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Intact motivated attention in schizophrenia: Evidence from event-related potentials

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ABSTRACT

Emotionally significant stimuli typically capture attention (called motivated attention) even when they are irrelevant to tasks where attention is directed. Previous studies indicate that several components of emotional processing are intact in schizophrenia when subjects are instructed to attend to emotionally-evocative stimuli. However, few studies have examined whether emotional stimuli capture attention to a normal degree in people with schizophrenia when attention is directed elsewhere. The current event-related potential study examined motivated attention to task-irrelevant emotional stimuli in 35 stabilized outpatients and 26 healthy controls with a modified visual P300 oddball detection task. Participants viewed images of rare target and commonly occurring standard letter stimuli, as well as intermixed emotional (unpleasant, pleasant, neutral) pictures. Subjects were instructed to count the number of rare targets; the emotional valence of the picture stimuli was, therefore, task-irrelevant. We separately evaluated the Early Posterior Negativity (EPN) and Late Positive Potential (LPP) to emotional pictures and the P300 to target stimuli. Patients and controls showed similar patterns of EPN and LPP amplitude to the emotional stimuli, such that the EPN and LPP were larger for both pleasant and unpleasant versus neutral pictures. Although patients performed worse than controls on the target counting task, both groups showed comparable P300 differentiation between target versus non-target stimuli. Emotional stimuli captured attentional resources in people with schizophrenia even when the emotional stimuli were task-irrelevant, suggesting intact motivated attention at the level of early electrophysiological responding.

1. Introduction

People with schizophrenia often show diminished emotional expression and pleasurable experiences based on clinical rating scales (Blanchard et al., 2011). However, when directly exposed to evocative stimuli (e.g., pictures, foods), patients show normal emotion-modulated experiential, cardiovascular, electrodermal, and startle eyeblink responses (Kring and Moran, 2008). Motivationally relevant stimuli rarely present themselves in this way in daily life; they are often incidental to the primary tasks we are performing. In healthy subjects, incidental emotional stimuli naturally capture attention, an adaptive process called “motivated attention” (Bradley, 2009). Adaptive functioning, however, requires an optimal balance: incidental emotional stimuli need to capture attention but not deplete the resources required for ongoing goal-directed pursuits. The current study used an event-related potential (ERP) paradigm to evaluate processing of task irrelevant emotional stimuli in schizophrenia.

In healthy subjects, two ERPs, the early posterior negativity (EPN) and late positive potential (LPP), are larger for both pleasant and unpleasant compared with neutral pictures, reflecting increased attention to motivationally relevant stimuli (see Hajcak et al., 2010). The EPN (200–300 ms) reflects early and relatively automatic selective attentional processing, whereas the LPP (400–1000 ms) reflects more sustained allocation of attentional resources. Consistent with the concept of motivated attention, the EPN and LPP are larger for emotional than neutral pictures even when the valence of pictures is irrelevant to the primary task to which attention is directed (Hajcak et al., 2010).

Recently, we found patients showed generally normal early and late ERP's to emotional versus neutral pictures during a task in which subjects attended to the pictures (Horan et al., 2010). However, we are not aware of any prior studies that examined whether patients also show intact ERPs to task-irrelevant emotional images. To address this question, the current study used a modified visual P300 task modeled on Fichtenholtz et al. (2004) that involved rare target letter stimuli intermixed with irrelevant images of varying emotional content. A handful of behavioral and functional magnetic resonance imaging (fMRI) studies show mixed evidence of intact versus impaired automatic emotional processing in schizophrenia (e.g., Dichter et al., 2010, Roux et al., 2010, Schwartz et al., 2010, Strauss et al., 2011);

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our prior ERP study led to the prediction that patients would show a larger EPN and LPP to task-irrelevant emotional versus neutral stimuli, similar to healthy controls.

2. Methods

2.1. Participants

Thirty-five outpatients with schizophrenia based on the Structured Clinical Interview for DSM-IV Axis I Disorders (SCID; First et al., 1996). Patients were medicated at clinically determined dosages. Psychiatric symptoms were rated using the expanded 24-item Brief Psychiatric Rating Scale (BPRS; Kopelowicz et al., 2008). Twenty-five healthy controls from the local community were screened with the SCID and SCID-II (Cluster A). Procedures were approved by the local Institutional Review Board. Groups were demographically comparable, except for personal education (Table 1).

2.3. ERP paradigm

To elicit the P300, two letters ('X' and 'O') were chosen as visual stimuli. The 'O' was always the standard and presented with a probability of 85%, while the 'X' was always the target and presented with a probability of 15%. To elicit the EPN and LPP, 20 pleasant, 20 unpleasant, and 20 neutral pictures from the International Affective Picture System (IAPS; Lang et al., 2005) were presented with equal probability. Participants were told they would view a series of letters and pictures on the screen, and that their task was to count silently the number of times the 'X' appeared. Thus, picture valence was irrelevant to the target detection task where attention was directed. After instruction and practice, participants performed 400 total trials, with breaks after each block of 50 trials. Each block consisted of a series of trials in which letters or pictures were presented in an alternating sequence from trial-to-trial. Each trial consisted of a letter or picture presented for 1 s, and intertrial interval of 300 ms. Order of standards, targets, and pictures was randomly determined for each participant. After each block, participants were asked to input the number of targets presented.

Table 1
Demographic and clinical data.

	Schizophrenia (N = 35)	Controls (N = 26)	Statistic
Sex (% male)	74.3	73.1	X^2 (1,61) = .92
Age (SD)	48.3 (7.6)	44.9 (8.5)	t(59) = 1.66
Ethnicity			
White	41.2	46.2	X^2 (4,61) = 3.73
African American	38.2	42.3	
Asian	8.8	3.8	
Hispanic	8.8	0.0	
Other	2.9	7.7	
Marital status			
Never married	62.9	65.4	X^2 (2,61) = 3.95
Currently married	5.7	19.2	
Ever married	31.4	15.4	
Education (SD)	13.2 (1.6)	14.5 (1.7)	t(59) = 3.10*
Parental education (SD)	13.9 (3.4)	14.9 (2.1)	t(59) = .18
Age of onset (SD)	22.0 (5.8)		
Duration of illness (SD)	26.0 (8.8)		
BPRS			
Positive symptoms (SD)	2.1 (0.8)		
Negative symptoms (SD)	1.7 (0.9)		
Total (SD)	41.4 (10.5)		

Notes: BPRS = Brief Psychiatric Rating Scale. The patients had lower personal education levels than controls but the groups did not differ in parental education, which was the variable intended to control for family socio-economic status, as opposed to personal education, which can be influenced by the illness itself.
* p<.005.

2.4. EEG recording and processing

EEG activity was continuously recorded from 64 channels using a custom cap (Cortech Solutions, Wilmington, North Carolina, USA) and the ActiveTwo BioSemi system (BioSemi, Amsterdam, Netherlands; see Horan et al., in revision for details). EEG data were re-referenced offline to the average of all electrodes and band-pass filtered with cutoffs of 0.1 and 30 Hz. EEG was segmented beginning 200 ms before each stimulus and continuing for 1000 ms post stimulus onset. Each EEG segment was corrected for blinks and physiological artifacts using standard procedures. ERPs were constructed by separately averaging segments of the five stimulus types (X and O images; pleasant, unpleasant, neutral pictures). Average activity in the 200-ms window prior to picture onset was the baseline. For letters, P300 was mean activity from 350–450 ms at Pz. For pictures, EPN was quantified as the mean activity from 200–300 ms at temporo-occipital sites (Oz,O1,O2, POz,PO3,PO4) and the LPP was quantified as the mean activity from 400–1000 ms at fronto-central sites (CPz,C1,Cz,C2,FCz; where effects were largest in this sample).

3. Results

3.1. ERP's to pictures

Grand average ERPs are presented in Figs. 2 and 3, and mean ERP amplitudes are presented in Table 2. For the EPN, a 3 (Valence) × 2 (Group) repeated-measures ANOVA revealed a significant Valence effect. Compared to neutral pictures, LPP was significantly more positive for both unpleasant, t(60) = 5.23, p<.001, and pleasant pictures, t(60) = 4.38, p<.001, which did not significantly differ from each other, t(60) = 1.39, p>.05. The Group and Interaction effects were not significant, indicating a similar pattern of enhanced EPN for emotional pictures across groups.

For the LPP, there was a significant Valence effect indicating that, compared to neutral pictures, LPP was significantly more positive for both unpleasant, t(60) = 5.51, p<.001, and pleasant pictures, t(60) = 3.46, p<.001, which did not significantly differ from each other, t(60) = .99, p>.05. There was a trend-level Group effect (p = .08) and the Interaction effect was non-significant, indicating that the pattern of enhanced LPP for emotional pictures was also similar across groups.

3.2. Target detection task

As shown in Table 3, patients were significantly less accurate at counting the target stimuli than controls. For P300, grand average ERPs are shown in Fig. 1. A 2 (Trial Type) × 2 (Group) repeated-measures ANOVA revealed a significant Trial Type effect, indicating that P300 for target trials was significantly more positive than for standard trials. The Group and Interaction effects were not significant, indicating a similar P300 pattern across groups.

3.3. Exploratory correlations with symptoms

Within the schizophrenia group, the ERP variables showed no significant or trend-level correlations with BPRS positive, negative, and total symptom scores[1].

4. Discussion

This study found normal early and late emotion-modulated ERPs in schizophrenia. Hence, the results from our earlier study (Horan et al., 2010) extend to processing task-irrelevant emotional stimuli.

[1] We also examined potential ERP differences between patient subgroups based on a median split on the BPRS negative symptoms subscale (low scorers = 21; high scorers = 14). There were no significant differences for any of the ERP variables.

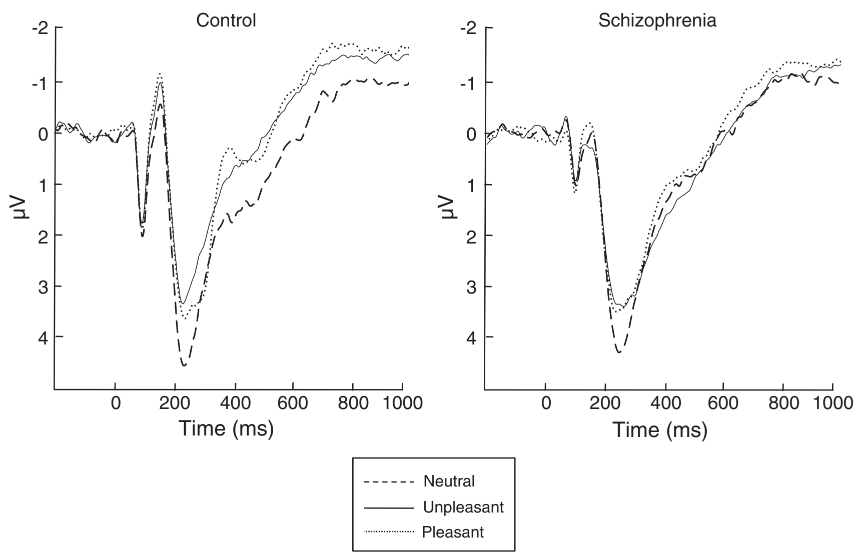

Fig. 1. The EPN grand average at pooled electrodes Oz, O1, O2, POz, PO3, PO4 for unpleasant, pleasant, and neutral pictures for control (left) and schizophrenia (right) groups. Stimulus onset occurred at 0 ms and negative is plotted up.

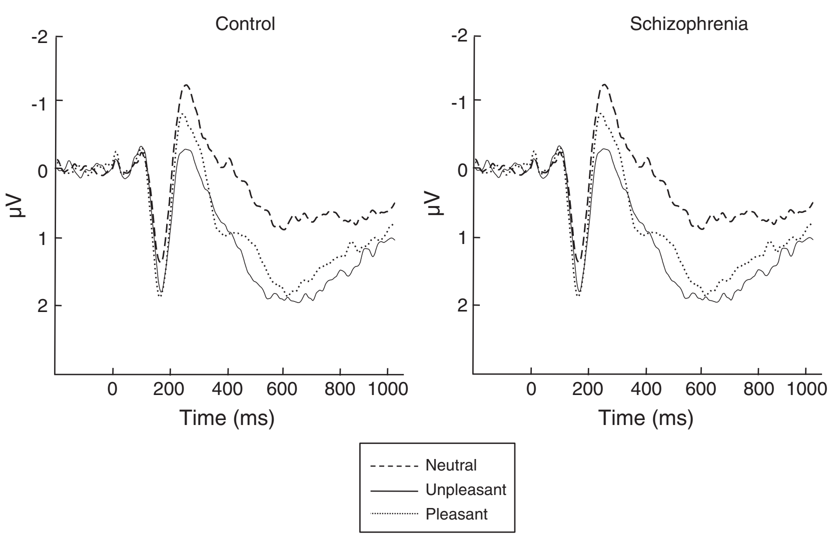

Fig. 2. The LPP grand average at pooled electrodes CPz, C1, Cz, C2, FCz for unpleasant, pleasant, and neutral pictures for control (left) and schizophrenia (right) groups. Stimulus onset occurred at 0 ms and negative is plotted up.

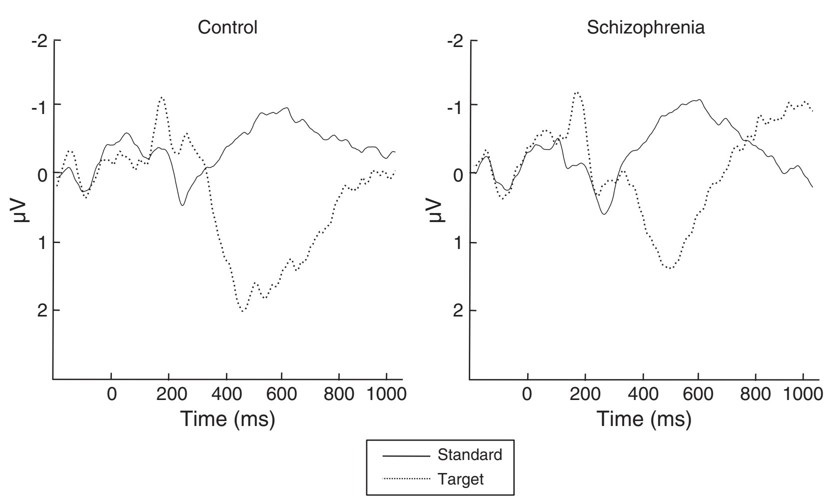

Fig. 3. The P300 grand average at Pz for standard and target trials for control (left) and schizophrenia (right) groups. Stimulus onset occurred at 0 ms and negative is plotted up.

Table 2
ERP data for pictures.

	Schizophrenia (N = 35)	Controls (N = 26)	F values		
			Valence (df = 2,59)	Group (df = 1,59)	Valence × Group (df = 2,59)
Early Posterior Negativity			17.63***	.01	1.40
Neutral	3.71 (3.31)	3.91 (2.64)			
Pleasant	3.19 (3.32)	3.15 (2.96)			
Unpleasant	3.09 (3.08)	2.77 (2.74)			
Late Positive Potential			19.07***	3.16†	.32
Neutral	.13 (1.17)	.61 (1.36)			
Pleasant	.97 (1.70)	1.32 (1.14)			
Unpleasant	1.07 (1.46)	1.60 (1.67)			

Note: Mean scores reflect mean amplitudes. Standard deviations are presented in parentheses.
*** $p<.001$.
† $p<.10$.

Automatic "grabbing" of attention by, and sustained processing of, emotional stimuli may reflect yet another area of relatively preserved emotion processing in schizophrenia. Our paradigm also allowed us to evaluate performance and ERPs in the target detection task where attention was directed. The patients showed impaired counting of the targets, consistent with a working memory deficit (Lee and Park, 2005). However, the groups showed comparable P300 differentiation between target and standard stimuli, as reported in some prior studies of visual target detection tasks (e.g., Bestelmeyer et al., 2009, Luck et al., 2009). Results suggest patients could allocate resources to the target and inhibit the impact of emotional stimuli, and they contribute to research on the interface between emotion and cognition in schizophrenia (Kring and Caponigro, 2010).

One study used a comparable target detection paradigm to ours, but with fMRI instead of EEG (Dichter et al., 2010). In contrast to our findings, that study found schizophrenia outpatients showed (a) diminished activation in frontolimbic regions to task-irrelevant unpleasant stimuli and (b) dorsal frontal hypoactivation and reduced frontolimbic deactivation during target detection trials, a pattern thought to reflect impaired inhibitory processes linked to shifting between attentional and emotional domains. This discrepancy may reflect differences in the neural network associated with the ERPs examined (Sabatinelli et al., 2007), various task parameters (e.g., our inclusion of both pleasant and unpleasant stimuli), or temporal resolution of ERP versus the more sluggish BOLD response. This discrepancy highlights the importance of examining the interface between emotion and cognition across multiple methods and time frames.

The current study suggests that motivated attention is intact in schizophrenia and may be a relative strength in terms of adaptive functioning; preferential processing of motivationally significant stimuli can rapidly draw attention to potential threats or rewards so that they can then be appropriately managed. If replicated, this information can help facilitate understanding and treating the functional impairments associated with schizophrenia. If basic neurophysiological processing of emotional stimuli is largely intact, efforts to identify and treat higher-level integrative or regulatory processing impairments that impact functioning will likely be more productive (Barch and Dowd, 2010, Kring and Caponigro, 2010).

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Contributors
Drs. Horan, Hajcak, and Green designed the study. All authors contributed to data analysis and intepretation. Dr. Horan wrote the first draft of the manuscript. All authors contributed to and have approved the final manuscript.

Conflict of interest
None.

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Table 3
Target detection task.

	Schizophrenia (N = 35)	Controls (N = 26)	t-value (df = 59)		
Target counting task	61.76% (28.36%)	78.00% (25.33%)	2.27*		
			F values		
			Trial type (df = 1,59)	Group (df = 1,59)	Type × Group (df = 1,59)
P300			18.22***	.05	.05
Target	−.38 (1.40)	−.41 (1.41)			
Standard	.97 (2.34)	.82 (2.57)			

Note: Accuracy on the target counting task was based on the percentage of trial blocks in which the number of reported targets correctly matched the actual number of presented targets. P300 means reflect mean amplitudes. Standard deviations are presented in parentheses.
* $p<.05$.
*** $p<.001$.

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