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Ann M. Kring, Marja Germans Gard, and David E. Gard

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# Emotion Deficits in Schizophrenia: Timing Matters

Ann M. Kring and Marja Germans Gard  
University of California, Berkeley

David E. Gard  
San Francisco State University

The past two decades of research on emotional response in schizophrenia has demonstrated that people with schizophrenia do not have a marked deficit in reported emotional experience in the presence of emotionally evocative stimuli. However, the extent to which people with schizophrenia maintain their emotional state to guide future behavior remains a largely unexplored area of investigation. In the present study, we tested hypotheses about whether people with schizophrenia maintained their emotional state in the absence of emotionally evocative stimuli. In addition to reported emotional experience, we measured startle response magnitude both during the viewing and after the offset of emotional pictures to assess whether people with schizophrenia ( $n = 31$ ) and without schizophrenia ( $n = 28$ ) differ in their patterns of immediate response to emotional pictures and in their patterns of maintenance of these responses. Our findings indicated that people with and without schizophrenia did not differ in their self-report or startle response magnitude during presentation of emotional pictures. However, healthy controls maintained these responses after the stimuli were removed from view, but people with schizophrenia did not.

*Keywords:* emotion, schizophrenia, affective startle modulation, motivation

In the past two decades, research on emotional responding in schizophrenia has revealed a strikingly consistent pattern of results. In response to emotionally evocative materials, people with schizophrenia are less facially expressive than people without schizophrenia, yet they report experiencing equal or greater amounts of emotion (for meta-analysis and review, see Cohen & Minor, 2010; Kring & Moran, 2008). This disconnect between the expression and experience of emotion has been observed across laboratories, medication status (on/off), samples (unselected schizophrenia patients, deficit patients), evocative stimuli (emotional films, social interactions, tastes, cartoons), and measurement methods (self-report, behavior, functional magnetic resonance imaging [fMRI], evoked potential, startle, electromyography).

Studies using physiological measures (skin conductance, electromyographic activity, event-related potentials) of emotional response have also found that people with schizophrenia exhibit responses to evocative stimuli that are more similar than dissimilar to those of people without schizophrenia (e.g., Curtis, Lebow, Lake, Katsanis, & Iacono, 1999; Horan, Wynn, Kring, Simons, & Green, 2010; Kring & Neale, 1996; Schlenker, Cohen, & Hopmann, 1995; Volz, Hamm, Kirsch, & Rey, 2003; Yee et al., 2010). Taken together, a good deal of evidence suggests that, at least with

respect to emotional experience in response to evocative stimuli, people with and without schizophrenia are quite similar to one another.

Recent research has pointed to the importance of considering the temporal course of emotion. That is, emotional responses are not wholly temporally constrained by the presence of an eliciting stimulus but instead vary in their anticipation, peak, and maintenance in ways that may hold important information about individual differences in emotional responding (Davidson, 1998). Assessing these different aspects of the time course of emotion in schizophrenia has illuminated areas of emotion deficits that would have gone unnoticed had the time course not been taken into consideration (Kring & Caponigro, 2010). For example, an accumulating body of evidence now supports the notion that people with schizophrenia do not have a deficit in *consummatory* pleasure (i.e., pleasure experienced “in-the-moment” or in the presence of emotionally evocative stimuli) but instead have a deficit in *anticipatory pleasure* (i.e., the ability to anticipate that future events will be pleasurable as well as the ability to experience pleasure in anticipation of things to come). Deficits in anticipatory pleasure among people with schizophrenia have been found in studies using self-report, psychophysiological, behavior, and fMRI methods (Burbridge & Barch, 2007; Gard, Kring, Germans Gard, Horan, & Green, 2007; Horan et al., 2010; Juckel et al., 2006).

## Maintaining Emotion

Another important aspect of the time course of emotional response is the maintenance of emotion (Davidson, 1994, 1998). From an affective science perspective, there is considerable agreement that emotional responses are relatively brief, phasic events that are organized along two opposing, overarching approach-or-avoidance motivational systems (e.g., Davidson, 1995; Dickinson & Dearing, 1979; Konorski, 1967; Lang, 1995). Furthermore, engagement of these approach-or-avoidance motivational systems through the maintenance of emotion is thought to facilitate goal-

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Ann M. Kring and Marja Germans Gard, Department of Psychology, University of California, Berkeley; David E. Gard, Department of Psychology, San Francisco State University.

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Correspondence concerning this article should be addressed to Ann M. Kring, Department of Psychology, University of California, Berkeley, 3210 Tolman Hall, Berkeley, CA 94720. E-mail: akring@berkeley.edu

directed behavior toward something desirable or away from something noxious, respectively. In addition, there is some evidence to suggest that emotional responses that engage these motivational systems persist beyond the offset of the eliciting stimulus, as has been shown in studies with healthy individuals using self-report (e.g., Frost & Green, 1982; Garrett & Maddock, 2001), corrugator electromyographic activity (e.g., Bradley, Cuthbert, & Lang, 1996; Sirota, Schwartz, & Kristeller, 1987), pupillary dilation (e.g., Siegle, Granholm, Ingram, & Matt, 2001), amygdalar activity (e.g., Siegle, Steinhauer, Thase, Stenger, & Carter, 2002), and EEG asymmetry (e.g., Jackson et al., 2003; Larson & Davidson, 2001).

One particularly effective method for assessing the time course of emotional response is the affective startle modulation paradigm. In this paradigm, activation of motivational systems exerts a modulatory influence on defensive startle responses, such that presentation of negatively valenced affective material engages an avoidance motivational system and primes associated behaviors (e.g., Lang, 1994, 1995; Lang, Bradley, & Cuthbert, 1990, 1997). Thus, the magnitude of the eyeblink, one manifestation of the defensive startle reflex, elicited during the engagement of the aversive motivational system will be more potent than that of the same eyeblink response engaged in the absence of this motivational activation. By contrast, presentation of positively valenced affective material engages an approach motivational state and primes appetitive behaviors. The eyeblink response component of the startle reflex elicited in an approach motivational context will be attenuated because of its incompatibility with the primed appetitive behaviors.

A number of studies have examined the maintenance of affective modulation of the startle response by continuing to measure the eyeblink startle reflexive response following the offset of emotionally evocative stimulus presentation. With two exceptions (Bradley, Cuthbert, & Lang, 1993; Dichter, Tomarken, & Baucom, 2002), these studies have found that an affective modulation of the startle response is maintained following picture presentation, such that eyeblink responses following the offset of unpleasant emotional stimuli are larger than eyeblink responses following the offset of pleasant emotional stimuli (Bradley et al., 1996; Germans Gard & Kring, 2007; Jackson et al., 2003; Larson & Davidson, 2001; Larson, Sutton, & Davidson, 1998; Schupp, Cuthbert, Bradley, Birbaumer, & Lang, 1997). Studies that found affective modulation of the startle response maintenance typically required participants to “do” something during the offset period, whether it was following an instruction to explicitly imagine that the picture is still there (e.g., Schupp et al., 1997) or following an implicit instruction to maintain emotion so that participants can report on their experienced emotion following the offset period (e.g., Germans Gard & Kring, 2007). Participants in the Bradley et al. (1993) study were asked to report on their experienced emotion following the offset period; however, these participants failed to show affective modulation of the startle response in the offset period, perhaps due to the time at which the startle response was measured or the particular stimuli that were presented.

### Maintaining Emotion in Schizophrenia

Four studies to date have assessed affective modulation of the startle response in schizophrenia, and all have found that people

with schizophrenia exhibit the same pattern of startle modulation in the presence of evocative stimuli as do people without schizophrenia (Curtis et al., 1999; Schlenker et al., 1995; Volz et al., 2003; Yee et al., 2010). No study has examined the maintenance of affective modulation of the startle response in schizophrenia. To our knowledge, only two studies have assessed emotion-related maintenance in schizophrenia (Heerey & Gold, 2007; Ursu et al., in press). In an fMRI study (Ursu et al., in press), people with schizophrenia and healthy controls exhibited comparable regions of brain activation while viewing emotional pictures, yet people with schizophrenia diverged from healthy controls in brain activation once the pictures were removed from view. Both groups showed activation in dorsolateral prefrontal cortex (PFC), orbitofrontal and ventromedial PFC, and amygdala during picture presentation. However, only controls continued to exhibit activity in dorsolateral, ventromedial, and orbitofrontal PFC following picture offset, supporting the notion that people with schizophrenia have difficulty maintaining emotion in the service of goal-directed behavior.

In a behavioral study, Heerey and Gold (2007) showed people with and without schizophrenia emotionally evocative pictures in two conditions and had them press a button quickly either to see it again (for positive images) or to not see it again (for negative images). In the first, called the representational responding condition, button pressing took place after the image was removed from view for 3 s. In the second, called the evoked responding condition, button pressing commenced during picture viewing. Interesting group differences emerged in the representational condition, in which participants presumably needed to maintain a representation of the pictures to guide their button pressing. Healthy individuals exhibited a pattern of button pressing that was distinguishable by valence (i.e., they pressed the button more frequently for the emotional than the neutral pictures), but participants with schizophrenia did not show such differentiation. Taken together, these fMRI and behavioral studies point to difficulties in maintaining emotion in the service of motivated behavior among people with schizophrenia.

### The Present Study

In the present study, we sought to replicate and extend previous investigations of emotional responding in schizophrenia by examining both self-reported emotional experience and affective modulation of the startle response during the presentation of emotionally evocative pictures. In addition, we sought to explore the time course of emotion by examining affective modulation of the startle response after the offset of emotional stimuli to obtain an index of maintenance of emotional processes in people with and without schizophrenia.

On the basis of previous studies, we hypothesized that individuals with schizophrenia would exhibit comparable reports of experienced emotion and physiological responses during presentation of emotionally evocative stimuli. In particular, we expected that individuals with and without schizophrenia would engage the avoidance motivational system during the presentation of negative pictures. This would manifest as potentiated startle responses during negative compared to positive or neutral pictures. Additionally, we expected that individuals with and without schizophrenia would engage the approach motivational system during the

presentation of positive pictures, which would manifest as attenuated startle responses during positive compared to negative or neutral pictures.

We additionally hypothesized that individuals with schizophrenia would exhibit a deficit in their ability to maintain their physiological responses once the stimuli were removed from view. That is, we expected that controls would continue to exhibit potentiated startle responses following the offset of negative pictures and attenuated startle responses following the offset of positive pictures, similar to those seen in healthy samples reviewed above, but that individuals with schizophrenia would not continue to show such differentiated startle responses by valence.

## Method

### Participants

Demographic and clinical characteristics of the participants are presented in Table 1.

Participants were 31 outpatients diagnosed with schizophrenia ( $n = 27$ ) or schizoaffective disorder ( $n = 4$ ) and 28 healthy controls. Participants with schizophrenia were recruited from outpatient treatment facilities in the greater San Francisco Bay area as well as from local board and care facilities. Diagnoses were based on the *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.; *DSM-IV*; American Psychiatric Association, 1994) and were confirmed with the Structured Clinical Interview for *DSM-IV*, Patient Version (SCID/P-IV; First, Spitzer, Gibbon, & Williams, 1994), administered by one of the authors who had received

extensive training in diagnostic interviewing. The four people with schizoaffective disorder were not in a mood episode at the time of testing, and all people with schizophrenia or schizoaffective disorder were taking first generation ( $n = 5$ ), second generation ( $n = 23$ ), or both types ( $n = 3$ ) of antipsychotic medication at the time of testing. Any potential participant with a history of severe head trauma, stroke, neurological disease, current mood disorder, or substance abuse was not recruited for the study. Participants in the clinical group were interviewed for general psychiatric symptoms with the 24-item expanded UCLA version of the Brief Psychiatric Rating Scale (BPRS; Lukoff, Nuechterlein, & Ventura, 1986; Overall & Gorham, 1962), a widely used measure of psychiatric symptoms that has demonstrated good reliability across several studies (Hedlund & Vieweg, 1980). BPRS items were rated on a 7-point scale from 1 (*not present*) to 7 (*extremely severe*). A positive symptom scale (sum of unusual thought content, disorientation, hallucinations, and suspiciousness items) and a negative symptom scale (sum of the blunted affect, emotional withdrawal, and motor retardation) were computed.

In total, 28 control participants were recruited via fliers posted in the community. Interested individuals phoned the laboratory and participated in a brief screening. Any individual who reported a personal or family history of schizophrenia spectrum illnesses, current mood or substance abuse, head trauma, stroke, or neurological illness was not invited to participate. Control participants who were invited to participate were interviewed with the Structured Clinical Interview for *DSM-IV*, Nonpatient Version (SCID-NP; First et al., 1994), to confirm the lack of current psychiatric diagnoses.

The groups did not differ with respect to years of parental education,  $t(56) = 0.75$ , *ns*; ethnicity,  $\chi^2(6, N = 59) = 5.45$ , *ns*; marital status,  $\chi^2(4, N = 59) = 2.28$ , *ns*; or gender,  $\chi^2(1, N = 59) = 0.00$ , *ns*. However, compared to controls, participants with schizophrenia tended to be older,  $t(57) = 1.97$ ,  $p = .053$ ; to have more years of education,  $t(5) = 2.05$ ,  $p = .045$ ; and to be less likely to be employed,  $\chi^2(1, N = 59) = 20.69$ ,  $p < .001$ .

### Picture Stimuli

Fifty-four emotionally evocative pictures (18 positive, 18 neutral, 18 negative) were selected from the International Affective Picture System collection (Center for the Study of Emotion and Attention, 1999). Positively valenced pictures included contents of action/adventure ( $n = 9$ ) and other-sex erotica ( $n = 9$ ). Negatively valenced pictures included contents of victimization ( $n = 6$ ) and threat ( $n = 12$ ). Neutral pictures ( $n = 18$ ) included images of household objects. Pictures were selected on the basis of published normative ratings (1–9 scale; Lang, Bradley, & Cuthbert, 1999; Lang, Bradley, & Cuthbert, 2005) such that positive and negative pictures were similar on arousal (normative positive picture mean arousal = 6.34; normative negative picture mean arousal = 6.57) but greater than neutral (mean arousal = 2.91). Similarly, neutral pictures were of a valence (normative mean valence = 4.92) between that of negative pictures ( $M = 2.39$ ) and positive pictures ( $M = 7.06$ ). As in prior studies (e.g., Gard, Germans Gard, Mehta, Kring, & Patrick, 2007), separate picture sets meeting these criteria

Table 1  
*Demographic and Clinical Characteristics*

Characteristic	Group		<i>p</i>
	Schizophrenia	Control	
Age	42.47 (9.20)	37.46 (10.03)	.053
Education	14.23 (2.75)	13.09 (1.06)	.045
Parental education	13.60 (3.20)	12.73 (3.44)	.477
Gender, <i>n</i> men/women	20/11	18/10	.599
Ethnicity, <i>n</i>			.488
African American	10	10	
Caucasian	15	7	
East or South Asian	1	3	
Multiethnic	2	3	
Latino	3	4	
Marital status, <i>n</i>			.684
Married/living with	2	2	
Divorced/widowed	5	7	
Single	23	18	
Separated	1	1	
Employment status, <i>n</i>			.001
Unemployed	25	22	
Employed	6	6	
Prior hospitalizations, <i>n</i>	4.63 (4.53)		
Illness duration	19.03 (9.94)		
BPRS total	41.43 (7.88)		
BPRS positive	10.97 (4.62)		
BPRS negative	7.32 (3.22)		

*Note.* Tabled values are means unless otherwise specified. Standard deviations are in parentheses. Age, education, parental education, and illness duration are in years. BPRS = Brief Psychiatric Rating Scale.

were selected for male and female participants, in accordance with the published picture ratings available for each gender.<sup>1</sup>

## Procedure

After informed consent had been obtained, we conducted the clinical interview from which SCID and BPRS ratings were made. Next, electrodes were applied and impedance was checked. Participants were told that they would see a series of pictures presented on the computer screen and that they should look at each picture the entire time that the picture was on the screen. They were told that after each picture, they would be prompted to make a rating of how they felt while they were viewing the picture. Participants were also told that they would occasionally hear noises over the headphones that they were asked to wear, but that they could ignore these noises. To familiarize them with the procedure and the startle probe, participants viewed eight picture trials, of which seven contained startle probes.

After the familiarization trials, participants completed 54 experimental trials. Each trial consisted of an image presented for 6 s, followed by a 5 s blank screen, during which "maintenance" probes were presented on select trials. After the blank screen, participants rated their experienced valence (pleasant, unpleasant) and arousal at the end of each trial using the computerized, 0- to 20-point version of the Self-Assessment Manikin (SAM; Cook, Atkinson, & Lang, 1987). The rating form displayed a cartoon figure that participants adjusted, using computer keys, to indicate (a) how happy or unhappy and (b) how calm or aroused they felt during the presentation of each picture. After completion of the SAM rating, there was an intertrial interval (randomly timed between 2.5 and 5 s) prior to the onset of the next picture.

## Stimulus Presentation

Presentation of the digitized images was controlled by a desktop computer by digitally pulsing a yoked laptop computer outfitted with a 36 cm LCD display positioned approximately 0.5 meters from the participant at a visual angle subtending 15.9 degrees. Pictures were presented in one of two orders such that all valences and probe times were evenly distributed throughout the sequence of trials (pairwise comparisons of mean serial positions for trials in each Valence  $\times$  Probe Time cell yielded  $t_s < 1$ ). Based on prior research, startle probes were presented either 3,500 ms after picture onset (during picture presentation) or 2,500 ms after picture offset (maintenance period). Within gender, for each valence, pictures probed during picture presentation and after offset were comparable on valence and arousal ratings from published norms (Lang et al., 1999). Six trials of each valence were probed at each probe time, six trials of each valence were left unprobed, and 9 intertrial interval trials were probed. The intertrial interval probes and unprobed trials were included so that probes during picture presentation or maintenance would not become predictable. Probes during the ITI were presented at 2, 3, or 4 s into the ITI period to further reduce predictability. No more than one probe was presented per trial. No more than two pictures of the same valence and no more than three of the same probe times were presented sequentially. Acoustic startle probes were digitally generated WAV files of a white noise burst 50 ms in duration, with instantaneous rise and fall times. Startle probes were amplified by a

Radio Shack SA-155 Integrated Stereo Mini-Amplifier to 100 dB and binaurally presented through Sennheiser HD 490 headphones. Probe stimuli were calibrated before each test session.

## Startle Response Recording and Data Reduction

Stimulus presentation and data acquisition were controlled by VPM software (Cook et al., 1987). The EMG signal was filtered through a 13–1,000 Hz bandpass and amplified by a gain of 10,000 with a Coulbourn V75-04 isolated bioamplifier with bandpass filter. EMG was sampled at 1,000 Hz by a Labmaster DMA A/D board for 50 ms prior to the startle probe onset and 250 ms after the startle probe onset. Trials with activity in the 50 ms window prior to probe onset (operationalized as  $> 3 SD$  for all probes for all participants) were counted as missing ( $< 1\%$  of the overall data). Electrode placement and skin preparation followed current guidelines for human startle research (Berg & Balaban, 1999; Blumenthal et al., 2005). Raw electromyographic (EMG) activity was collected with two Med-Associates Na-NaCl mini (4.2 mm sensor) Beckman-style reusable mini electrodes placed over the orbicularis oculi on the left eye, with one sensor directly under the pupil and the other lateral to this. The sensors, which were filled with Teca electrolyte gel, were placed just above the orbital ridge. Interelectrode distance was approximately fifteen millimeters. A third sensor was placed in the middle of the forehead as a ground. Before recording electrodes were placed, the skin was cleansed with distilled water and lightly abraded with fine sandpaper to lower impedance. Impedance was checked, and efforts were made to keep all impedances under 10 k $\Omega$ .

The EMG signal was digitally refiltered offline through a 28–500 Hz bandpass (van Boxtel, Boelhouwer, & Bos, 1998) and digitally rectified and integrated with a 30-ms time constant. Trained research assistants scored the integrated EMG data segments, marking the onset and peak of each blink using the EYEBLINK subroutine in VPM, which is based on the Balaban algorithm (Balaban, Losito, Simons, & Graham, 1986). Response amplitude (in A/D units) was computed by subtracting EMG activity at response onset from that at response peak (within 100 ms of probe onset). Because of extreme interindividual differences in average blink magnitude, data were standardized within each individual to produce a metric of responsivity ( $T$  scores) that was comparable across participants. That is, blink magnitude means and standard deviations were computed across the valence conditions (positive, negative, neutral) and converted to  $T$  scores ( $M = 50$ ,  $SD = 10$ ). The standardization procedure did

<sup>1</sup> The following IAPS picture numbers were used in this study: positive action, 5621w, 5626w, 5629w, 8030m, 8080m, 8161w, 8170m, 8180, 8185, 8186m, 8200m, 8210w, 8300w, 8370m, 8400; positive erotic, 4180m, 4210m, 4220m, 4290m, 4310m, 4538w, 4572w, 4650, 4656w, 4660, 4670w, 4677w, 4680, 4681w, 4690m; neutral, 2190w, 2200m, 2440w, 2480w, 2570w, 5120w, 5500m, 5510m, 6150m, 7000m, 7009, 7010m, 7020m, 7025w, 7031w, 7034, 7060w, 7080m, 7090, 7095m, 7110w, 7170, 7211, 7224w, 7234w, 7235w, 7490m, 7500m, 7700w, 7710m, 9070m; negative threat, 1050; 1525, 3530; 6230m, 6242w, 6243, 6250, 6260, 6300, 6370, 6510; 6540m; 6550; 6571; negative victim, 3000m, 3010m, 3051w, 3060m, 3061w, 3080w, 3400m, 6570w, 9050, 9250 (m = picture used exclusively for men, w = picture used exclusively for women).



not change the relative pattern of participants' responses across the picture types. This form of standardization is part of the current recommendations for startle research (Blumenthal et al., 2005) and has been used in a number of prior studies involving the emotion modulated startle paradigm (e.g., Forbes, Miller, Cohn, Fox, & Kovacs, 2005; Levenston, Patrick, Bradley, & Lang, 2000; Miranda, Meyerson, Myers, & Lovallo, 2003; Patrick, Bradley, & Lang, 1993; Sutton, Vitale, & Newman, 2002).

SAM valence and arousal ratings ranged from 0 to 20 (e.g., Levenston et al., 2000). For the valence ratings, lower values indicate more unpleasantness and higher values indicate more pleasantness, with a rating of 10 as neither unpleasant nor pleasant. For the arousal ratings, lower values indicate more calm and higher values indicate more aroused or energized.

### Data Analytic Plan

Repeated-measures multivariate analyses of variance (MANOVAs) were used for the analyses. Effect sizes are reported using eta squared. Given our use of *T* scores for the startle data, direct comparisons of responses to the individual valence conditions between individuals with and without schizophrenia are not appropriate. Therefore, in the analyses of startle data, significant interactions involving group were followed up with within group contrasts to examine the pattern of blink responses to the different valence conditions and time points separately for individuals with and without schizophrenia. Planned comparisons of all pairwise valence combinations were examined with Sidak's adjustment of significance level for multiple comparisons. Though the number of women in each group was fairly small, we nevertheless conducted preliminary analyses including sex as a between-subjects variable. There was neither a significant main effect of sex nor any significant interactions involving sex in the startle data, consistent with results of other studies of startle response in schizophrenia that looked for sex differences (Curtis et al., 1999; Volz et al., 2003); thus, we did not include this variable in the reported analyses. However, significant sex differences were observed in the experienced emotion data, and we thus included sex in these analyses.<sup>2</sup>

## Results

### Emotional Experience

**Valence ratings.** Descriptive statistics for reported emotional experience (valence and arousal) are presented separately by sex and group in Table 2.<sup>3</sup> A 2 (Group: patient, control)  $\times$  2 (Sex: men, women)  $\times$  3 (Valence: positive, neutral, negative) repeated-measures MANOVA of valence ratings yielded a significant main effect for valence,  $F(2, 53) = 64.68, p < .001, \eta_p^2 = .71$ , and a significant main effect for sex,  $F(1, 54) = 8.51, p = .005, \eta_p^2 = .14$ . No other effects were significant. As hypothesized, valence ratings were highest (i.e., more reported pleasantness) for positive pictures, followed by neutral and then negative pictures ( $ps < .01$ ) for both groups. Regardless of diagnostic group, men reported experiencing more pleasantness (i.e., higher valence ratings) across the picture types.

**Arousal ratings.** The valence main effect for arousal ratings was significant,  $F(2, 53) = 6.21, p = .004, \eta_p^2 = .19$ . However, this was qualified by a significant Sex  $\times$  Valence interaction,  $F(2,$

$53) = 8.73, p = .001, \eta_p^2 = .25$ . As seen in Table 2, men reported experiencing more arousal when viewing positive than neutral or negative pictures ( $ps < .01$ ). By contrast, women experienced the negative pictures as more arousing than either the positive or the neutral pictures ( $ps < .01$ ). The Group  $\times$  Sex interaction was also significant,  $F(1, 54) = 8.38, p = .005, \eta_p^2 = .13$ . Among participants with schizophrenia, women reported experiencing more arousal overall than did men,  $t(28) = 2.75, p < .01$ ; men and women controls did not differ from one another. Men with schizophrenia, however, reported experiencing less arousal than men without schizophrenia,  $t(35) = -2.59, p = .014$ ; women with and without schizophrenia did not differ from one another in experienced arousal.

In summary, participants with and without schizophrenia reported experiencing similar levels of valence, feeling most pleasant to positive pictures and least pleasant to negative pictures. Men experienced all the pictures as more pleasant than did women. With respect to experienced arousal, men experienced the positive pictures as most arousing, whereas women experienced the negative pictures as most arousing. Men in the control group experienced more arousal overall than men in the schizophrenia group. Within the schizophrenia group, however, women experienced more arousal than men.

### Startle Magnitude

A 2 (Group: patient, control)  $\times$  2 (Probe time: during picture, after picture)  $\times$  3 (Valence: positive, neutral, negative) repeated-measures MANOVA indicated that neither the group nor the probe time main effects were significant. The valence main effect was significant,  $F(2, 56) = 27.63, p < .001, \eta_p^2 = .58$ ; however, it was qualified by significant two-way interactions, including the Probe Time  $\times$  Valence interaction,  $F(2, 56) = 4.25, p = .019, \eta_p^2 = .13$ , and the Group  $\times$  Valence interaction,  $F(2, 56) = 4.20, p = .02, \eta_p^2 = .13$ . These, in turn, were qualified by a significant Group  $\times$  Valence  $\times$  Probe Time interaction,  $F(2, 56) = 3.14, p = .05, \eta_p^2 = .10$ .

Generally speaking, the Time  $\times$  Valence interaction indicated that both groups showed greater valence modulation during picture presentation than the offset period. The Group  $\times$  Valence interaction indicated that individuals without schizophrenia showed greater valence modulation across the time points than did individuals with schizophrenia.

To deconstruct the significant three-way interaction, we examined patterns of valence modulation of startle magnitude within each time point for each group using repeated-measures MANOVAs computed for each group at each time point. As illustrated in Figure 1a, the valence main effect was significant for both groups during picture presentation (schizophrenia:  $F(2, 29) = 26.68, p < .001, \eta_p^2 = .65$ ; control:  $F(2, 26) = 15.55, p < .001, \eta_p^2 = .55$ ). All pairwise comparisons were significant for controls, such that blink magnitude was smaller during positive than during

<sup>2</sup> We also examined whether there were differences across ethnic groups in experienced emotion and startle responding; no significant effects involving ethnicity were observed. Similarly, we included age as a covariate in all analyses, and this did not change the reported results.

<sup>3</sup> Emotional experience data for one participant in the clinical group were lost due to computer malfunction.

Table 2  
Reports of Experienced Emotion

Emotional experience	Group			
	Schizophrenia		Control	
	Men	Women	Men	Women
Valence ratings				
Positive pictures	12.91 (2.79)	12.13 (2.84)	14.52 (2.35)	12.15 (2.50)
Neutral pictures	11.06 (1.62)	10.69 (2.95)	10.59 (1.11)	9.99 (1.32)
Negative pictures	5.31 (2.44)	4.17 (3.40)	5.11 (2.96)	5.77 (3.89)
Arousal ratings				
Positive pictures	11.62 (3.30)	11.98 (2.59)	13.82 (1.74)	11.34 (1.90)
Neutral pictures	11.06 (1.63)	10.69 (2.95)	10.59 (1.11)	9.99 (1.32)
Negative pictures	9.09 (3.59)	14.88 (3.29)	11.53 (3.95)	12.28 (3.78)

Note. Tabled values are means. Standard deviations are in parentheses. Scores range from 0 to 20. For the valence ratings, lower values indicate more unpleasantness and higher values indicate more pleasantness; for the arousal ratings, lower values indicate more calm and higher values indicate more aroused or energized.

neutral and negative pictures ( $ps = .00$  and  $.034$ , respectively), and blink magnitude was smaller during neutral than negative pictures ( $p = .025$ ). For participants with schizophrenia, blink magnitude was smaller during positive than during neutral and negative pictures ( $ps < .01$ ); however, blink magnitude did not differ during neutral and negative pictures.

A different pattern emerged after picture offset, as shown in Figure 1b. Controls continued to show a significant valence main effect,  $F(2, 26) = 6.77$ ,  $p = .001$ ,  $\eta_p^2 = .34$ . Subsequent pairwise comparisons revealed that, for controls, startle magnitude was

smaller following positive picture offset than that of neutral,  $t(27) = 2.31$ ,  $p = .03$ , and negative pictures,  $t(27) = 3.75$ ,  $p = .001$ , and that startle magnitude following the offset of negative pictures was larger than magnitude following neutral pictures,  $t(27) = 2.11$ ,  $p = .045$ . By contrast, the valence main effect was not significant for participants with schizophrenia. Startle magnitude did not differ between valence conditions for participants with schizophrenia during the maintenance period (i.e., after picture offset).

To further examine the time course effects by group, we compared startle magnitude during picture presentation with startle magnitude after picture offset within each group. For controls, startle magnitude during positive, negative, and neutral pictures did not differ from startle magnitude after positive, negative, and neutral pictures ( $ps > .8$ ). That is, controls responded similarly during picture presentation and after picture offset, suggesting that they were maintaining responses after the pictures were removed from view. A different pattern emerged for participants with schizophrenia, however. Startle magnitude following positive picture offset was greater than startle magnitude during positive picture presentation,  $t(30) = 2.81$ ,  $p = .025$ , and startle magnitude following negative picture presentation was smaller than startle magnitude during negative picture presentation,  $t(30) = -2.57$ ,  $p = .014$ . These findings are consistent with affective modulation of startle responding dissipating after the pictures were removed from view.

In summary, during picture presentation, participants with and without schizophrenia showed potentiation to negative pictures relative to positive pictures and attenuation to positive pictures relative to neutral and negative pictures. By contrast, after picture offset, controls continued to show greater potentiation to negative than to positive pictures and greater attenuation to positive than to neutral and negative pictures, but participants with schizophrenia did not.

## Discussion

The present study replicates and extends previous research on emotional responding in schizophrenia by examining the time course of responding. Consistent with results of prior studies,

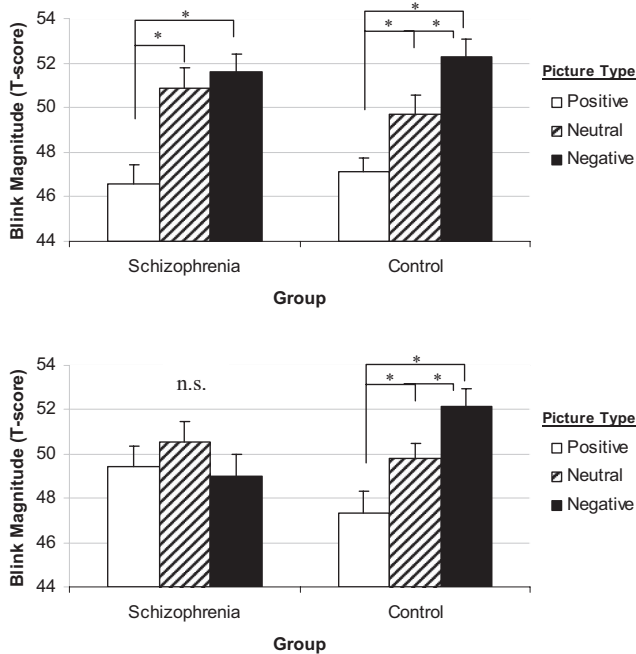


Figure 1. Mean startle magnitude ( $+SE$ ) by valence for each group at each time point. Top panel indicates startle response during picture viewing; bottom panel indicates startle response after picture viewing. n.s. = nonsignificant.  $*p < .01$ .

people with and without schizophrenia showed a very similar pattern of reported experience and startle response in the presence of emotionally evocative stimuli (e.g., Curtis et al., 1999; Schlenker et al., 1995; Volz et al., 2003; Yee et al., 2010). Just moments after the emotional pictures were removed from view, however, reliable group differences were observed. Healthy individuals showed a comparable response during picture viewing and after picture offset (i.e., heightened startle after the removal of negative pictures and attenuated startle after the removal of positive images). This is consistent results of other studies with healthy participants (Bradley et al., 1996; Germans Gard & Kring, 2007; Jackson et al., 2003; Larson & Davidson, 2001; Larson et al., 1998; Schupp et al., 1997) and indicates that the motivational system remains engaged shortly after emotionally evocative stimuli are removed from view, perhaps to help guide appropriate behavioral responses. In contrast, people with schizophrenia did not show this continued engagement of motivational systems once the evocative pictures were removed from view.

These findings are consistent with research indicating some areas of emotional responding are intact but that others are disrupted (Gold, Hahn, Strauss, & Waltz, 2009; Kring & Caponigro, 2010). Indeed, people with and without schizophrenia in the present study reported experiencing comparable levels of pleasantness and unpleasantness in response to the pictures. However, we found some interesting sex differences in reported arousal. Consistent with results from studies of healthy individuals (e.g., Germans Gard & Kring, 2007), women experienced more arousal in response to the negative pictures, and men experienced more arousal in response to the positive pictures. Within diagnostic group, women with schizophrenia reported experiencing more arousal overall than did men with schizophrenia; a finding that is also consistent with the literature on sex differences in healthy individuals. By contrast, men with schizophrenia reported experiencing less arousal than did men without schizophrenia. To our knowledge, only one other schizophrenia study (out of eight) that used the IAPS pictures included women or analyzed their data for sex differences in arousal, and this study (Heerey & Gold, 2007) did not find sex differences. It will be important for future studies to test for sex differences, not just in reported arousal but also in all domains of emotional response.

The failure to maintain affective modulation of the startle response during the offset period among people with schizophrenia in the present study did not appear to interfere with their ability to report on their experienced emotion at the end of the offset period. However, other studies indicate that even though reported experience in the presence of emotional stimuli is largely intact, people with schizophrenia have difficulty connecting their emotional experience to an appropriate behavioral response (Gold, Waltz, Prentice, Morris, & Heerey, 2008; Heerey & Gold, 2007; Ursu et al., in press). Presumably, participants are continuing to “process” the pictures, whether visualizing the picture, thinking about what they just saw, or thinking about how they feel. Because we did not explicitly instruct participants to do anything during the offset period, we cannot test the supposition that maintaining emotion supports later action. An important direction for future research would thus be to design a study that explicitly instructs maintenance of emotion in the service of behavior or that builds in behavioral demands that require the active maintenance of emotion. Indeed, the maintenance of emotion likely draws upon neural

resources (e.g., dorsolateral PFC; Ursu et al., in press) and psychological processes (e.g., cognitive control, working memory; Barch & Dowd, 2010; MacDonald & Carter, 2003) that are known to be fundamentally impaired in schizophrenia. Thus, the nature of deficits in emotion, at least with respect to time course, really lies at the interface of emotion and cognition.

Though speculative at this point, the present study’s findings suggest possible points of intervention in schizophrenia, for example, encouraging efforts by people with schizophrenia to maintain and reflect upon their emotion experience. Although the adage “out of sight, out of mind” could be used to characterize our findings, this is no longer regarded as a healthy way to manage emotions, no matter what the disorder (Sloan & Kring, 2009). Of course, there is also likely a sweet spot when it comes to maintaining emotion in the service of future behavior. Hanging on for too long, as in the case of rumination, is not a healthy form of emotion regulation either. Interventions that target emotion in schizophrenia and negative symptoms more broadly, whether psychopharmacological or psychosocial, are desperately needed.

Although the findings reported here extend our understanding of emotional responding in schizophrenia in a number of ways, we acknowledge important limitations. First, only one time point was used for the assessment of the maintenance of emotional responses. This allows for only a snapshot of emotion maintenance and does not provide a panoramic view of the full chronometry of emotional responding. On the other hand, this is one of the few studies to examine responding both during and after stimulus presentation among people with schizophrenia (see also Heerey & Gold, 2007; Ursu et al., in press). Additional studies that employ multiple measures of emotion (e.g., measures of autonomic physiology, facial expression, continuous self report ratings via rating dial, as well as startle modulation) and sample at multiple time points during picture presentation and after picture offset to examine both peak and recovery of emotional responses will be particularly useful to better map out differences in the chronometry of emotional responses in schizophrenia. A study by Volz et al. (2003) is notable in this respect. They assessed affective modulation of the startle response at five different points during picture presentation, and they also assessed skin conductance, heart rate, and reported experience. There were no clear differences between participants with and without schizophrenia in self-report, autonomic activity, and startle response at the later probe times. However, participants with schizophrenia did not show affective modulation early in picture presentation (i.e., 300 ms), whereas participants with schizophrenia did show affective modulation at this early probe time. Thus, individuals with schizophrenia may have an initial delay in responding affectively to evocative stimuli.

A second limitation in the current study is the fact that we did not give explicit instructions to have participants hold on to their emotional experience. Although our assumption here is that it is important to maintain an emotional response seconds after an eliciting stimulus in order to guide future behavior, in the present study there was no requirement to engage behavior after the offset of the image beyond the self-report of experience. Researchers may wish to compare differences when behavior must be explicitly engaged. Third, all participants with schizophrenia were taking antipsychotic medication. Though this reflects the norm among people with schizophrenia and thus boosts our finding’s generalizability in one respect, it is nevertheless difficult to fully disen-



tangle whether our findings reflect something about schizophrenia or something about medication. Prior startle modulation studies in schizophrenia also included participants taking medication; Curtis et al. (1999) indirectly examined medication effects on startle responding by examining patterns of response between different medication types and found no differences. However, a more direct test of medication effects is a counterbalanced cross over design whereby the same group of participants completes the task on and off medication (Spohn & Strauss, 1989), and this has not yet been conducted. Other studies in healthy individuals have found that antianxiety medications can blunt the startle response (Patrick, Berthot, & Moore, 1996); none of the participants in the current study were taking this type of medication.

In summary, findings from the present study point to the importance of considering the time course of emotional responding in order to better understand the nature of emotion deficits in schizophrenia. In the presence of emotionally evocative stimuli, people with and without schizophrenia show comparable physiological and emotional experience responses. However, people with schizophrenia did not maintain this response after the evocative stimuli were removed from view.

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