COGNITIVE NEUROPSYCHIATRY, 2016
VOL. 21, NO. 1, 45–59
http://dx.doi.org/10.1080/13546805.2015.1127222

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Attention and memory bias to facial emotions underlying negative symptoms of schizophrenia

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ABSTRACT

Introduction. This study assessed bias in selective attention to facial emotions in negative symptoms of schizophrenia and its influence on subsequent memory for facial emotions.

Methods. Thirty people with schizophrenia who had high and low levels of negative symptoms ($n = 15$, respectively) and 21 healthy controls completed a visual probe detection task investigating selective attention bias (happy, sad, and angry faces randomly presented for 50, 500, or 1000 ms). A yes/no incidental facial memory task was then completed. Attention bias scores and recognition errors were calculated.

Results. Those with high negative symptoms exhibited reduced attention to emotional faces relative to neutral faces; those with low negative symptoms showed the opposite pattern when faces were presented for 500 ms regardless of the valence. Compared to healthy controls, those with high negative symptoms made more errors for happy faces in the memory task. Reduced attention to emotional faces in the probe detection task was significantly associated with less pleasure and motivation and more recognition errors for happy faces in schizophrenia group only.

Conclusions. Attention bias away from emotional information relatively early in the attentional process and associated diminished positive memory may relate to pathological mechanisms for negative symptoms.

ARTICLE HISTORY
Received 17 May 2015
Accepted 27 November 2015

KEYWORDS
Attention–emotion interaction; anhedonia; attention bias; emotional memory; emotion deficit

Negative symptoms are an important predictor of functional outcomes in individuals with schizophrenia, but the precise pathological mechanism is poorly understood (Millan, Fone, Steckler, & Horan, 2014). Anhedonia – one domain of negative symptoms – was once considered an inability to experience pleasure; however, in recent studies, individuals with schizophrenia have generally shown intact in-the-moment positive emotional experiences but deficits in non-current hedonic capacities (anticipating and recalling pleasurable

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Supplemental data for this article can be accessed at doi:10.1080/13546805.2015.1127222.

experiences; Cohen & Minor, 2010; Gard, Kring, Gard, Horan, & Green, 2007). Researching why individuals with schizophrenia report fewer future or past pleasures and less engagement in motivated activities, even with intact current hedonic capacity, is important to help understand negative symptoms pathology.

This disjunction between the current and non-current hedonic experiences may be associated with aberrant emotional information processing (encoding, consolidation, or retrieval of emotional experiences; Cohen, Najolia, Brown, & Minor, 2011). That is, low access to positive memories could lead to low anticipation of future positive events and subsequent diminished motivated behaviours towards them, even with the intact capacity to experience pleasure in the moment. Consistent with this idea, some studies have found diminished positive memory in schizophrenia, which is attributed to the aberrant consolidation process of positive events (Hall, Harris, McKirdy, Johnstone, & Lawrie, 2007; Herbener, Rosen, Khine, & Sweeney, 2007). Compared to the consolidation process, the encoding process has received little attention as a candidate mechanism for diminished positive memory in schizophrenia. However, considering the pivotal role of attention on memory, biased attention during the encoding process could also affect emotional memory. Consistent with this, attentional bias to negative stimuli could be closely related to memory bias for negative stimuli in depressed individuals; however, no studies have been conducted in schizophrenia (Blaut, Paulewicz, Szastok, Prochwicz, & Koster, 2013).

Some recent studies indicated that aberrant attention to emotional information is potentially implicated in negative symptoms (Dichter, Bellion, Casp, & Belger, 2010; Strauss, Catalano, Llerena, & Gold, 2013). In an Emotional Attentional Blink task (Strauss et al., 2013), participants needed to attend to two target words – emotional or neutral – among rapid serial presentations of the word stimuli. Successful identification of the first target word is known to lead to decrement in the identification of the second target word (attentional blink effect). Whereas the recall of the second word was largely affected by whether the first or the second word had emotional content or not in healthy participants and patients with low negative symptoms of schizophrenia, the recall was unaffected by emotional content in patients with high negative symptoms of schizophrenia, suggesting diminished attentional capture of emotional stimuli related to negative symptoms. Martin, Becker, Cicero, and Kerns (2013) used the paradigm in which a cue word was followed almost immediately (one of three intervals; 85, 170, and 270 ms) by a target word both of which were either positively or negatively valenced; participants rated the valence of a target word after silently reading a cue word. Affective interference was calculated by differences in reaction times (RTs) and error rates when the valences of target and cue words were the same or different. The severity of anhedonia was related to decreased affective interference, suggesting chronic inattention to emotion related to anhedonia in schizophrenia.

These findings suggest a potential association between negative symptoms and diminished attention to emotional information; however, not all study findings concur. Horan, Foti, Hajcak, Wynn, and Green (2012) reported that patients with schizophrenia showed intact initial attention allocation to emotional stimuli. Study methods may be one of reasons for the discrepancy (e.g., the differences in sample and task characteristics: stimuli number and duration, existence of distractors, task instructions). Notably, reduced attentional capture of emotional stimuli related with negative symptoms may

be observed specifically when stimuli compete with distractors for selective attention (Strauss et al., 2013).

Therefore, we examined selective attention bias to facial emotions and its relationship with subsequent emotional memory in schizophrenia patients with high or low negative symptoms. We used a visual probe detection task, a widely used experimental paradigm for assessing selective attention bias; emotional and neutral faces were presented simultaneously for 50, 500, and 1000 ms. Bias in the 50 ms presentation possibly indicates bias in initial orienting; as the duration increases, the observed bias would more likely to be the result of top-down processing (MacLeod, Mathews, & Tata, 1986; Mogg, Bradley, De Bono, & Painter, 1997). An incidental recognition task was administered immediately after to examine the potential role of biased attention on subsequent memory. Until now, whether decreased attention to emotional information would be observed in the facial stimuli and its relationship with subsequent memory for emotional faces has not been investigated. Based on previous study results, we hypothesised that the high negative symptoms group would show attention bias away from emotional faces in the relatively early temporal stage (50 and 500 ms) and diminished memory for emotional faces. The low negative symptoms and healthy control participants were hypothesised not to exhibit such biased attention and memory. Attention bias away from emotional faces was hypothesised to be related with decreased emotional memory in schizophrenia patients only.

Methods

Participants

Thirty patients with chronic schizophrenia – 26 recruited from long-term inpatient units and 4 from community mental health centres – and 21 healthy controls (20–55 years old) participated. The participants had schizophrenia spectrum disorders as their primary diagnosis according to DSM-5 criteria and no history of substance use disorders within the last 6 months, confirmed by the Structured Clinical Interview for DSM (SCID) disorders as administered by psychiatrists (First, Spitzer, Gibbon, & Williams, 2012). Those with a neurological disease history were excluded based on their medical records. All patients were chronic and stably taking antipsychotic medications (mean chlorpromazine equivalent = 651.41) with no significant changes in psychotropic medication doses for the past 2 weeks. The current hospital stay of inpatients was over 4 weeks. The patients with schizophrenia were divided into the low and high negative symptoms groups based on the composite *t*-score on the Positive and Negative Syndrome Scale (PANSS) negative symptom factor and Motivation and Pleasure-Self Report (MAP-SR) total scores (Llerena et al., 2013; Wallwork, Fortgang, Hashimoto, Weinberger, & Dickinson, 2012). Patients with composite scores in the upper 50% were defined as high negative (median split). Demographic and clinical characteristics were compared to confirm the group assignment (Table 1). Age-matched healthy participants were recruited through online advertisements. With the screening interview, those who reported a history of psychiatric illness, neurological disorders, substance use disorders, or currently taking psychotropic medications were excluded. Informed consent was obtained before participation in the assessment.

Table 1. Demographic and clinical information: *M* (SD).

Characteristics	High negative symptoms group ($n = 15$)	Low negative symptoms group ($n = 15$)	Healthy controls ($n = 21$)	Statistics	p
Age	41.93 (9.92)	40.53 (10.32)	36.38 (5.15)	F (2, 50) = 2.16	.13
Parental education (years)[a]	9.67 (4.78)	7.75 (4.70)	10.47 (2.55)	F (2, 33.34) = 1.81	.19
Education (years)	13.73 (2.58)	11.87 (2.53)	14.76 (1.73)	F (2, 50) = 7.29	<.01**(2 < 3)
Male (%)	73%	67%	48%	$\chi^2 = 2.74$	.26
Duration of illness (years)[a]	16.14 (9.26)	14.00 (7.50)	–	t (27) = 0.69	.50
Number of hospitalisations[a]	3.00 (1.96)	3.43 (2.24)	–	t (27) = −0.55	.73
Antipsychotics (chlorpromazine equivalents)[a]	592.73 (487.16)	714.29 (376.33)	–	t (28) = −0.57	.59
PANSS					
Positive	3.72 (1.57)	2.87 (0.90)	–	t (22.42) = 1.82	.08
Negative	3.53 (1.43)	2.49 (0.97)	–	t (28) = 2.34	<.05*
Disorganised	3.13 (1.33)	2.38 (1.05)	–	t (28) = 1.73	.10
Depressed	2.83 (1.21)	2.25 (1.14)	–	t (28) = 1.75	.09
Total	95.03 (32.33)	72.07 (21.23)	–	t (28) = 2.3	<.05*
MAP-SR	28.47 (8.90)	46.87 (6.12)	–	t (28) = −6.60	<.001***
Composite negative symptoms[b]	113.40 (11.84)	88.18 (7.52)	–	t (28.) = 6.97	<.001***
Liebowitz Social Anxiety Scale-Anxiety score ($n = 14$ for low negative symptoms group)	32.20 (17.12)	22.86 (19.51)	–	t (27) = 1.39	.18
Neurocognitive functions					
Completion time for Trail-Making Test-A	50.00 (23.52)	41.07 (15.10)	25.32 (6.86)	F (2, 26.18) = 9.93	.001**(1,2 > 3)
Completion time for Trail-Making Test-B	162.47 (105.75)	180.27 (118.51)	54.59 (17.01)	F (2, 28.16) = 9.68	.001**(1,2 > 3)
Coding	46.07 (17.48)	53.60 (16.76)	93.32 (15.94)	F (2, 49) = 44.17	<.001***(1,2 < 3)

*$p < .05$.
**$p < .01$.
***$p < .001$.
[a]Duration of illness, number of hospitalisations, and chlorpromazine equivalents for one participant in the low negative symptoms group could not be obtained. One participant in the low negative symptoms group and two in the healthy control group did not report parental education.
[b]Composite negative symptoms were calculated by summing *t*-scores of PANSS negative factor score and MAP-SR total score.

Measures

Positive and negative syndrome scale

This semi-structured interview evaluates the severity of psychiatric symptoms (psychopathology items = 7 positive, 7 negative, 16 general; Kay, Flszbein, & Opfer, 1987). The five-factor model PANSS was used instead of the original scale (Wallwork et al., 2012). Cronbach's α in the current study for each factor was as follows: positive (.85), negative (.93), disorganised (.83), excited (.87), and depressed (.88). Interrater reliability was .91.

The motivation and pleasure scale-self report

This is a 15-item measure of internal experiences of pleasure and motivation. A higher score indicates more hedonic experiences and less anhedonia. Developed based on the Clinical Assessment Interview for Negative Symptoms (Kring, Gur, Blanchard, Horan, & Reise, 2013), this has good internal consistency ($\alpha = .90$) and validity (Llerena et al., 2013). The MAP-SR measured deficits insufficiently covered by the PANSS (anhedonia and amotivation; Daniel, 2013). In the current study using the Korean version, Cronbach's α was .89.

The Liebowitz social anxiety scale-self report

This self-report version of the Liebowitz Social Anxiety Scale (Liebowitz, 1987) measures social anxiety in patients with schizophrenia with good reliability ($\alpha = .97$) and validity (Heimberg et al., 1999; Kang, Lee, Oh, & Lim, 2013). It was administered to match the social anxiety level between the groups with schizophrenia, which has been related to attention biases for emotional faces. Cronbach's α was .97 in this study.

Neurocognitive tasks

The Trail-making Test A and B and the coding subtest of the Korean-Wechsler Adult Intelligence Scale assessed attention, executive function, and processing speed (Oh, Yum, Park, Kim, & Lee, 1992; Reitan, 1958; Wechsler, 2008). These tasks were administered to match the cognitive functions of the groups with schizophrenia.

Visual probe detection task

Participants completed 236 trials (two blocks of 118 trials) of the visual probe detection task per Gotlib et al.'s (2004) study except for the inclusion of additional stimuli durations (50 and 500 ms) and 20 trials with inverted facial cues randomly presented during the task. Each trial began with a fixation point displayed in the centre of the screen for 500 ms, followed by a facial pair presented randomly at 50, 500, or 1000 ms. A small asterisk (probe) then appeared in the location where one of the facial pairs had been displayed (left or right), remained until participants responded, or disappeared if no response was made within 2 s (Figure 1). Participants sitting approximately 90 cm from a monitor responded manually, as quickly as possible, to the probe location by pressing keys: "q" with the left hand (left-sided probe) or "p" with the right hand (right-sided probe). No key was pressed if the probe was preceded by a pair of two inverted neutral faces, which was adopted to maintain minimal attention to the stimuli during the task (Pollak & Tolley-Schell, 2003). A "beep" sound was heard briefly as auditory feedback for incorrect responses

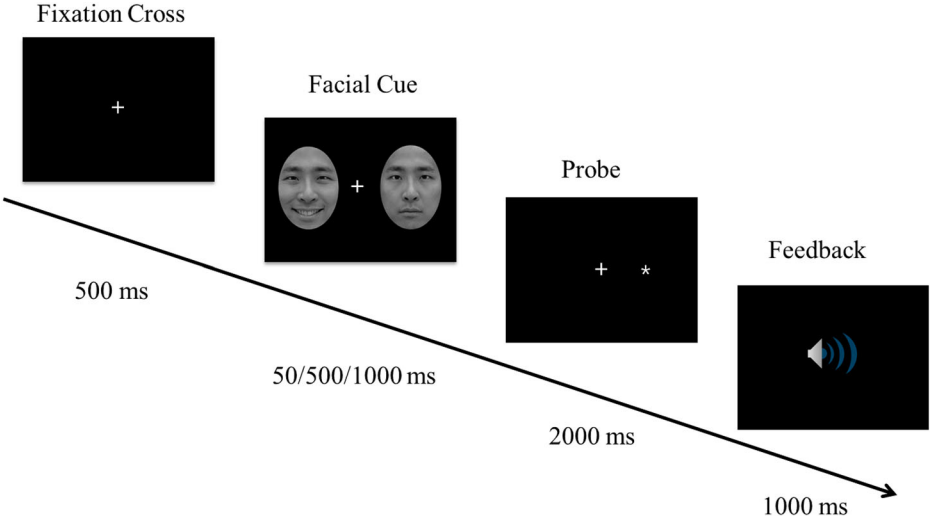

Figure 1. Temporal sequence of experimental trials.

(150 ms). Accuracy and latency were recorded for each trial. Before the main trials, participants completed two blocks of practice trials. One included 12 trials of a simple probe detection task with no facial cue; the second included 18 trials of a visual probe detection task with neutral–neutral facial cues.

Facial cues consisted of one emotional expression and one neutral expression of the same model (half were from women), presented side by side. These were approximately 9×10 cm, located 10 cm apart from each other. Stimuli consisted of happy, angry, and sad faces (16 each) and 31 neutral faces selected from the Korea University Facial Expression Collection which was validated for the Korean population (Lee, Lee, Lee, Choi, & Kim, 2006). These stimuli were reviewed again by experts trained in the Ekman Facial Emotion Scoring Technique to confirm whether the stimuli expressed the designated emotion (Ekman & Friesen, 2003). Based on previous study data (Kim, Choi, & Cho, 2011), the arousal of emotional faces was matched at a moderate level (mean = 4.72), which was significantly higher than that of the neutral faces ($p < .001$). The valence of angry and sad faces was significantly more negative than that of the happy and neutral faces; the valence of the happy faces was significantly more positive than that of the neutral, sad, and angry faces ($p < .001$). Using Photoshop CS5, facial pictures were grey-scaled and hairs, scars, and blemishes were removed to minimise influences of irrelevant factors beyond facial emotions. The location (left or right), valence (happy, sad, and angry), and duration (50, 500, and 1000 ms) of the emotional faces were counterbalanced.

Bias scores, our main dependent variables, were calculated as follows (Mogg et al., 1997; Pine et al., 2005). Trials with errors, outliers identified using Tukey's method, and RTs under 100 ms were eliminated to minimise the influence of premature or delayed responses (Hoaglin, Mosteller, & Tukey, 1983); total discarded trials amounted to 5% of the control group and 8% of the schizophrenic groups with no significant difference between them ($p > .05$). Mean RTs of trials where the probe was cued by an emotional face were subtracted from those of trials where the probe was cued by a neutral face. Positive values indicated faster responses to probes presented at the location of the emotional faces, indicating attention bias towards emotional faces. Negative values indicated attention bias away from emotional faces (Gotlib et al., 2004).

Incidental recognition task

Immediately after the visual probe detection task, participants performed a yes or no recognition task for facial expressions (Koster, De Raedt, Leyman, & De Lissnyder, 2010). The task comprised 24 randomly presented facial pictures, including 8 happy, sad, and angry faces, half of which were presented in the prior task with the same frequency; the remaining half were new. The number of errors was recorded separately for misses and false alarms to investigate the potential role of error types (Brébion, David, Jones, & Pilowsky, 2005).

Data analysis

The differences of attention bias and recognition in the three groups were examined by repeated-measures ANOVA (RM-ANOVA) followed by *post hoc* ANOVAs and the Brown and Forsythe (1974) tests for unequal variances among groups. If the assumption of sphericity was violated, results of the multivariate analysis (Wilks' λ) were reported

when appropriate. After the between-group comparison, correlations between psychiatric symptoms, attention bias scores, and recognition indices in the groups with schizophrenia were calculated. Both categorical and dimensional approaches were taken, as there has been no consensus about which approach is most appropriate and both approaches have yielded slightly different results (Strauss et al., 2013). To investigate whether attentional bias is related to emotional memory, we calculated correlations between attention bias scores and recognition errors. All analyses were two tailed. We repeated the analysis with the attention bias score adjusted for RT and its standard deviation, and reported the analysis based on the original score because we found no change in the results. The comparison between all participants can be found in Supplementary Note 2.

Results

Demographic and clinical information

Participants did not significantly differ on demographic and clinical variables except for education and negative symptoms variables. The patients with low negative symptoms had significantly lower education than control participants, and higher MAP-SR total scores, lower PANSS negative factor and total scores, and composite negative symptoms scores than the patients with high negative symptoms. The groups with schizophrenia were not different for parental education, antipsychotics dosage, neurocognitive functions, and social anxiety level (Table 1).

Attention bias

The $3 \times 3 \times 3$ mixed RM-ANOVA with emotion (happy, sad, and angry) and duration (50, 500, and 1000 ms) as within-subjects factors and group (high and low negative symptoms and control as a between-subjects factor) revealed a significant interaction between duration and group, $F\ (4,\ 96) = 6.08$, $p < .001$. Patients with high negative symptoms showed attention bias away from emotional faces when faces were presented for 500 ms compared to those with low negative symptoms and controls ($p = .001$ and $p < .05$, respectively). Additionally, those with low negative symptoms showed attention bias towards emotional faces presented for 500 ms compared to control participants ($p < .01$). Then, attentional bias scores for overall emotional faces at each presentation duration were tested against the absolute value of zero using one-sample *t*-tests to ensure that the group differences in bias scores were not merely due to the relative difference between groups. The 500 ms bias scores of the high and low negative symptoms groups were significantly different from zero, $t\ (14) = -2.9$, $p < .05$ and $t\ (14) = 4.67$, $p < .001$, respectively. There were no other significant main effects or interactions (Figure 2).

Correlation analyses between bias scores (50, 500, and 1000 ms bias scores) and psychiatric symptoms (PANSS positive, negative, disorganised, depressed symptoms, and MAP-SR total score) indicated that only the 500 ms bias score was positively correlated with the MAP-SR total score ($r = .489$, $p < .01$). No significant correlations were found (Table 2).

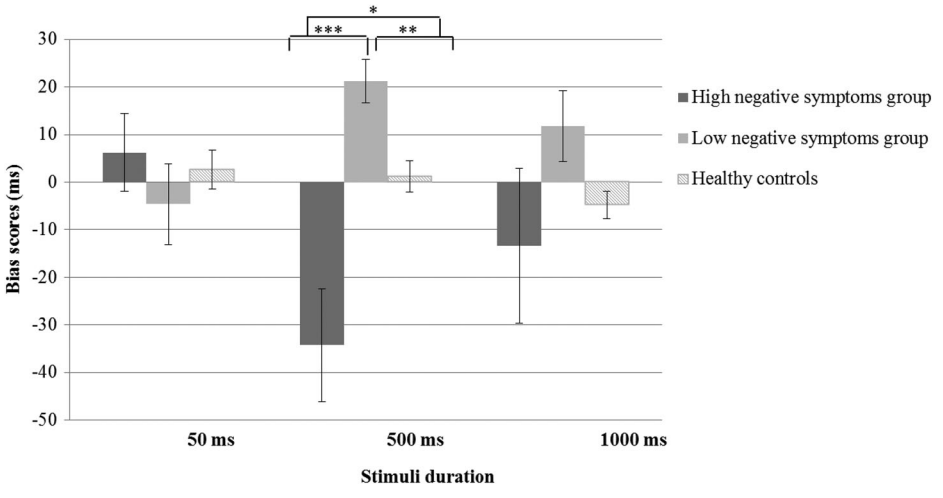

Figure 2. Means and standard errors of attention bias scores (ms) for emotional faces presented at 50, 500, and 1000 ms.

Table 2. Correlations between negative symptoms, attention bias scores, and recognition in schizophrenia group.

	PANSS negative factor score	MAP-SR total score
Attention bias[a]		
50 ms	−.329	−.320
500 ms	−.207	.489**,[a]
1000 ms	.138	.252
Recognition – miss		
Happy	.452*	−.387*
Sad	.466**	−.158
Angry	.302	−.192
Recognition – false alarm		
Happy	−.255	.180
Sad	−.316	.234
Angry	−.342	.230

*$p < .05$.
**$p < .01$.
[a]Attentional bias scores for emotional faces presented for 50, 500, and 1000 ms, respectively.

Recognition

The group difference on recognition errors was examined using the $3 \times 2 \times 3$ mixed RM-ANOVA with emotion (happy, sad, and angry) and error type (miss and false alarm) as within-subjects factors and group (high and low negative symptoms and control) as a between-subjects factor. There was a significant main effect of emotion, F (2, 96) = 5.52, $p < .01$, due to a lower number of errors for angry and happy faces than sad faces ($p = .001$ and $p < .01$, respectively). This was qualified by a significant interaction of emotion and error type, F (2, 96) = 9.046, $p < .001$, indicating a relatively lower number of misses in angry faces than happy and sad faces ($p < .01$ and $p < .05$, respectively) and a relatively higher number of false alarms for the angry and sad faces than happy faces (both $p < .01$). Last, we found a significant interaction between emotion and group, F (4, 96) = 2.63, $p < .05$. Patients with high negative symptoms made more errors for the happy faces than the control participants ($p < .05$).

We also conducted within-group paired samples *t*-tests on the overall number of errors to examine the impact of emotion on the recognition performances in each group. Patients with high negative symptoms made significantly fewer errors for the angry faces than the happy and sad faces, $t\ (14) = 2.75$, $p < .05$ and $t\ (14) = 3.5$, $p < .01$, respectively. The number of errors across different emotions within the group of patients with low negative symptoms was the same. The control group made significantly fewer errors for happy faces than sad faces, $t\ (20) = -3.02$, $p < .01$ (Figure 3).

Correlations between recognition errors and symptoms were calculated. There were no significant correlations between psychiatric symptoms and the total number of errors for each facial emotion type. When specific error types were examined, the number of misses but not false alarms for the happy faces was significantly positively correlated with the PANSS negative and disorganised factors and negatively correlated with the MAP-SR total scores ($r = .452$, $p < .05$, $r = .394$, $p < .05$, and $r = -.387$, $p < .05$, respectively). The number of misses for sad faces was also positively correlated with the PANSS negative and disorganised factors ($r = .466$, $p < .01$ and $r = .448$, $p < .05$, respectively). Positive, excited, and depressed symptoms were not significantly associated with recognition errors. The descriptive statistics of the attention bias and recognition and the comparison between the combined schizophrenia group and the healthy control group were included in Supplementary Table 1 and Supplementary Note 2, respectively.

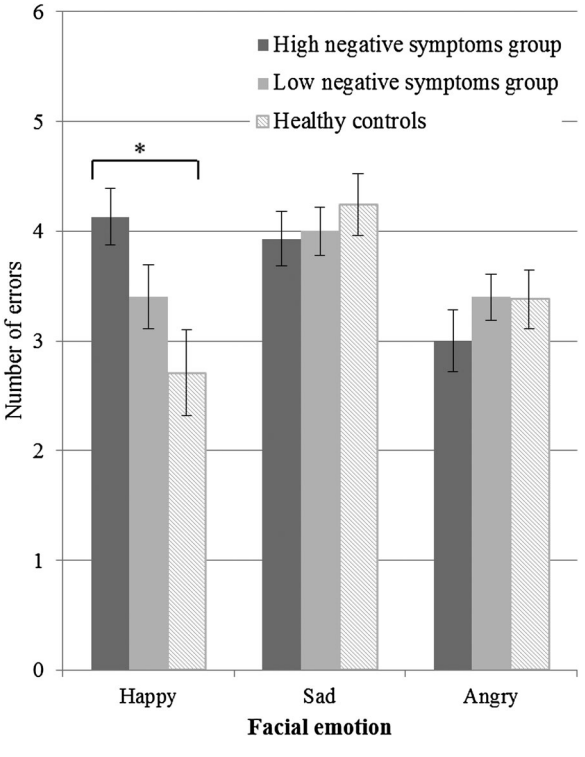

Figure 3. Means and standard errors for the number of recognition errors for happy, sad, and angry faces.

Attention bias and recognition

Among the attention bias scores for emotional faces at 50, 500, and 1000 ms, only the 500 ms bias score was negatively correlated with the number of total errors and misses for happy faces ($r = -.480$, $p < .01$ and $r = -.401$, $p < .05$, respectively) for the groups with schizophrenia, but not for control participants ($p > .05$). There were no other significant correlations between attentional bias and recognition errors for other facial emotions (Figure 4).

Discussion

This is the first attempt to investigate visual selective attention towards emotional faces and its possible link with emotional memory as a function of negative symptoms in schizophrenia. The results showed that patients with high negative symptoms exhibited attentional bias away from emotional faces relative to neutral faces when they were presented for 500 ms. This is consistent with our hypothesis and may be interpreted as inattention or diminution of the attentional capture of emotional information, based on previous studies (Martin et al., 2013; Strauss et al., 2013). It is also consistent with the notion that inattention to affective information would be more evident in the relatively early course of attentional processes than the later stage, as a significant group difference was only found in the 500 ms condition (Martin et al., 2013; Pinheiro et al., 2013). Facial presentations for 50 ms did not induce biased processing in the current study, however. One reason for this could be 50 ms was too short to allow the emergence of the complex interaction between attention and emotion (Walsh-Messinger et al., 2014).

Attention bias at 500 ms was positively correlated with the MAP-SR total score, indicating greater attention allocation to emotional stimuli associated with higher self-reported pleasure and motivation in the daily lives of patients with schizophrenia. Depressed individuals – often anhedonic – exhibited reduced attention to emotional stimuli – specifically for the positive in past studies (McCabe, Gotlib, & Martin, 2000),

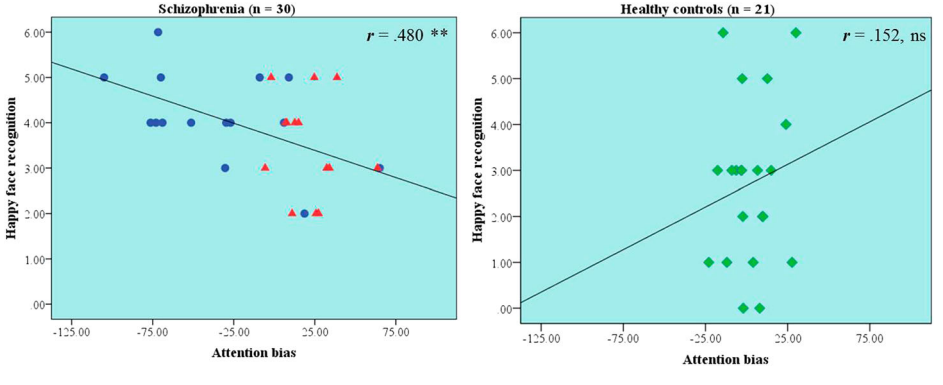

Figure 4. Correlation between attention bias scores for emotional faces at 500 ms ("Attention bias" in the graph, ms) and the number of recognition errors on happy faces ("Happy face recognition" in the graph) in schizophrenia patients and healthy controls. In the graph of schizophrenia group, blue circles indicate patients with high negative symptoms and red triangles indicate patients with low negative symptoms.

suggesting that shared information processing bias may underlie anhedonia (Frewen, Dozois, Joanisse, & Neufeld, 2008). The attentional bias away from not only positive but overall emotional stimuli in the patients with high negative symptoms may reflect that negative symptoms often accompany a lack of negative emotions. The current findings suggest that inattention to emotional information could be more closely related with reports of internal hedonic experiences measured by the MAP-SR rather than external behaviours that are the main source of negative symptoms ratings in the PANSS (Garcia-Portilla et al., 2015). Future studies with instruments using both internal experience and external referents would help clarify the role of attention bias on different aspects of negative symptoms (Kring et al., 2013).

Compared to the patients with high negative symptoms, those with low negative symptoms exhibited facilitated attention allocation to emotional faces and healthy participants showed no such bias. This is similar to several previous findings, indicating that selective attention of patients with low negative symptoms may be influenced largely by emotional salience (Bentall & Kaney, 1989; Strauss et al., 2013). This may correspond with the account of salience dysregulation in schizophrenia (Winton-Brown, Fusar-Poli, Ungless, & Howes, 2014) and suggests that selective attentional process of emotional stimuli may largely vary across the heterogeneous manifestation of symptoms, partly explaining inconsistencies of the previous literature.

In the recognition task, patients with high negative symptoms recognised angry faces best, those with low negative symptoms did not differ across three emotions, and control participants recognised happy faces best. Patients with high negative symptoms had significantly more recognition errors on happy faces compared to control participants, but showed similar memory for angry faces, partially supporting the hypothesis that they would show decreased memory for emotional faces. Their exhibition of decreased positive but not negative memory was not initially hypothesised but may be explained by previous literature on short-term emotional memory. Whereas positive emotion enhanced its memory via increased attention allocation during the encoding, the memory of negative emotion largely depended on arousal independently of attention (Talmi, Schimmack, Paterson, & Moscovitch, 2007). Consistent with this finding, the 500 ms attention bias score was related to the recognition performance of happy but not angry faces in groups with schizophrenia. The memory of negative facial stimuli may be preserved in the current study presumably because of relatively intact experience of arousal in such patients (Llerena, Strauss, & Cohen, 2012). The current result is different with that of Harvey, Bodnar, Sergerie, Armony, and Lepage (2009) which found overall decreased emotional memory regardless of the valence in schizophrenia compared to healthy controls. However, it should be noted that the brief presentation, the existence of distractors, and the additional cognitive demand to detect the probe would have made the current task different from – perhaps harder than – the previous one for all participants.

These findings were very similar to those of Herbener et al. (2007) who found positive but not negative valence failed to enhance the memory of patients with schizophrenia. However, whereas we examined short-term emotional memory, allowing little time for consolidation, this study investigated relatively long-term emotional memory. The impaired positive memory would be related with biased attention during the encoding process in our study, whereas it would be attributed to an aberrant consolidation process in the previous study. Until now, no study has quantified the attention given to

emotional stimuli competing with neutral ones for limited attentional resources during the encoding process and examined its relationship with emotional memory in schizophrenia. Therefore, the current results suggest that not only consolidation, but also encoding, of the emotional stimuli may go awry especially in the context of selective attention and contribute to decreased positive memory and negative symptoms in schizophrenia. This may have been difficult to detect in prior studies, which have usually provided environments for emotional stimuli to be sufficiently elaborated and generate emotional experiences (e.g., relatively long presentation of a single stimulus; Hall et al., 2007; Harvey et al., 2009).

Here, participants generally made fewer misses and more false alarms to negative faces compared to positive faces, indicating a liberal response tendency to negative emotions. This is largely consistent with Windmann and Kutas (2001) in which they claimed retrieval criterion is relaxed to negative stimuli mediated by prefrontal cortex not to miss events with a high potential survival value. We also found evidence that specific types of errors may have more relevance to negative symptoms (within errors made on happy faces, misses but not false alarms correlated with negative symptoms). Whereas high numbers of misses on happy faces are thought to be closely related with encoding failure as suggested by significant correlations between attention bias score and recognition errors, it could also partially reflect altered response criterion, as some previous studies found anhedonia was related with conservative response criterion (high misses and low false alarms) in verbal recognition tasks (Brébion et al., 2005). Therefore, future studies may benefit from considering the role of both selective attention and specific error type on emotional memory in schizophrenia.

There are several study limitations. First, current findings were based on a small sample size and included both inpatients and outpatients. Additionally, we did not use the SCID-IV for the control participants, although we conducted the screening interview outlined in the "Methods" section. Whereas participants were stabilised patients with chronic schizophrenia and the additional analysis including only inpatients did not alter the results, current findings should be taken as preliminary and warrant replication in studies with a larger sample size, a more homogeneous group, and a control group whose psychiatric status is confirmed by structured interview. Lastly, our emotional facial stimuli were matched for moderate arousal levels; future studies could investigate the effect of varying degrees of arousal on attention bias and memory performance.

In the current study, negative symptoms of schizophrenia were found to be related to diminished attention to emotional faces and decreased memory for happy faces, replicating two cognitive processes recently proposed to underlie negative symptoms (Martin et al., 2013; Strauss et al., 2013). This study extends previous findings to facial stimuli; linking these two independently reported processes has revealed the potential role of biased encoding on aberrant positive memory in schizophrenia. The current findings suggest that selective attention process and error types are important factors for future studies on emotional information processing as candidate mechanisms for negative symptoms, which have had mixed findings. Failure to form positive memory is directly implicated in negative symptoms such as anhedonia and avolition and would have detrimental effects by contributing to low mood and damaging individuals' capacities to use positive experiences to guide behaviour. The current study can help the development of effective interventions for negative symptoms – which severely affect the functioning of patients with schizophrenia, but are hard to treat – by adding the possibility of a novel cognitive

mechanism for the pathology of negative symptoms, that is, decreased positive memory via biased encoding of emotional stimuli.

Acknowledgements

The authors would like to thank the study participants, Yong-Chun Bahk, Hyun-Seung Lee, Kyeong-Eun Lee, Yoon-ji Kim, and Soo-Rin Cho who conducted the testing, and the staff at the Yong-In Mental Hospital. The authors also wish to thank Dr William Horan and Dr Tae-Ho Lee for their helpful comments on this manuscript.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by the National Research Foundation of Korea Grant funded by the Korean Government [grant number NRF-2013S1A5A8023956], The Korea University Institutional Review Board approved this study.

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