hypothesis 3: CN would demonstrate significant increases in pupil dilation for unpleasant images with a nonarousing focus relative to the unpleasant images with an arousing focus, consistent with prior studies indicating that increased attempts at emotion regulation result in greater recruitment of effortful cognitive control processes (van Reekum et al., 2007; Urry et al., 2006). In contrast, SZ patients were expected to demonstrate significant increases in pupil dilation for both unpleasant conditions relative to neutral stimuli, suggesting intact emotional reactivity to unpleasant stimuli; however, they were not expected to evidence greater pupil dilation for unpleasant images with a nonarousing focus compared to unpleasant images with an arousing focus due to abnormalities in emotion regulation and failure to engage effortful cognitive control processes.

Method

Participants

Thirty-one individuals with SZ and 28 CN completed study procedures. In our group's ERP studies of psychiatric populations, we exclude participants who have artifacts on greater than 50% of trials. Three SZ and 3 CN were excluded for this reason from the current study, yielding a final sample of SZ $n = 28$ and CN $n = 25$. All results reflect this final sample.

Individuals with SZ were recruited through the Outpatient Research Program at the Maryland Psychiatric Research Center and evaluated during a period of clinical stability as evidenced by no changes in medication type or dosage for a period greater than or equal to 4 weeks. Consensus diagnosis was established via a best-estimate approach based upon multiple interviews and a detailed psychiatric history. This diagnosis was subsequently confirmed using the Structured Clinical Interview for *Diagnostic and Statistical Manual of Mental Disorders–IV* (First, Spitzer, Gibbon, & Williams, 2001). All patients were prescribed one or more antipsychotics at the time of testing: Clozapine ($n = 5$), Risperidone ($n = 4$), Olanzapine ($n = 2$), Abilify ($n = 1$), Aripiprazole ($n = 1$), Chlorpromazine ($n = 1$), Fluphenazine ($n = 1$), Haloperidol ($n = 1$), Seroquel ($n = 1$), Zyprexa ($n = 1$), Clozapine + Risperidone ($n = 3$), Clozapine + Quetiapine ($n = 1$), Risperidone + Abilify ($n = 1$), Risperidone + Olanzapine ($n = 1$), Risperidone + Aripirazole ($n = 1$), Seroquel + Geodon ($n = 1$), Seroquel + Invega ($n = 1$), Seroquel + Zyprexa ($n = 1$).

CN subjects were recruited by means of random digit dialing, word-of-mouth among recruited participants, and through the use of newspaper advertisements. CN had no current Axis I or II diagnoses as established by the Structured Clinical Interview for *Diagnostic and Statistical Manual of Mental Disorders–IV* (First et al., 2001) and Structured Interview for *DSM-IV* Personality (SID-P) (Pfohl, Blum, & Zimmerman, 1997), no family history of psychosis, and were not taking psychotropic medications. All participants denied a history of neurological injury or disease, medical disorders that could interfere with test results (e.g., cancer, infectious disease, sleep apnea), and did not meet criteria for substance abuse or dependence disorders within the last 6 months. All participants provided informed consent for a protocol approved by the University of Maryland Institutional Review Board.

The CN and SZ groups did not significantly differ in age, parental education, gender, or ethnicity. SZ had lower personal education than CN. On average, patients displayed moderately severe positive and negative symptoms at the time of testing (see Table 1).

General Procedures

Participants completed separate ERP and eye-tracking emotion regulation tasks, which were counterbalanced in order. Patients also completed a clinical interview after which the Brief Psychiatric Rating Scale (Overall & Gorham, 1962), Brief Negative Symptom Scale (Kirkpatrick et al., 2011; Strauss, Hong, et al., 2012; Strauss, Keller, et al., 2012), and Level of Function Scale (Hawk, Carpenter, & Strauss, 1975) were rated. Questionnaires completed by participants included the Positive and Negative Affect Scale (Watson & Clark, 1992) using the "in general" (i.e., trait) reporting timeframe and the Temporal Experience of Pleasure Scale (TEPS: Gard, Gard-Germans, Kring, & Oliver, 2006). The Dot Pattern Expectancy (DPX: (Henderson et al., 2012) task was administered to assess general cognitive control and goal maintenance, and the standard AY-BX contrast score was used to index a participant's ability to represent and maintain contextual information relevant to task goals.

ERP Procedures, Data Processing, and Task

Participants completed an emotion regulation paradigm modeled after Dunning and Hajcak (2009) and Urry (2010) while the electroencephalogram (EEG) was recorded. A sample trial sequence is presented in Figure 1.

Participants were told that they would see a series of unpleasant and neutral images, and that each image would be presented

Table 1
Participant Demographic and Clinical Characteristics

	SZ (n = 28)	CN (n = 25)	Test statistic	p value
Age	45.4 (12.0)	43.7 (10.0)	F = 00.3	p = .58
Parental education	13.0 (2.4)	14.0 (2.2)	F = 02.2	p = .15
Participant education	12.9 (1.8)	15.6 (2.2)	F = 26.2	p < .001
% Male	67.9%	64.0%	χ^2 = 00.8	p = .78
Race			χ^2 = 01.9	p = .60
White	60.7%	64.0%		
African American	32.1%	36.0%		
Asian American	03.6%	00.0%		
American Indian	03.6%	00.0%		
Neuropsychological tests				
DPX (AY–BX trials)	−0.06 (0.2)	0.03 (0.2)	F = 01.8	p = .19
PANAS trait self-report				
NA	19.5 (8.1)	13.7 (3.4)	F = 11.1	p < .01
PA	27.2 (7.2)	32.5 (6.6)	F = 07.4	p < .01
TEPS self-report				
ANT	04.2 (1.0)	04.5 (0.6)	F = 02.0	p = .16
CON	04.1 (1.0)	04.9 (0.7)	F = 11.0	p < .01
Symptom ratings				
BNSS total	27.8 (20.2)	—	—	—
LOF total	16.9 (9.8)	—	—	—
BPRS total	41.4 (13.0)	—	—	—
Positive	02.4 (1.5)	—	—	—
Negative	02.4 (1.3)	—	—	—
Disorganized	01.7 (0.7)	—	—	—

Note. SZ = schizophrenia group; CN = healthy control group; DPX = Dot Pattern Expectancy Task % error difference score on AY–BX trials; PANAS = Positive and Negative Affect Schedule; NA = PANAS Trait Negative Affect subscale; PA = PANAS Trait Positive Affect subscale; TEPS = Temporal Experience of Pleasure Scale; ANT = TEPS Anticipatory subscale; CON = TEPS Consummatory Pleasure subscale; BNSS = Brief Negative Symptom Scale total score; LOF = Level of Function Scale total score; BPRS = Brief Psychiatric Rating Scale.

for 6 s. They were also told that for the first 3 s, part of the image would be highlighted by a clear window and the rest of the image would be faded out, and for the last 3 images the window would disappear and they would see the image without fading. Participants were instructed to focus their attention only within the target window for the entire time it was on screen (first 3 s), and that when it disappeared they could view the image freely (last 3 s). After the 6-s presentation, there was a 2-s interval where a blank screen appeared, after which participants were prompted to report how negative they felt by averaging across the entire 6 s using the Self-Assessment Manikin. The scale was anchored from 1 (*not at all negative*) to 5 (*extremely negative*), and unlimited time was allowed for self-report.

Stimuli were 40 unpleasant (e.g., threat, mutilation) and 20 neutral (e.g., household objects, social interactions) images taken from the IAPS (Lang et al., 2001).[1] The unpleasant images were normatively lower in valence (Unpleasant M = 2.19, SD = 0.47; Neutral M = 5.04, SD = 0.41; F = 539.7, p < .001) and higher in arousal (Unpleasant M = 6.12, SD = 0.66; Neutral M = 3.10, SD = 0.59; F = 294.2, p < .001) than the neutral images. The 40 unpleasant IAPS images were edited to produce two versions: an unpleasant image with an arousing focus and an unpleasant image with a nonarousing focus. For all 20 neutral images, the target window was placed over a nonarousing aspect of the image. Modeled after Urry et al. (2010), stimuli used in the directed attention portion of the trial were edited using Adobe® Photoshop to produce a clear square “target window” of 250x250 pixels, with the remaining image faded by layering 30% opacity. This procedure allowed the target window to direct attention without obstructing view of any part of the image. The target window portion of images and the full images were matched on red, green, and blue saturation, as well as on luminance and visual complexity. The context highlighted by arousing and nonarousing target windows was also balanced (e.g., both focusing on faces). A total of 5 practice and 60 experimental trials were presented (20 unpleasant images with an arousing focus, 20 unpleasant images with a nonarousing focus, 20 neutral images with a nonarousing focus). All participants viewed the same 60 IAPS images; however, the unpleasant stimuli were randomly assigned to be presented with either an arousing or nonarousing focus. The order of trials was randomized for each participant. Stimuli were displayed across the entirety of the screen (17” monitor, 1280 × 1024 resolution, 60 Hz refresh rate) at a viewing distance of approximately 70 cm.

[1] The following IAPS images were used in the ERP task: unpleasant (2717, 9325, 9300, 6260, 9622, 2276, 3261, 3017, 6242, 6550, 9429, 6415, 9561, 3170, 3059, 6022, 3063, 3131, 3500, 9253, 9433, 9908, 3030, 2352, 9412, 9183, 9420, 3001, 9430, 3213, 7361, 2095, 6520, 3212, 3053, 9902, 2345, 3005, 9332, 9252); neutral (2381, 7052, 7053, 2980, 7055, 7490, 2383, 2206, 7059, 5520, 7560, 7179, 7187, 7161, 7160, 2235, 5120, 7012, 7003, 7026).

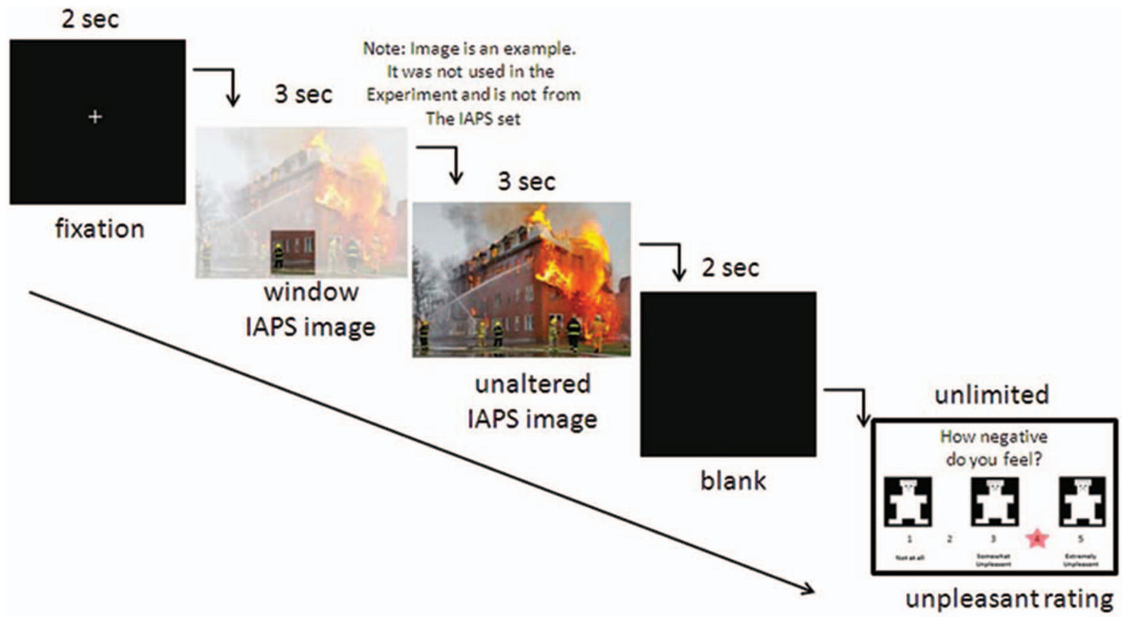

Figure 1. Sample trial sequence for event-related potential task. Participants saw a fixation for 2 s, followed by an unpleasant or neutral image for 6 s. The first 3 s of the image presentation constituted the emotion regulation portion of the trial, where they were told to direct attention to the clear target window within the image and keep it there for the entire time that it was on screen. The last 3 s of image presentation consisted of the passive viewing/reactivity portion of the trial, where the image was presented in its normal fashion (i.e., without the window or fading) and participants were told to view the image freely. After the 6-s image presentation, there was a 2-s blank screen and participants then had unlimited time to provide emotional self-report for how negative they felt on that trial using the Self-Assessment Manikin anchored on a scale from 1 (*not at all negative*) to 5 (*extremely negative*). IAPS = International Affective Picture System. See the online article for the color version of this figure.

EEG Recording and Data Processing Procedures

The EEG was recorded from Ag/AgCl electrodes mounted in an elastic cap using a subset of the International 10/20 System (Fz, C3, Cz, C4, CPz, P3, Pz, P4, Oz, Fp1, Fp2, and left mastoid). The signals were recorded online using a right mastoid reference electrode, and the signals were rereferenced offline to the average of the left and right mastoids (Luck, 2005). The horizontal electrooculogram (EOG) was used to measure horizontal eye movements and was recorded as the voltage between electrodes placed lateral to the external canthi. The vertical EOG was used to detect eyeblinks and vertical eye movements and was recorded from an electrode beneath the left eye. All electrode impedances were kept below 15KΩ. The EEG and EOG were amplified by a Neuroscan Synamps amplifier with a gain of 5,000, a bandpass filter of 0.05–100 Hz, and a 60-Hz notch filter. The amplified signals were digitized at 500 Hz and averaged offline.

All signal processing and analysis procedures were performed in Matlab using EEGLAB toolbox (Delorme & Makeig, 2004) and ERPLAB toolbox (Lopez-Calderon & Luck, 2014). Data preprocessing included the removal of large muscle artifacts or extreme offsets (identified by visual inspection). Independent component analysis was performed on the continuous data to identify and remove eyeblink activity (Jung et al., 2000). The independent-component-analysis–corrected EEG data were segmented into epochs that began 200 ms prior to the onset of the stimulus and continued for 6,000 ms and baseline corrected using a 200 ms prestimulus period. ERPs were constructed by separately averaging trials from the three conditions of interest.

ERP Measurement Procedures

The LPP was calculated separately during the passive viewing and directed attention portions of the trial as the sites where the LPP was maximal (CPz, Pz) (Hajcak, Dunning, & Foti, 2007; MacNamara & Hajcak, 2009). During directed attention, the LPP was segmented into early (1,000–2,000 ms) and late (2,000–3,000 ms) epochs. Early (4,000–5,000 ms) and late (5,000–6,000 ms) LPPs were also calculated for the passive viewing portion of the trial. Measurement procedures are consistent with prior work in this area and task (Dunning & Hajcak, 2009).

Eye-Tracking Measurement Procedures and Task

The eye-tracking task was conducted separately from the ERP task, in a different testing room. Participants were seated 70 cm from a 17-in. CRT monitor with a refresh rate of 60 Hz, with head positioned in a chin-and-forehead rest to reduce motion artifacts. Eye position was recorded monocularly from the right eye at 2,000 Hz using an SR Research Eyelink 1000 desk-mounted system. A 9-point calibration was used and drift-correction was performed prior to each trial. Calibration required an average error less than 0.49° and maximum error less than 0.99° to be acceptable. Data processing was conducted offline using SR Research Data Viewer software.

The eye-tracking task was similar to the ERP task except stimulus duration was 3 s and only consisted of directed attention. Behavioral response was not recorded. Different sets of IAPS stimuli were used in the eye-tracking and ERP tasks.[2] The unpleasant images were normatively more negative (unpleasant $M = 2.32$, $SD = 0.49$; neutral $M = 5.33$, $SD = 0.30$; $F = 545.8$, $p < .001$) and higher in arousal (unpleasant $M = 5.96$, $SD = 0.80$; neutral $M = 3.62$, $SD = 0.33$; $F = 144.74$, $p < .001$) than the neutral images. Normative IAPS valence ($t = 0.71$, $p = .49$) and arousal ($t = 0.68$, $p = .50$) ratings did not significantly differ between eye-tracking and ERP tasks for unpleasant stimuli. Neutral stimuli used in the eye-tracking task had higher normative valence ($t = 2.73$, $p < .02$) and arousal ($t = 3.47$, $p < .01$) than the ERP task.

A total of 20 neutral and 20 unpleasant stimuli were included in the eye-tracking task, with each unpleasant stimulus presented twice: once with an arousing focus and once with a nonarousing focus. Thus, there were a total of 20 neutral images with a nonarousing focus, 20 unpleasant images with an arousing focus, and 20 unpleasant images with a nonarousing focus; the order of trials was randomized for each participant.

Three primary eye-tracking variables were analyzed: (a) first fixation time: the time in ms at which the first fixation landed within the area of interest (AOI); (b) total percentage of fixations within the AOI: out of the total number of fixations made on the trial, the proportion of fixations that fell within the AOI; (c) average pupil size: the mean pupil size at fixation (in pixels) within the AOI. For these analyses, the AOI consisted of the directed attention focus window. To follow-up the first fixation time results, secondary analyses were calculated, which examined the location of fixations on unpleasant images with a nonarousing focus. A new AOI set was created for each image, which was delineated as the area of the picture that was highlighted by the target window in the unpleasant stimulus arousing focus condition. This analysis was possible because each image was presented twice during the eye-tracking task, once with an arousing focus and once with a nonarousing focus. Thus, the analysis examined fixations within arousing areas of the scene to determine whether gaze was more likely to be directed toward arousing scene regions when participants were not fixating in the nonarousing target window.

Data Analysis

Self-report data was evaluated using a 2 (Group: SZ, CN) × 3 (Condition: Unpleasant Pictures With an Arousing Focus, Unpleasant Pictures With a Nonarousing Focus, Neutral Pictures With a Nonarousing Focus) repeated-measures ANOVA. The LPP was evaluated separately in directed attention and passive viewing portions of the trial. For directed attention, a 2 Group × 3 Condition × 2 Epoch (Early 1,000–2,000 ms, Late 2,000–3,000 ms) repeated-measures ANOVA was conducted. For passive viewing, a 2 Group × 3 Condition × 2 Epoch (Early 4,000–5,000 ms, Late 5,000–6,000 ms) repeated-measures ANOVA was conducted. Within-group paired-samples *t* tests were selected a priori to test hypothesized emotional reactivity and regulation effects within each group.

Separate 2 Group × 3 Condition repeated-measures ANOVAs were used to evaluate eye-tracking behavior, with first fixation time and proportion of total fixations within the AOI serving as dependent variables. Pupil response was evaluated using average pupil diameter at fixation using a 2 Group × 3 Condition repeated-measures ANOVA. Significant interactions and main effects were followed-up with one-way ANOVAs and *t* tests. For all repeated-measures ANOVAs, the Greenhouse–Geisser correction was applied in instances when the assumption of sphericity was violated.

Bivariate correlations were calculated separately for patient and control groups to determine whether LPP amplitudes were significantly associated with eye-tracking scores and whether LPP and eye-tracking variables were significantly associated with self-reported negative emotion to stimuli in the ERP task, Positive and Negative Affect Schedule trait positive and negative affect, TEPS anticipatory and consummatory pleasure, DPX AY–BX contrast, positive, negative, disorganized, total symptoms (patients only), and functional outcome (patients only).

Results

Self-Report

Repeated-measures ANOVA with subjective negative emotional experience ratings from the ERP task as the dependent variable revealed a significant within-subjects effect of Emotion, $F(1, 92) = 463.3$, $p < .001$ ($\eta^2_{\text{partial}} = 0.91$), and a significant Emotion × Group interaction, $F(1, 92) = 3.39$, $p < .04$ ($\eta^2_{\text{partial}} = 0.07$). The between-subjects effect was nonsignificant, $F(1, 46) = 0.02$, $p = .89$ ($\eta^2_{\text{partial}} = 0.01$). One-way ANOVAs indicated that CN and SZ did not differ in self-reported negative emotion to unpleasant stimuli with an arousing, $F(1, 46) = 0.47$, $p = .50$, or nonarousing focus, $F(1, 46) = 0.96$, $p = .33$, although SZ reported significantly more negative emotion than controls to neutral stimuli, $F(1, 46) = 8.8$, $p < .01$. Within-group paired samples *t* tests indicated that CN reported significantly less negative emotion to unpleasant images with a nonarousing focus than unpleasant images with an arousing focus ($t = 2.39$, $p < .03$); however, there were no differences between these conditions in SZ ($t = 1.48$, $p = .15$). Thus, CN participants reported less negative affect to unpleasant pictures with a nonarousing focus relative to unpleasant pictures with an arousing focus, consistent with successful emotion regulation; however, directing attention to nonarousing aspects of unpleasant scenes did not have the same effect of decreasing negative emotion in SZ (see Figure 2).

On the Positive and Negative Affect Schedule, SZ reported significantly more trait negative affect and less positive affect than CN. TEPS results were consistent with Strauss et al. (2011), indicating that SZ reported significantly less consumatory pleasure than CN and no group differences on the anticipatory subscale (see Table 1).

[2] The following IAPS images were used in the eye-tracking task: unpleasant (3010, 3150, 3015, 3069, 3060, 3225, 9571, 9414, 9326, 9301, 9008, 3400, 9184, 6231, 9007, 9419, 9320, 9321, 9925, 7359, 3010, 3150, 3015, 3069, 3060, 3225, 9571, 9414, 9326, 9301, 9008, 3400, 9184, 6231, 9007, 9419, 9320, 9321, 9925, 7359); neutral (2026, 7039, 7038, 7036, 2377, 2514, 2487, 7057, 7365, 5471, 7058, 2390, 7710, 7513, 2597, 7033, 2305, 7095, 2273, 7546).

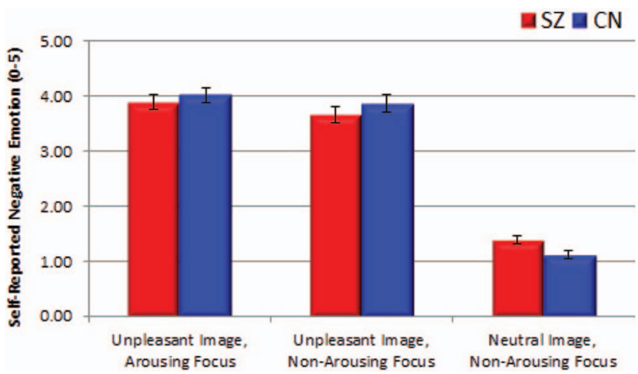

Figure 2. Mean self-reported state negative emotional experience in response to stimuli. SZ = schizophrenia; CN = control. See the online article for the color version of this figure.

ERP Directed Attention Results

The Group × Condition × Epoch repeated-measures ANOVA indicated a significant three-way interaction, $F(2, 102) = 3.21$, $p < .05$ ($\eta^2_{\mathrm{partial}} = 0.05$), as well as a significant within-subjects effect of emotion, $F(2, 102) = 53.81$, $p < .001$ ($\eta^2_{\mathrm{partial}} = 0.07$). The between-subjects effect, main effect of epoch, and all two-way interactions were nonsignificant. As can be seen in Figure 3, LPP amplitude decreased over the first 3 s in both CN and SZ. This may be because the LPP is an index of attention, and that there are fewer scene regions attended to as the trial progresses from seconds 1–3. As is sometimes observed (Hajcak et al., 2010), the LPP was negative in absolute polarity, with a greater relative positivity for emotional than neutral stimuli.

Follow-up paired-samples *t* tests confirmed the expected effects of emotional reactivity in both groups (unpleasant > neutral) and the hypothesized effect of emotion regulation condition in controls and lack thereof in SZ. Specifically, in CN, amplitude of the LPP was higher for unpleasant stimuli with an arousing focus than unpleasant stimuli with a nonarousing focus and neutral stimuli in the early and late epochs ($p < .05$ for all). SZ patients also showed higher amplitude LPP for both unpleasant stimulus conditions than neutral ($p < .01$ for all). Both groups therefore demonstrated a robust neural response to unpleasant stimuli. CN also demonstrated successful emotion regulation as indicated by lower LPP amplitude for unpleasant stimuli with a nonarousing focus than unpleasant stimuli with an arousing focus in the early ($t = 3.05$; $p < .01$) and late epochs ($t = 3.31$, $p < .01$). In contrast, the amplitude of the LPP did not differ between unpleasant stimuli with arousing and nonarousing focus in SZ for the early ($t = 0.49$, $p = .63$) or late epochs ($t = 1.07$, $p = .29$) (see Figure 4).

ERP Passive Viewing Results

Repeated-measures ANOVA revealed a significant Epoch × Condition interaction, $F(2, 102) = 5.24$, $p < .01$ ($\eta^2_{\mathrm{partial}} = 0.09$), within-subjects effect of condition, $F(2, 102) = 33.8$, $p < .001$ ($\eta^2_{\mathrm{partial}} = 0.40$), and between-subjects effect of group, $F(1, 51) =$

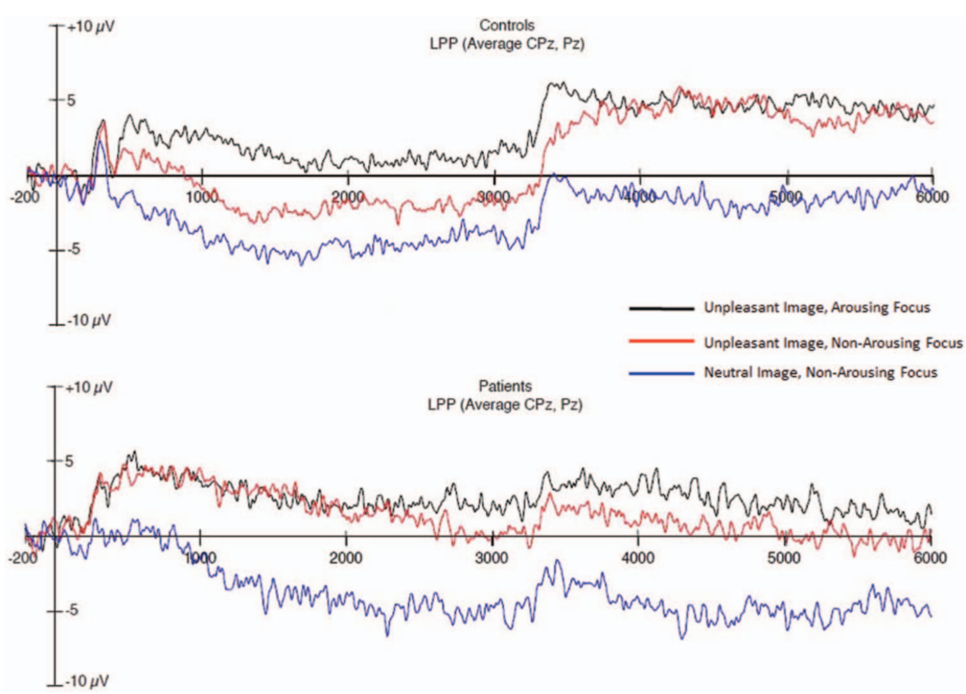

Figure 3. Late positive potential (LPP) grand average waveforms. Top panel presents grand average LPP waveforms for controls; Bottom panel presents grand average LPP waveforms for individuals with schizophrenia. The directed attention portion of the trial occurred between 0 and 3,000 ms; The passive viewing/reactivity portion of the trial occurred from 3,000 to 6,000 ms. Unpleasant image with arousing focus = black; Unpleasant image with nonarousing focus = red; Neutral image with nonarousing focus = blue. See the online article for the color version of this figure.

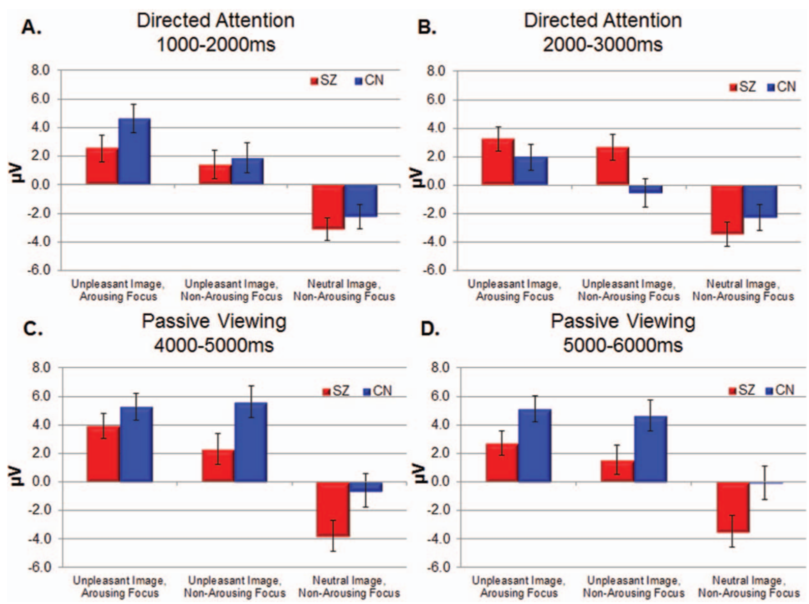

Figure 4. Mean late positive potential (LPP) amplitudes in early and late epochs for directed attention and passive viewing portions of the trial. Panel A presents mean LPP amplitude in the early window of the directed attention portion of the trial (1,000–2,000 ms); Panel B presents mean LPP amplitude in the late window of the directed attention portion of the trial (2,000–3,000 ms); Panel C presents mean LPP amplitude in the early window of the passive viewing portion of the trial (4,000–5,000 ms); Panel D presents mean LPP amplitude in the late window of the passive viewing portion of the trial (5,000–6,000 ms). SZ = schizophrenia; CN = control. See the online article for the color version of this figure.

6.85, $p < .02$ ($\eta^2_{partial} = 0.12$). All other two- and three-way interactions were nonsignificant.

A priori selected within-group paired samples *t* tests were used to test hypothesized effects of emotional reactivity in each group. In early and late epochs, CN had higher LPP amplitude for unpleasant stimuli with an arousing focus and unpleasant stimuli with a nonarousing focus compared to neutral stimuli (*p*s <0.001); unpleasant stimuli with an arousing and nonarousing focus did not differ from each other (*p*s >0.58). The same effect emerged in SZ, where unpleasant stimuli with an arousing and nonarousing focus were larger in amplitude than neutral stimuli for early and late windows (*p*s <0.001), but did not differ from each other (*p*s >0.23). Thus, both SZ and CN evidenced the expected emotional reactivity effects to unpleasant stimuli during the passive viewing portion of the trial.

Eye-Tracking Results

First-fixation time in AOI. First fixation time was used to index the bottom-up capture of attention by arousing aspects of emotional scenes. Repeated-measures ANOVA indicated a significant Group × Condition interaction, $F(1.38, 69.02) = 5.30$, $p < .02$ ($\eta^2_{partial} = 0.10$), as well as significant effects of condition, $F(1.38, 69.02) = 204.32$, $p < .001$ ($\eta^2_{partial} = 0.80$), and group, $F(1, 50) = 4.49$, $p < .04$ ($\eta^2_{partial} = 0.08$). Follow-up one-way ANOVAs indicated that SZ had significantly longer first fixation time than CN for the unpleasant stimulus with nonarousing focus condition, $F(1, 50) = 6.88$, $p < .01$; however, there were no group differences for unpleasant stimuli with an arousing focus, $F(1, 50) = 0.16$, $p = .69$, or neutral stimuli, $F(1, 50) = 2.16$, $p = .15$. Thus, SZ showed a selective deficit in the unpleasant stimulus with a nonarousing focus condition (see Figure 5, Panel A).

Percentage of fixations within arousing AOIs for unpleasant images with non-arousing focus. SZ could have displayed longer first fixation times for the unpleasant stimulus nonarousing focus condition for two reasons: fixating on other nonarousing aspects of the unpleasant scene that were located outside of the target window or fixating on arousing aspects of the unpleasant scene located outside of the target window. Additional analyses were conducted using the unpleasant stimulus nonarousing focus condition to evaluate these two possibilities. Using the arousing AOIs (see methods section), one-way ANOVA indicated that SZ had a significantly higher proportion of fixations in arousing areas of the scene that were located outside of the nonarousing target window than CN, $F(1, 50) = 7.36$, $p < .01$ (see Figure 5, Panel B). Thus, SZ were more likely than CN to fixate on arousing scene regions when the target window cued focus toward a nonarousing scene region.

Percentage of total fixations in AOI. The proportion of total fixations within the AOI was calculated to assess general attentional control and allocation of top-down attention to the target window (see Figure 5, Panel C). Repeated-measures ANOVA indicated significant effects of condition, $F(2, 100) = 134.4$, $p < .001$($\eta^2_{partial} = 0.73$), and group, $F(1, 50) = 8.07$. $p < .01$ ($\eta^2_{partial} = 0.14$). The Condition × Group interaction was nonsignificant, $F(1.47, 73.6) = 2.05$, $p = .15$ ($\eta^2_{partial} = 0.04$). Follow-up one-way ANOVAs indicated that SZ had fewer fixations within the AOI than CN in all three conditions: unpleasant image with arousing focus, $F = 5.12$, $p < .03$; unpleasant image with nonarousing

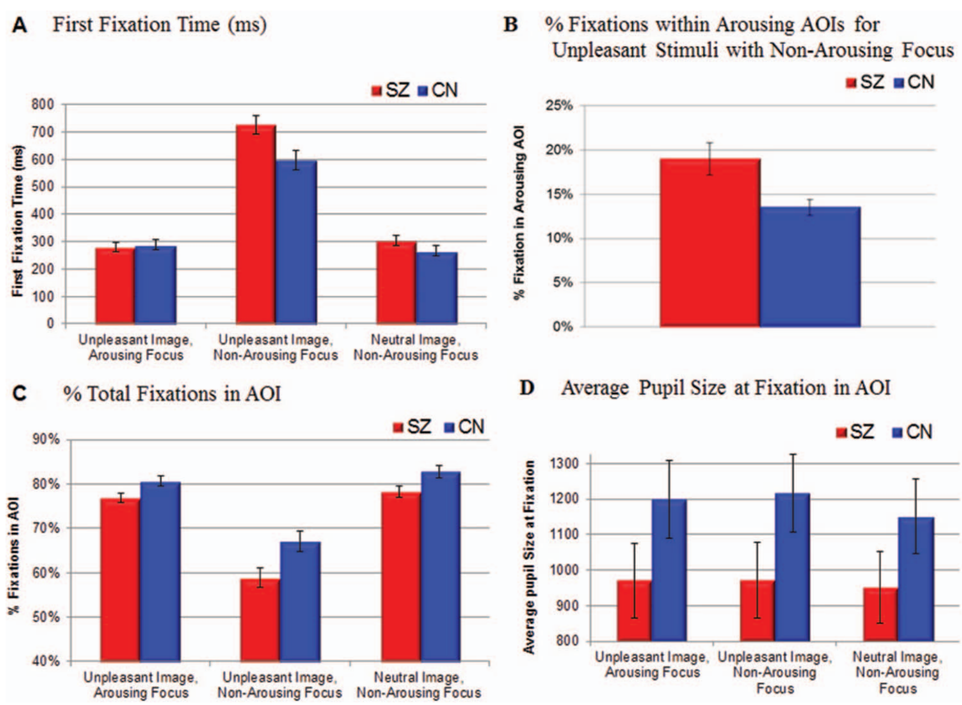

Figure 5. Eye-tracking and pupil size data. SZ = schizophrenia; CN = control. See the online article for the color version of this figure.

focus, $F = 6.51$, $p < .02$; neutral image with nonarousing focus, $F = 5.56$, $p < .03$. Within-group paired samples t tests indicated that SZ and CN showed a similar pattern of performance across conditions. SZ evidenced no differences between unpleasant stimuli with an arousing focus and neutral stimuli ($t = 1.61$, $p = .12$), similar to CN ($t = 1.67$, $p = .11$). SZ had a lower proportion of fixations in the AOI for unpleasant images with a nonarousing focus than neutral images ($t = 9.84$, $p < .001$) and unpleasant images with an arousing focus ($t = 8.12$, $p < .001$); this pattern was also seen in CN ($t = 11.4$, $p < .001$; $t = 7.63$, $p < .001$). Thus, both SZ and CN had more difficulty directing attention to the target window for unpleasant images with a nonarousing focus than unpleasant images with an arousing focus or neutral images, and SZ had more difficulty fixating within the target window than CN across all conditions.

Average pupil dilation during fixations in AOI. Average pupil size at fixation within the AOI was examined as an indicator of affective response and recruitment of effortful cognitive control processes. Repeated-measures ANOVA indicated a significant Group × Condition interaction, $F(2, 100) = 7.84$, $p < .001$ ($\eta^2_{\text{partial}} = 0.14$), as well as a significant within-subjects effect of condition, $F(2, 100) = 30.82$, $p < .001$ ($\eta^2_{\text{partial}} = 0.38$; see Figure 5, Panel D). The between-subjects effect of group was nonsignificant, $F(1, 50) = 2.23$, $p = .14$ ($\eta^2_{\text{partial}} = 0.04$). Follow-up one-way ANOVAs indicated that SZ and CN did not differ on any of the three conditions ($F < 2.58$, $p > .12$). Within-group paired samples t tests conducted in the CN group indicated significantly greater pupil dilation in the unpleasant nonarousing focus ($t = 6.09$, $p < .001$) and unpleasant arousing focus conditions ($t = 5.04$, $p < .001$) than neutral; pupil diameter was also significantly higher for unpleasant nonarousing focus than unpleasant arousing focus ($t = 2.14$, $p < .05$). In SZ, the unpleasant arousing focus (3.07, $p < .01$) and unpleasant nonarousing focus (2.70, $p < .02$) conditions were both higher than neutral; however, there were no significant differences between unpleasant arousing focus and unpleasant nonarousing focus ($t = 0.38$, $p = .71$). Thus, both SZ and CN demonstrated an affective arousal effect of greater pupil dilation for unpleasant than neutral stimuli; however, only CN demonstrated the expected emotion regulation effect on pupil dilation.

Correlations

In both SZ and CN, LPP amplitude during directed attention and eye-tracking variables of interest during directed attention (first fixation time, percentage total fixations in AOI, pupil size) were not significantly associated with state negative affect, trait negative affect, TEPS subscales, DPX performance, symptoms (patients), or functional outcome (patients). There were no significant correlations between eye-tracking variables, LPP amplitude, or DPX scores in SZ or CN.

Discussion

The current study is the first to evaluate whether individuals with SZ can effectively use attentional deployment strategies to down regulate negative emotion. Results supported the hypothesis that both CN and SZ would be sensitive to the emotional content of IAPS stimuli, as indicated by larger LPP amplitude to unpleasant compared to neutral images during the passive viewing portion of the trial. Most importantly, there was also support for the hypothesis that individuals with SZ would display a neurophysiological emotion regulation abnormality. Specifically, CN had lower LPP amplitude for unpleasant images with a nonarousing focus than unpleasant images with an arousing focus during the directed attention portion of the trial; these findings replicate prior studies using this paradigm in samples of undergraduate students and extend them into a community sample (Dunning & Hajcak, 2009; Hajcak, Dunning, & Foti, 2009; Hajcak, MacNamara, Foti, Ferri, & Keil, 2013). However, as hypothesized, individuals with SZ failed to show differences in the amplitude of the LPP between these conditions. Behavioral data also indicated that CN reported less negative emotion to unpleasant stimuli with a nonarousing focus than unpleasant stimuli with an arousing focus; however, individuals with SZ did not report differences in negative emotion between these conditions. Furthermore, consistent with prior studies examining self-report to laboratory-based stimuli, SZ also reported more negative affect than CN to neutral stimuli (Cohen & Minor, 2010). Overall, these findings are consistent with other studies reporting an emotion regulation abnormality in SZ using reappraisal and expressive suppression paradigms (Fan et al., 2013; Horan et al., 2013; Kimhy et al., 2012; Morris et al., 2012; Strauss et al., 2013; van der Meer, et al., 2009), and extend prior studies by providing the first evidence that directed attention strategies are ineffective at down-regulating negative affect in SZ. When viewed in relation to Gross' (Gross, 2002) process model of emotion regulation, results of the current study on directed attention and past studies on reappraisal suggest that antecedent focused strategies may be ineffective at down-regulating negative emotion in SZ.

Although the ERP and behavioral results indicate that emotion regulation is abnormal in SZ, they do not suggest why directed attention was ineffective at decreasing affective response to unpleasant stimuli. Data from the eye-tracking task, although collected separately from the ERP task, was useful in this regard because it suggests potential explanations for why SZ failed to evidence LPP modulation. There were several key eye-tracking findings. First, SZ had a more latent first fixation time within the target window AOI than CN for unpleasant images with a nonarousing focus. This deficit could have occurred because patients were attending to either arousing aspects of the scene outside of the target window or other neutral scene regions. Follow-up analyses confirmed that SZ were indeed more likely to fixate on arousing areas of the image outside of the target window than CN. These results are consistent with data from prior studies using behavioral tasks which indicated that task-irrelevant unpleasant stimuli capture bottom-up attention in SZ more than CN (Besnier et al., 2011; Kinderman, 1994; Kinderman, Prince, Waller, & Peters, 2003; Park, Park, Chun, Kim, & Kim, 2008), as well as studies indicating that SZ have more difficulty disengaging top-down attention once they have attended to unpleasant stimuli (Strauss, Allen, Duke, Ross, & Schwartz, 2008; Strauss, Llerena, & Gold, 2011). Additionally, the data on total proportion of fixations within the AOIs suggests that general cognitive control deficits also contribute to the ineffective use of the directed attention to down-regulate negative affect. Although we did not find a significant correlation between DPX performance and emotion regulation variables, the total fixation data are consistent with results of prior studies indicating general cognitive control deficits in SZ using nonaffective tasks (Braver, Barch, & Cohen, 1999; Cohen, Braver, & O'Reilly, 1996). Tasks requiring basic cognitive control and tasks involving emotion regulation both rely on the prefrontal cortex (Ferri, Schmidt, Hajcak, & Canli, 2013; Ochsner et al., 2012). The prefrontal cortex may fail to exert top-down control over the amygdala when patents attempt to direct attention toward more neutral aspects of the environment and inhibit the processing of goal-irrelevant arousing content. Significant effort is required to focus attention away from unpleasant stimuli that automatically capture attention; deficits in goal representation or maintenance may make this task even more difficult for patients, rendering them more susceptible to the bottom-up capture of aversive content and less able to adaptively shift attention to decrease negative affect. Difficulty down-regulating negative emotion may therefore represent another manifestation of cognitive control impairments in SZ.

Pupilary data provided further support for the role of cognitive control deficits in poor emotion regulation. Prior studies using reappraisal paradigms in healthy individuals have shown increased pupil size for unpleasant stimuli that are reappraised than those that are passively viewed, suggesting that emotion regulation requires effortful cognitive control processes (van Reekum et al., 2007; Urry et al., 2006). Consistent with this finding, CN displayed greater pupil size for unpleasant images with a nonarousing focus than unpleasant images with an arousing focus. However, individuals with SZ evidenced no differences in pupil size between unpleasant images with an arousing and nonarousing focus, despite showing greater pupil dilation for both unpleasant conditions than neutral. When viewed in conjunction with past studies, these findings may indicate that patients fail to recruit effortful cognitive control processes needed to inhibit the prepotent response of attending to arousing aspects of unpleasant scenes.

There are some considerations that may limit interpretation of the current results. First, interpretation of the behavioral data obtained during the ERP task is complicated by the fact that self-reports of negative affect were made after the passive viewing portion of the trial. By including the passive viewing portion of the trial after directed attention, this may have attenuated effects on subjective experience. CN may have been more likely to respond to demand characteristics of the directed attention manipulation, or to have been better at holding their subjective experience of negative emotion in working memory across the entire trial. Second, there was a significant between-subjects effect during the passive viewing portion of the trial that was not observed in previous studies using the LPP (e.g., Horan et al., 2010, 2012), This finding may have emerged because passive viewing followed the directed attention portion of the trial, which had a differential long-term effect in SZ and CN. Given that passive viewing occurred after directed attention, interpretation of this between-groups difference must be made with caution. Third, small sample sizes may have limited the ability to observe significant correlations between task performance variables and measures of emotional experience, symptoms, and functional outcome. Fourth, the role of antipsychotic medications on task behavior could not be adequately assessed. Given known effects of antipsychotics on pupil dilation (Steinhauer, van Kammen, Colbert, Peters, & Zubin, 1992), it will be important for future studies to explore the role of D2 antagonism when using pupillary and eye-tracking measures. We did not, however, observe significant group differences in pupil size in the current study, and we do not expect that antipsychotics could account for the condition-related pupil results given that they would be expected to influence all three conditions similarly. Finally, although the current ERP results are consistent with an emotion regulation abnormality in SZ, there is some debate as to what the LPP actually measures, with evidence suggesting that it is sensitive to both attention and emotion regulation effects (Hajcak et al., 2010). Therefore, further research is needed to determine whether the current findings best reflect a problem with emotion regulation, a problem with attention, or some combination of the two.

Future studies should further explore the role of general cognitive control in emotion regulation abnormalities in SZ, as well as the role of visual attention while patients are implementing other regulation strategies. Given that visual attention has been shown to account for a significant proportion of variance in emotion regulation effectiveness during reappraisal (van Reekum et al., 2007), it will be important for future ERP and fMRI studies to incorporate eye-tracking to determine the extent to which attention contributes to ineffective reappraisal in SZ. Although cues to direct attention to nonarousing scene regions failed to decrease the subjective and neural response to unpleasant stimuli in people with SZ in the current study, it is possible that patients could be taught to utilize this emotion regulation strategy more effectively with training. Several attentional training programs have been developed to shift selective attention away from aversive stimuli and toward more neutral stimuli (MacLeod & Mathews, 2012; Wadlinger & Isaacowitz, 2011). The amount of time that these effects on attention persist after training has concluded may depend upon the number of trials and sessions administered (MacLeod & Mathews, 2012); however, it is promising that significant improvements in attention can be found even after a single session with approximately 500 trials (MacLeod & Mathews, 2012). Thus, it will be important for future studies to explore whether attention training has a beneficial effect on emotion regulation in SZ.

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