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Anticipatory pleasure for future rewards is attenuated in patients with schizophrenia but not in individuals with schizotypal traits

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ABSTRACT

The anhedonia paradox is consistently observed in individuals with schizophrenia. However, the underlying mechanism of the dissociation between trait and state hedonic capacity remains unclear. In the present study, we aimed to re-examine anhedonia in patients with schizophrenia (SCZ) and individuals with high schizotypy (HS) using the Monetary Incentive Delay (MID) task to assess different dimensions of anticipatory and consummatory pleasure. We recruited 44 SCZ patients, 46 matched healthy controls (HC), 30 individuals with HS and 35 with low schizotypy (LS). The modified MID task was used to measure anticipatory and consummatory pleasure in terms of valence and arousal ratings. To measure the predictive value of anticipatory pleasure, participants were asked to predict their hedonic experience before the MID task. For SCZ patients, there was no significant Group main effect or Group × Prize interaction on consummatory pleasantness to reward received or loss avoidance. As expected, SCZ patients (particularly male patients) reported less pleasantness and arousal to future rewards in both the prediction and feeling dimensions compared with HC. Additionally, male patients reported less anticipatory and consummatory negativity than HC. Individuals with HS predicted more arousing experience to high-rewards than LS individuals. They also reported and predicted more negativity to in-the-moment and future monetary losses. Further, the negative dimension of schizotypy predicted low levels of pleasantness and arousal towards future rewards, but the positive dimension predicted increased arousing experience towards future rewards. In conclusion, the anhedonia paradox in schizophrenia could be partially accounted for by the dissociation between anticipatory and consummatory pleasure.

1. Introduction

Many studies have reported the existence of an anhedonia paradox in schizophrenia (SCZ) (Cohen and Minor, 2010; Strauss et al., 2016). Specifically, SCZ patients have been found to exhibit an impairment in trait hedonic capacity (Horan et al., 2006; Yan et al., 2012), but their state hedonic experience, as measured by laboratory tasks, appears to be unaffected (Cohen and Minor, 2010). However, the underlying psychopathological mechanism of the anhedonia paradox is unclear.

One possible explanation stems from the Temporal Experience of Pleasure model, proposing two distinct pleasure domains: anticipatory and consummatory pleasure (Kring and Barch, 2014; Kring and Elis, 2013). The former refers to the positive state people experience while anticipating or predicting future pleasurable outcomes. Moreover, anticipatory pleasure comprises two distinctive dimensions: feeling (e.g., the emotional state in anticipating of forthcoming outcomes) and prediction (e.g., the forecasting feeling about future events) (Frost and Strauss, 2016; Kring and Barch, 2014). Consummatory pleasure, on the other hand, refers to the emotional state while engaging with pleasurable activities. A deficit in trait hedonic capacity purportedly reflects an individual's anticipatory pleasure impairment, which is closely associated with dysfunctional mental representation and impairment in working memory (Forbes et al., 2009; Heerey and Gold, 2007).

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However, laboratory tasks used in this area could only capture consummatory pleasure without the involvement of these cognitive processes, resulting in comparable performances between SCZ and controls.

Following this rationale, although many studies have attempted to address the hypothesis of anticipatory anhedonia, their findings have remained inconsistent (Frost and Strauss, 2016). Using the Temporal Experience of Pleasure Scale (TEPS) and ecological monetary assessment, many studies have reported a reduced level of anticipatory pleasure but intact consummatory pleasure in both first-episode (Lui et al., 2015; Mote et al., 2014) and chronic SCZ patients (Barch et al., 2014; Fortunati et al., 2015; Gard et al., 2007). Other studies, however, have reported a decreased level of consummatory pleasure in these patients (Mann et al., 2013; Strauss et al., 2013). The inconsistent findings may be related to the construct validity of the TEPS since anticipatory and consummatory pleasure measured by this scale is evaluated in response to "hypothetical situations" without assessing a person's experiential emotion knowledge. However, in studies that used laboratory tasks to study anhedonia in SCZ patients, most included measurements of consummatory but not anticipatory pleasure (Edwards et al., 2015; Heerey and Gold, 2007; Lui et al., 2016).

Another area that needs addressing is whether this deficit is a stable marker in schizophrenia. As part of the schizophrenia spectrum, schizotypy shares a variety of difficulties (e.g., odd thought) with SCZ (Raine, 2006), and some difficulties (e.g., social anhedonia) can predict the emergence of psychotic disorders in the future (Debbané and Barrantes-Vidal, 2015; Kwapil et al., 2013). An additional advantage of studying individuals with high schizotypal (HS) traits is that it is possible to exclude the confounding effect of antipsychotic medications. However, few studies have investigated anticipatory pleasure in people with HS.

In this study, we aimed to investigate anticipatory pleasure experience in SCZ patients and HS individuals. In addition, given that male patients in general exhibit more severe negative symptoms (Shtasel et al., 1992) and more impaired social functioning (Vaskinn et al., 2011; Willhite et al., 2008), we also examined the effect of sex on anticipatory pleasure. We hypothesized that: 1) male SCZ patients would exhibit diminished anticipatory but intact consummatory pleasure in response to monetary rewards; and 2) individuals with HS would show a similar pattern as SCZ patients in the two pleasure domains.

Table 1
Demographic information, clinical symptoms scores, questionnaire scores and neurological assessments performances in schizophrenia patients and healthy controls.

	SCZ/SCZAff ($n = 44$)		HC ($n = 46$)		t/χ^2	p	Cohen's d
	Mean	SD	Mean	SD			
Age (years)	27.82	7.43	26.00	6.95	1.20	.234	0.25
Education (years)	13.10	13.28	13.89	2.59	−1.16	.249	−0.08
Gender (male: female)	20:24		22:24		0.05	.882	
IQ score	104.07	17.15	115.07	13.71	−3.37	**.001**	−0.71
TEPS_ant_abs	16.64	3.91	19.26	3.49	−3.36	**.001**	−0.71
TEPS_ant_cont	14.34	5.09	16.52	3.63	−2.35	**.021**	−0.50
TEPS_con_abs	24.34	5.02	27.20	4.31	−2.90	**.005**	−0.61
TEPS_con_cont	13.77	3.48	15.87	2.82	−3.15	**.002**	−0.66
RCSAS[a]	10.93	5.40	9.17	6.84	1.33	.188	0.29
RCPAS[b]	21.86	7.55	14.89	8.51	4.08	<**.001**	0.87
LM_Immediate	9.20	4.38	14.54	4.10	−5.98	<**.001**	−1.26
LM_Delayed	7.36	4.39	12.57	4.40	−5.61	<**.001**	−1.18
VM_Immediate	22.05	2.28	22.54	2.17	−1.06	.291	−0.22
VM_Delayed	21.52	2.22	22.41	2.45	−1.80	.075	−0.38
LNS (Cor. Num)	14.52	3.49	16.30	4.09	−2.22	**.029**	−0.47
LNS (longest item)	5.70	1.00	6.39	1.37	−2.72	**.008**	−0.57
DUI (years)	5.70	4.37					
Drug dose (CPZ equivalence, mg/d)	314.50	267.22					
% SGA	95.45%						
% FGA	9.09%						
PANSS_Positive	11.93	5.02					
PANSS_Negative	16.02	7.21					
PANSS_General	28.48	9.59					
PANSS_Total	56.43	19.44					
AIMS[b]	0.05	0.21					
BARS[b]	0.47	1.47					

Note: SCZ = schizophrenia ($n = 40$), SCZAff = schizoaffective disorder ($n = 4$), HC = healthy control, TEPS = Temporal Experience Pleasure Scale, ant = anticipatory pleasure, con = consummatory pleasure, abs = abstract, cont = contextual, RCSAS = revised Chapman Social Anhedonia Scale, RCPAS = revised Chapman Physical Anhedonia Scale, LM = Logical Memory Task, VM = Visual Memory Task, LNS = Letter Number Span task (Chinese version), Cor N = correct number, DUI = duration of illness; SGA = second generation antipsychotic medication; FGA = first generation antipsychotic medication; PANSS = Positive and Negative Syndrome Scale, AIMS = Abnormal Involuntary Movement, BARS = Barnes Akathisia Rating Scale. [a]: N of Sz = 42; [b]: N of Sz = 43. 39 patients only took SGA; three took both FGA and FGA; and one only took FGA.
The numbers in bold indicate p values that are lower than .05.

2. Methods

2.1. Participants

We recruited patients with SCZ or schizoaffective disorder ($n = 44$), diagnosed using the Structured Clinical Interview for DSM-IV Axis I disorders (First et al., 2002) from the Anding Hospital, the Castle Peak Hospital and the Shanghai Mental Health Centre. Potential participants were excluded if they had: 1) a history of neurological disorders; 2) substance abuse; 3) low intelligence (estimated IQ < 70); 4) significant changes in medication or dosage in the previous four weeks; or 5) received modified electroconvulsive therapy in the previous six weeks. All but one patient was taking at least one antipsychotic medication. The Positive and Negative Syndrome Scale (PANSS, Kay et al., 1987), the Abnormal Involuntary Movement Scale (AIMS, Guy, 1976) and the Barnes Akathisia Rating Scale (BARS, Barnes, 1989) were used to measure clinical symptoms and medication side effects. Forty-six healthy controls (HC) with matched age, sex and education level were recruited from the neighbouring communities of the hospitals using hard copies of fliers and advertisements on various social media platforms (see Table 1 and Supplementary materials).

Individuals with HS and low schizotypal (LS) traits were screened from 2276 freshman students through an online survey across four universities in China. Those whose total score on the Schizotypal Personality Questionnaire (SPQ, Raine, 1991) were in the lower 50% were recruited as LS individuals, whereas those whose scores were in the upper 10% were recruited as HS individuals (Shi et al., 2012). Finally, 30 individuals with HS and 35 with LS were recruited in the study. The two groups were matched for age, length of education, sex ratio and estimated IQ (see Table 2).

All participants gave written informed consent prior to the commencement of the study. The study was approved by the Ethics Committee of the Institute of Psychology, Chinese Academy of Sciences.

2.2. Assessment

2.2.1. Monetary Incentive Delay (MID) Task

The modified MID task (Nielsen et al., 2008) was used to measure anticipatory and consummatory pleasure. All trials began with a fixation cross (2000 ms), followed by cues (circle/square, 2000 ms) indicating the amount of money at stake (gain or loss, 0 Chinese Yuan (CNY), 0.5CNY and 5CNY, 1CNY = 0.15 US dollar). A fixation (2000–3000 ms) then appeared after a variable delay period (1000–2500 ms), followed by a target (star) requiring participants to respond by hitting the space bar as quickly as possible. After a two-second delay, a feedback would appear to display the current earning (e.g., "Hit! + 5.00 CNY") for 1650 ms (see Fig. 1 and Supplementary materials for details).

Prior to the MID task, each participant was asked to complete a prediction questionnaire to forecast their affective experience (prediction dimension) to each condition they would come across in the MID task (e.g., if you see the cue indicating a chance to win 5CNY, how would

Table 2
Demographic information, clinical symptom, questionnaire scores and neurological assessments performances in highly schizotypal and lowly schizotypal individuals.

	HS ($n = 30$)		LS ($n = 35$)		t/χ^2	p	Cohen's d
	Mean	SD	Mean	SD			
Age (years)	20.87	1.98	20.29	1.58	−1.32	.193	0.04
Education (years)	14.07	1.48	13.77	1.35	−0.84	.404	0.03
Gender (male: female)	13:17		16:19		0.037	.847	
IQ score	127.37	8.28	127.77	10.47	0.17	.865	0.00
TEPS_ant_abs	19.17	3.85	19.14	2.49	−0.03	.976	0.00
TEPS_ant_cont	16.90	3.58	16.89	4.47	−0.01	.989	0.00
TEPS_con_abs	27.77	4.25	27.14	4.14	−0.60	.552	0.03
TEPS_con_cont	17.00	2.67	16.17	3.12	−1.14	.258	0.07
SPQ total score	44.07	5.54	9.94	6.31	−22.98	**<.001**	1.13
SPQ_co-pe	19.87	3.50	5.29	3.81	−15.86	**<.001**	1.05
SPQ_int	17.80	5.26	3.06	2.87	−13.66	**<.001**	1.15
SPQ_diso	10.73	2.35	2.12	1.79	−16.62	**<.001**	1.14
RCSAS[a]	13.43	6.50	4.71	3.88	−6.42	**<.001**	0.84
RCPAS[c]	17.56	7.82	12.28	6.11	−2.26	**.031**	0.39
LM_Immediate	16.10	3.33	16.51	3.97	0.45	.653	−0.04
LM_Delayed[b]	14.41	3.65	14.74	3.37	0.37	.709	−0.03
VM_Immediate	23.10	1.35	23.46	1.31	1.08	.284	−0.02
VM_Delayed[b]	22.93	1.46	22.91	1.48	−0.05	.964	0.00
LNS (Cor N.)	17.50	2.92	17.43	2.80	−0.10	.920	0.01
LNS (longest item)	6.67	1.06	6.43	0.88	−0.99	.327	0.05

Note: HS = highly schizotypal individuals; LS = lowly schizotypal individuals; TEPS = Temporal Experience Pleasure Scale, ant = anticipatory pleasure, con = consummatory pleasure, abs = abstract, cont = contextual, SPQ = Schizotypal Personality Questionnaire, co-pe = cognitive-perceptual subscale, int = interpersonal subscale, diso = disorganizational subscale, RCSAS = revised Chapman Social Anhedonia Scale, RCPAS = revised Chapman Physical Anhedonia Scale, LM = Logical Memory Task, VM = Visual Memory Task, LNS = Letter Number Span task, Cor N = correct number; [a]: sample size for controls was 34, [b]: sample size for schizotypy was 29, [c]: sample size for controls and schizotypy were 18, respectively.
The numbers in bold indicate p values that are lower than .05.

you feel at that time?). To capture baseline movements, all participants were asked to perform a motion controlling task by responding to the target as quickly as possible.

2.2.2. Neuropsychological assessment and questionnaires

Intellectual functioning was measured using four subtests (e.g. information, arithmetic, similarity, and digit span) of the Chinese version of the Wechsler Adult Intelligence Scale-Revised (Gong, 1992). Working memory, verbal and visual memory were assessed using the Letter-Number Span test (Chinese version, LNS, Chan et al., 2008) and the logical memory and visual reproduction subtests of the Wechsler Memory Scale-Revised (Gong et al., 1989; Wechsler, 1987), respectively.

To measure trait dispositions in both anticipatory and consummatory pleasure experience, we used the Chinese version of the Temporal Experience of Pleasure Scale (TEPS) (Chan et al., 2010; Gard et al., 2006), containing four factors (consummatory contextual and abstract, anticipatory contextual and abstract) with satisfactory psychometric properties.

To measure the inability to experience pleasure from social and physical settings, we used the Chinese version of the revised Chapman Social Anhedonia Scale (RCSAS, Chan et al., 2012; Eckblad et al., 1982) and the revised Chapman Physical Anhedonia Scale (RCPAS, Chan et al., 2012; Chapman et al., 1976), respectively.

The SPQ (Raine, 1991), which is a dichotomous questionnaire with three factors (cognitive-perceptual, interpersonal and disorganization), was used to screen for participants with HS and LS. The Chinese version of the SPQ, with good psychometric properties (Chen et al., 1997), was used in the present study.

2.3. Data preparation and analysis

To simplify the interpretation of the prediction dimension of anticipatory pleasure, we calculated composite scores by averaging ratings for both predicted anticipatory and consummatory ratings (see Supplementary materials for more details). In addition, the relative reaction time, reflecting relatively pure motivation, was calculated by subtracting the reaction time for movement in the motion controlling task from the reaction time for target hit in the MID task.

Independent-group *t*-test was used to determine group differences in age, education level, IQ, questionnaire scores and neuropsychological performances between SCZ patients and HC and between HS and LS. Chi-square test was used to compare the sex ratio between the two groups (see Tables 1 and 2 for statistics). For subjective ratings and reaction time, 2(Group: HC/LS vs SCZ/HS) × 3(Prize: None, Low, High) mixed ANOVAs were separately performed for valence/arousal ratings and reaction time. Greenhouse-Geisser corrections on degrees of freedom were used in cases of violation of the Mauchly's sphericity assumption. Multiple comparisons were corrected using Bonferroni correction. As we were particularly interested in the influence of sex on pleasure experience, we additionally performed 2(Group) × 3(Prize) × 2(Sex) mixed ANOVAs for valence and arousal ratings. Pearson correlations were also performed between subjective ratings, clinical symptoms/scale scores (i.e., SPQ/TEPS/RCPAS/RCSAS) and correct number on the LNS in SCZ and HS individuals. Based on the full-dimensional approach to schizotypy, hierarchical regression analyses were further conducted across all the participants by entering age in the first block, standardized cognitive-perceptual and disorganization factor scores of the SPQ in the second block and standardized RCPAS and RCSAS scores in the third block.

3. Results

3.1. Subjective ratings on the MID

3.1.1. Pleasure

3.1.1.1. SCZ vs HC. As shown in Fig. 2, for valence, there was no significant main effect for Group or Group by Prize interaction for the rewards received or loss avoidance conditions ($ps > .05$), indicating that SCZ patients exhibited a comparable level of consummatory pleasure as HC. As expected, for predicted pleasantness (prediction dimension), we observed a significant Group × Prize interaction ($F(2,176) = 3.355$, $p = .037$, $\eta^2_p = 0.037$). Simple effect analyses indicated that SCZ patients predicted less pleasantness towards future high-rewards than HC ($F(1,88) = 7.16$, $p = .009$($p_{Bonferroni\text{-}corrected} < .09$)). For the feeling dimension, SCZ patients exhibited a trend towards experiencing less pleasantness towards high-rewards as reflected by the simple effect analysis ($F(1,88) = 3.06$, $p = .06$($p_{Bonferroni\text{-}corrected} > .05$)) and the significant Group × Prize interaction ($F(2,176) = 3.086$, $p = .048$, $\eta^2_p = 0.034$).

Regarding arousal rating, SCZ patients showed an overall attenuated arousing experience compared with HC. This was reflected by the significant main effect of Group while receiving rewards ($F(1,84) = 8.132$, $p = .005$, $\eta^2_p = 0.088$) and avoiding losses ($F(1,81) = 14.606$, $p < .001$, $\eta^2_p = 0.153$), as well as predicting ($F(1,88) = 18.030$, $p < .001$, $\eta^2_p = 0.170$) and anticipating ($F(1,88) = 12.393$, $p = .001$, $\eta^2_p = 0.123$) future rewards. All the significant findings survived Bonferroni correction ($ps_{Bonferroni\text{-}corrected} < .05$). Furthermore, SCZ patients exhibited a flattened arousal pattern to monetary rewards in the loss avoidance condition compared with HC, as reflected by the significant Group × Prize interaction ($F(1,162) = 6.55$, $p = .002$, $\eta^2_p = 0.075$) and simple effect analyses (SCZ:$F(2,162) = 2.41$, $p = .093$($p_{Bonferroni\text{-}corrected} > .05$); HC:$F(2,162) = 29.94$, $p < .001$($p_{Bonferroni\text{-}corrected} < .01$)).

3.1.1.2. HS vs LS. For valence rating, the main effect of Group and Group × Prize interaction was not significant for consummation of loss

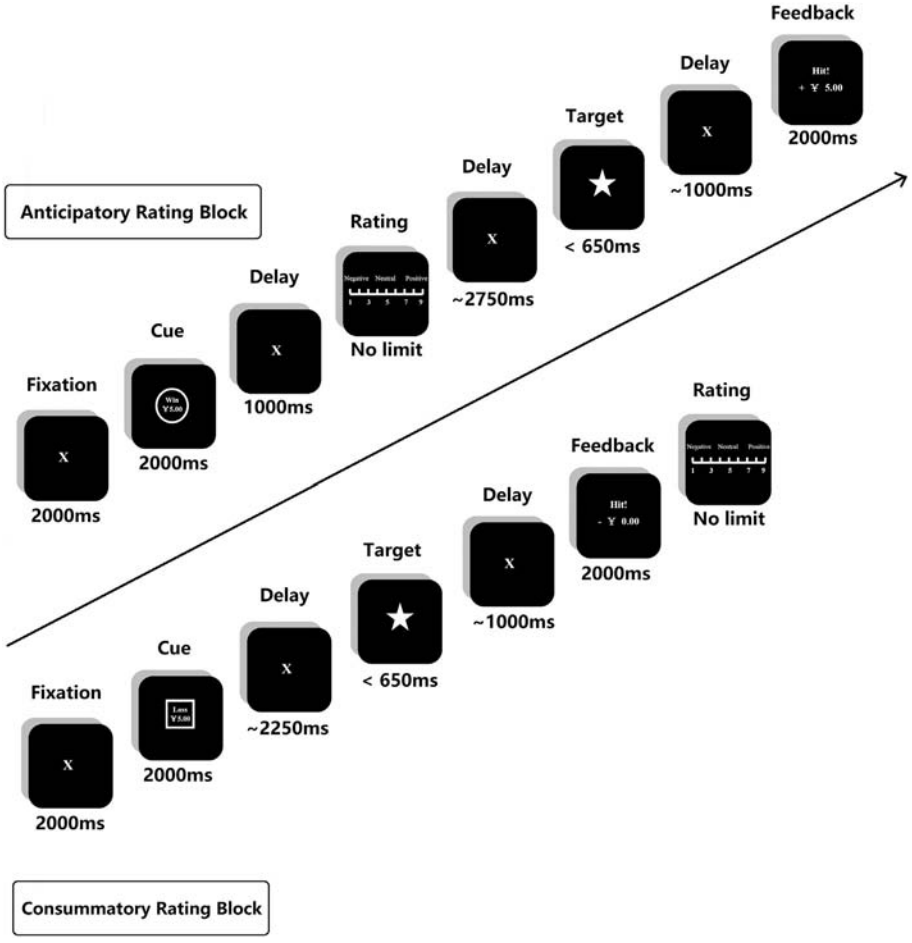

Fig. 1. Scheme of the Monetary Incentive Delay Task. At the beginning of each block, a cross was presented as a fixation for 2 s, followed by a cue presenting for around 2 s. A variable delay would appear during the anticipation phase, which was followed by a target (star) showing no >650 ms. Feedbacks were provided to the participants at the end of each trial for around 2 s. In this task, there were two types of blocks, which were used to measure anticipatory and consummatory pleasure (for more details, please refer to Supplementary materials).

avoidance or rewards anticipation/prediction (*ps* > .05, see Fig. 3). However, HS individuals had lower pleasantness ratings to none-reward ($p = .032(p_{Bonferroni\text{-}corrected} > .27)$) compared with LS individuals, as reflected by the significant Group × Prize interaction ($F(2,124) = 4.198$, $p = .017$, $\eta^2_p = 0.063$).

Regarding arousal rating, there was no significant main effect for Group or Group × Prize interaction during the consummation phase of rewards/loss avoidance or anticipation to rewards (feeling dimension, *ps* > .05). However, there was a significant Group × Prize interaction on the predicted ratings (prediction dimension, $F(2,126) = 3.738$, $p = .026$, $\eta^2_p = 0.056$), indicating that HS individuals predicted more arousing experience towards high-rewards than LS ($p = .031(p_{Bonferroni\text{-}corrected} > .27)$).

3.1.2. Negative affect

3.1.2.1. SCZ vs HC. During the consummatory phase, compared with HC, SCZ patients reported less negative affect towards losses ($F(1,66) = 5.309$, $p = .024(p_{Bonferroni\text{-}corrected} < .08)$, $\eta^2_p = 0.074$) as reflected by the significant main effect for Group. Regarding anticipatory affect, SCZ patients also exhibited less negative affect than HC while predicting future losses ($F(1,88) = 4.419$, $p = .038(p_{Bonferroni\text{-}corrected} < .11)$, $\eta^2_p = 0.048$). The Group × Prize interaction was significant for anticipated affect (feeling dimension, $F(1,88) = 6.956$, $p = .010$, $\eta^2_p = 0.073$), indicating less negative affect in SCZ patients while anticipating high-losses ($p < .001(p_{Bonferroni\text{-}corrected} < .01)$).

For arousal ratings, SCZ patients showed significantly less arousing experience than HC in response to reward omission ($F(1,71) = 15.683$, $p < .001(p_{Bonferroni\text{-}corrected} < .01)$, $\eta^2_p = 0.181$) and losses ($F(1,73) = 11.413$, $p = .001(p_{Bonferroni\text{-}corrected} < .01)$, $\eta^2_p = 0.135$). Also, SCZ patients exhibited attenuated arousing experience while predicting and anticipating low and high monetary losses compared with HC ($ps_{uncorrected} < .009(ps_{Bonferroni\text{-}corrected} < .09)$), as reflected by the significant Group × Prize interactions (prediction dimension: $F(1,88) = 5.907$, $p = .003$, $\eta^2_p = 0.063$; feeling dimension: $F(1,88) = 5.286$, $p = .006$, $\eta^2_p = 0.057$, see Fig. 2).

3.1.2.2. HS vs LS. Compared with LS, HS individuals exhibited significantly more negative affect towards reward omission ($F(1,54) = 8.127$, $p = .006(p_{Bonferroni\text{-}corrected} < .05)$, $\eta^2_p = 0.131$) and losses ($F(1,61) = 9.254$, $p = .003(p_{Bonferroni\text{-}corrected} < .05)$, $\eta^2_p = 0.132$), as reflected by the significant main effect for Group. However, no significant Group × Prize interaction was observed. For the anticipatory domain, there was a significant Group × Prize interaction on predicted negativity ($F(2,126) = 6.449$, $p = .002$, $\eta^2_p = 0.093$), indicating HS individuals predicted more negative affect towards future high-losses compared with LS individuals ($p = .001(p_{Bonferroni\text{-}corrected} < .02)$). No significant main effect for Group or Group × Prize interaction was observed for the feeling dimension of anticipatory affect.

Regarding arousal rating, there were significant Group × Prize interactions during the consummation of reward omission ($F(2,116) = 3.766$, $p = .026$, $\eta^2_p = 0.061$) and losses ($F(2,118) = 2.901$, $p = .059$, $\eta^2_p = 0.047$) as well as anticipation of future losses (feeling dimension, $F(2,126) = 2.741$, $p = .068$, $\eta^2_p = 0.042$). Further simple main effect analyses showed that HS individuals exhibited more arousing experience towards high-reward omission and high-losses as well as future

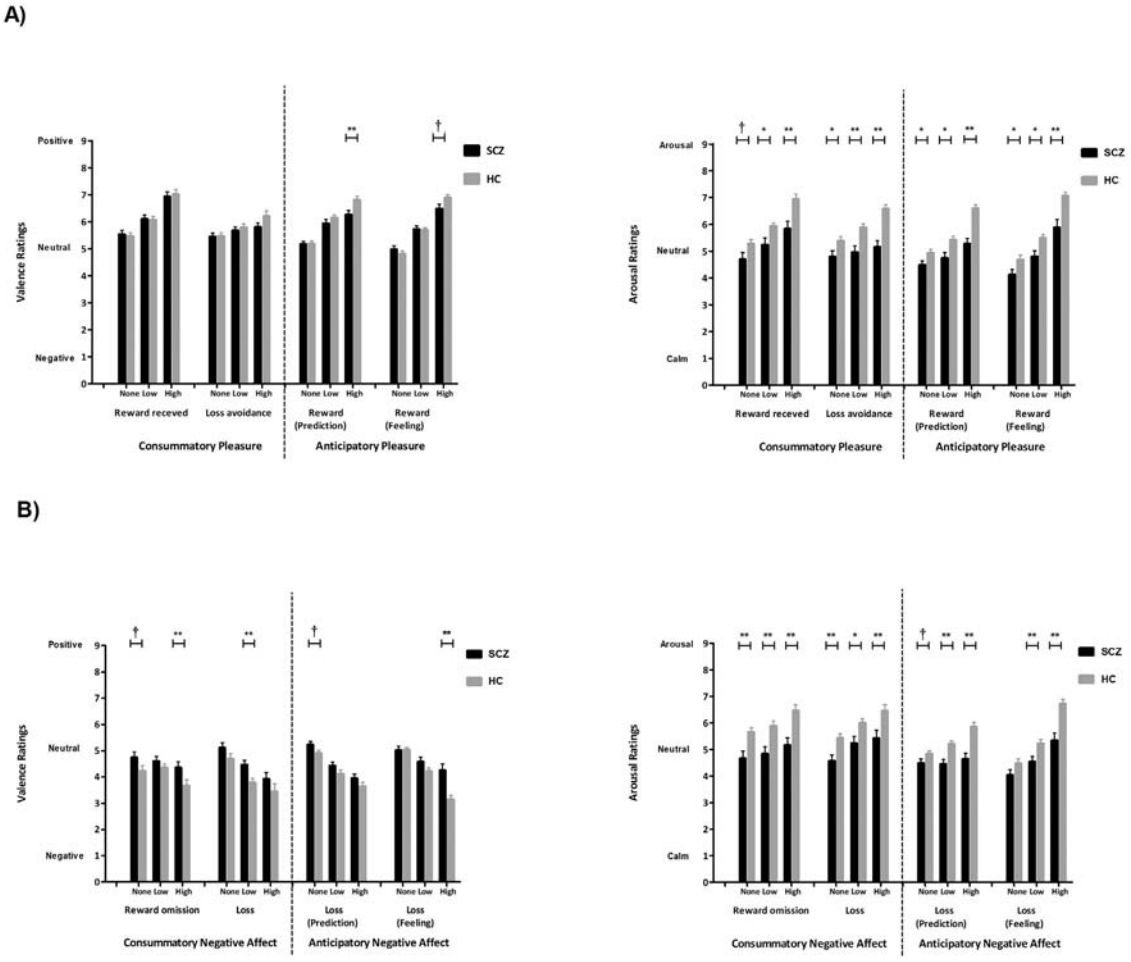

Fig. 2. Group differences in anticipatory and consummatory affect to rewards and punishments between SCZ patients and HC. A) Positive affect; B) Negative affect. Valence ratings are shown on the left panel and arousal ratings shown on the right side. Orange bar indicates SCZ patients and blue bar represents HC.

high-rewards (Reward omission: $p = .006$($p_{Bonferroni\text{-}corrected} < .06$); Losses: $p = .015$($p_{Bonferroni\text{-}corrected} > .05$); Anticipatory (feeling dimension): $p = .014$($p_{Bonferroni\text{-}corrected} > .05$)) compared with LS individuals. No significant main effect of Group or Group × Prize interaction was observed for prediction dimension ($ps > .05$, See Fig. 3).

Given the potential existence of carry-over effect of affective experience, we further performed a series of mixed ANOVAs on the residuals that was calculated in the regression models measuring carry-over effect. Overall, similar findings were observed for most of conditions during the anticipatory and consummatory phase in individuals with SCZ and HS when carry-over effects of affective experience in the previous trial was taken into consideration (see Supplementary materials for details).

3.2. Sex differences in anticipatory and consummatory pleasure

Compared to the corresponding HC, male rather than female patients with SCZ showed lower pleasantness (Male: $F(1,87) = 11.86$, $p = .001$($p_{Bonferroni\text{-}corrected} < .01$); Female: $F(1,87) = 0.26$, $p = .613$ ($p_{Bonferroni\text{-}corrected} > .05$)) and arousing experience (Male: $F(1,87) = 13.16$, $p < .001$($p_{Bonferroni\text{-}corrected} < .01$); Female: $F(1,87) = 2.63$, $p = .109$($p_{Bonferroni\text{-}corrected} > .05$)) in anticipation (feeling component) to forthcoming high-rewards, as reflected by significant Sex × Group × Prize interaction. Furthermore, a significant Sex × Group × Prize interaction was observed for valence ratings in anticipation of rewards (prediction dimension). Male SCZ patients predicted lower level of pleasantness towards high-rewards (Male: $F(1,87) = 13.32$, $p < .001$ ($p_{Bonferroni\text{-}corrected} < .02$); Female: $F(1,87) = 0.12$, $p_{\text{uncorrected}} = .725$ ($p_{Bonferroni\text{-}corrected} > .05$)). No main effect of sex or interaction with sex for consummatory pleasure was observed ($ps > .05$, see Supplementary Table 1).

On the other hand, male HS individuals exhibited higher levels of arousing experience in anticipation of rewards compared with male LS individuals (Male: $F(1,62) = 9.73$, $p = .003$($p_{Bonferroni\text{-}corrected} < .02$); Female: $F(1,62) = 0.25$, $p = .617$($p_{Bonferroni\text{-}corrected} > .05$)), as reflected by the significant Sex × Group interaction. No main effect of sex or interaction effect with sex was observed for consummatory pleasure ($ps > .05$, to save space, we only reported the results for pleasure; see Supplementary Tables 1 and 2 for negative affect).

3.3. Correlations between anticipatory affective, clinical symptoms and working memory in SCZ and HS

It was found that the anticipatory valence and arousal ratings (feeling dimension) towards high-rewards were inversely correlated with negative (valence: $r = -0.312$, $p = .039$; arousal: $r = -0.341$, $p = .024$) and positive symptoms (valence: $r = -0.356$, $p = .018$) scores on the PANSS. We did not find any significant relationships between anticipatory pleasure and number of correct responses on the LNS despite a few unexpected results indicating that worse performances on the LNS were associated with higher levels of anticipatory pleasure (feeling dimension: valence (low-reward), $r = -0.34$, $p = .026$; arousal (None reward), $r = -0.415$, $p = .005$). For negative affect, there were negative correlations between arousing experience (prediction dimension) to

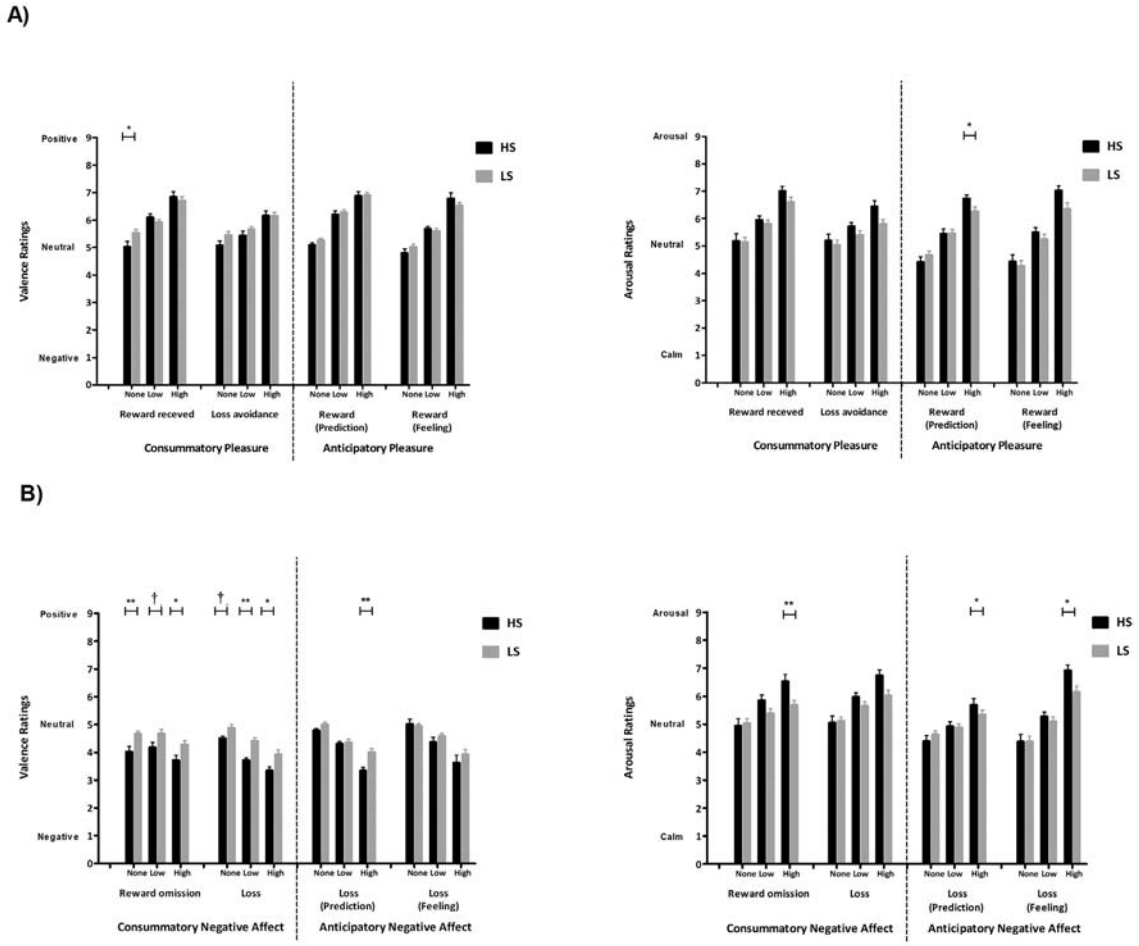

Fig. 3. Group differences in anticipatory and consummatory affect to rewards and punishments between individuals with HS and LS traits. A) Positive affect; B) Negative affect. Valence ratings are shown on the left panel and arousal ratings shown on the right side. Orange bar indicates HS individuals and blue bar represents LS individuals.

both future low- and high-losses and negative and general symptoms on the PANSS ($r = -0.331$ to -0.446; $ps < .05$). Further, worse performance on the LNS was significantly associated with lower arousing experience (prediction dimension, $r = 0.383$, $p = .005$), but unexpectedly higher arousing experience (feeling dimension, $r = -0.298$, $p = .049$) towards future low-losses (see Supplementary Figs. 1 and 2).

For HS individuals, lower scores on the abstract anticipatory subscale of the TEPS were associated with reduced predicted pleasantness towards low-rewards ($r = 0.381$, $p = .038$). We also found that arousal rating towards low-reward omission was positively correlated with score on the contextual consummatory subscale of the TEPS ($r = 0.419$, $p = .024$). The score on the RCPAS was significantly correlated with predicted valence ratings in the none-losses condition ($r = -0.595$, $p = .009$) and with consummatory arousal ratings towards non-reward omissions ($r = 0.472$, $p = .048$). Finally, fewer correct responses on the LNS was correlated with higher levels of arousing experience towards low-rewards (feeling dimension, $r = -0.365$, $p = .047$). However, none of these significant findings survived Bonferroni correction ($ps_{Bonferroni\text{-}corrected} > .05$).

3.4. The relationship between dimensional schizotypal features and affective experience to high-rewards and losses

Based on the full-dimensional approach to schizotypy, we further conducted hierarchical regression analyses to determine the relationships between affective experience and schizotypal features among SCZ patients, HC, HS and LS. We found that higher RCPAS scores significantly predicted lower levels of pleasantness (prediction dimension) and arousing experience (prediction and feeling dimension) towards future rewards as well as lower levels of arousing experience while receiving rewards and avoiding losses ($beta = -0.207$ to -0.348, $ps < .05$). The Cognitive-perceptual score on the SPQ, however, positively predicted arousing experience (prediction dimension) towards future rewards ($beta = 0.246$, $p = .040$, see Supplementary Table 3).

Regarding negative affect, individuals with higher RCPAS scores predicted significantly lower anticipatory arousing experience towards losses (prediction dimension: $beta = -0.216$, $p = .038$; feeling dimension: $beta = -0.295$, $p = .003$) and lower consummatory arousing experience ($beta = -0.285$, $p = .003$) towards reward omission. Scores on the cognitive-perceptual factor of the SPQ predicted elevated arousing experience towards reward omission ($beta = 0.262$, $p = .021$, see Supplementary Table 4).

4. Discussion

In the present study, we investigated anticipatory and consummatory pleasure in SCZ patients and HS individuals. As expected, SCZ patients demonstrated comparable level of consummatory pleasure experience, while their arousing experience was generally attenuated. In addition, SCZ patients, especially male patients, exhibited decreased anticipatory pleasure especially towards high-reward cues in terms of both valence and arousal, but did not exhibit as much anticipatory or consummatory negativity or arousing experience as HC. HS individuals

reported comparable level of consummatory pleasure as LS, but male HS individuals predicted higher level of arousal experience towards future rewards. More negativity than LS were observed in these individuals during the consummation of loss/reward omission and predicting future high-losses. Further, the negative dimension of schizotypy predicted lower levels of pleasantness and arousing experience in anticipation of future rewards and losses, while the positive dimension was correlated with increased level of arousing experience in anticipation of future rewards and while consuming reward omission.

In line with our hypothesis, consummatory pleasantness was unaffected in SCZ patients, which is consistent with previous meta-analytic studies employing a wide variety of stimuli including pictures, facial expressions and film clips (Cohen and Minor, 2010; Yan et al., 2012), supporting the notion of intact consummatory pleasure in SCZ (Frost and Strauss, 2016; Kring and Elis, 2013). Unexpectedly, we observed generally attenuated arousing experience in SCZ patients when receiving rewards or avoiding losses, which is in contrast to one previous meta-analysis reporting comparable level of arousing experience in SCZ patients (Llerena et al., 2012). The discrepancy in findings might be related to the stimulus selected to elicit emotion. In Llerena et al.'s meta-analysis, most included studies adopted affective stimuli containing social information such as words, facial expressions or conversations, which might not be sufficient to elicit the participants' sense of self-focus and motivational involvement compared with monetary incentives. Given that higher level of arousing experience might be elicited by monetary incentives compared with social incentives in the normal population (Xie et al., 2014), it might be more likely to observe reduced arousing experience in SCZ using monetary incentives. Similarly, HS individuals did not show altered consummatory pleasure, which is consistent with previous studies reporting normal approaching motivation towards monetary rewards in schizotypal individuals (Xie et al., 2014), but different from other studies employing social stimuli (Cohen et al., 2012; Hooker et al., 2014). This suggests that normality in consummatory pleasure in schizotypy may not be generalizable to every incentive type (Xie et al., 2014).

On the other hand, SCZ patients exhibited prominent deficit in their prediction dimension of anticipatory pleasure, which is in line with behavioural studies reporting lower anticipatory pleasure as measured by the TEPS (Gard et al., 2007; Kring and Barch, 2014) and neuroimaging studies showing decreased frontopolar and rostral anterior cingulate cortical activities during the anticipatory phase (Choi et al., 2014). The underlying explanation for this deficit in anticipatory pleasure might be related to patients' dysfunctional working memory, mental representation (Heerey and Gold, 2007; Strauss, 2013) and pleasure belief systems (Strauss and Gold, 2012). Other studies, however, did not observe impairments in anticipatory pleasure measured using laboratory tasks (Trémeau et al., 2010) or the TEPS (Mucci et al., 2015; Wang et al., 2015). These inconsistent findings might be related to the difference in severity of negative and depressive symptoms in the SCZ patients recruited. Specifically, SCZ patients with more severe negative or depressive symptoms are more likely to have lower anticipatory subscale score on the TEPS or attenuated ventral striatum activation compared with those with milder symptoms (Fortunati et al., 2015; Mote et al., 2014; Simon et al., 2010). Furthermore, the deficit in anticipatory pleasure in SCZ patients in this study was limited to high-reward conditions, which is consistent with previous imaging studies. In one fMRI study, attenuated left putamen activity was observed in SCZ patients in response to positive high-arousal rather than low-arousal pictures compared with HCs (Dowd and Barch, 2010). Similarly in another MEG study, HCs but not SCZ patients showed larger evoked magnetic responses in the caudal brain region towards high-arousal positive rather than neutral images (Rockstroh et al., 2006). Taken together, it is possible that deficit in anticipatory pleasure might be selective in SCZ.

Regarding the feeling dimension, our finding is consistent with previous neuroimaging studies reporting reduced ventral striatal activity (Grimm et al., 2012; Schlagenhauf et al., 2009) and reduced prefrontal-mesolimbic connectivity (Simon et al., 2015) in anticipation of rewards in SCZ patients. In another behavioural study, Edwards et al. (2015) found that SCZ patients displayed larger discrepancy between anticipatory and consummatory valence ratings for pleasant stimuli, indicating difficulties in the estimation of anticipatory pleasure. Contrary to our expectation, HS individuals predicted higher level of arousal towards future high-rewards. This finding, however, is consistent with previous neuroimaging studies that reported hyperactivation of the prefrontal cortex and the anterior cingulate cortex in anticipation of monetary rewards in individuals with positive schizotypy (Yan et al., 2016) and people at high familial risk for psychosis (de Leeuw et al., 2015; van Buuren et al., 2011). In view of the role of the prefrontal and cingulate cortex in emotional control (Rudebeck et al., 2013), excessive arousing experience might serve to compensate for the comparable level of anticipatory pleasure. Taken together, SCZ patients and HS individuals may both have differential difficulties in evaluating anticipated pleasure experience, especially when imagination is involved, despite different patterns of deficit.

Interestingly, the negative dimension of schizotypy was associated with lower levels of anticipatory pleasantness and arousing experience towards rewards whereas the positive dimension predicted higher levels of anticipatory and consummatory arousing experience towards rewards and reward omission. These findings are consistent with notion that negative schizotypy may be correlated with decreased positive affect and emotional intensity while positive schizotypy may be associated with increased affective intensity and negative affect (Phillips and Seidman, 2008). Further, it is also in line with Evidence from an fMRI study reporting that negative schizotypy exhibited decreased ventral striatum activation while positive schizotypy showed enhanced ventral lateral prefrontal cortical activity during reward anticipation (Yan et al., 2016). Taken together, our findings suggest that different dimensions of schizotypy may be associated with unique dysfunctions in anticipatory pleasure and negative affect, supporting the multidimensional model of schizotypy (Kwapil and Barrantes-Vidal, 2015).

Another interesting finding was that male rather than female SCZ patients and HS exhibited deficits in their anticipatory pleasure, which is consistent with previous evidence showing that negative symptoms and trait anhedonia are more common in male SCZ patients (Falkenburg and Tracy, 2014; Yan et al., 2012) and male HS individuals (Miettunen and Jaaskelainen, 2010). Previous studies have reported that male SCZ patients and male HS individuals exhibit impairments in emotion perception (i.e., facial affect recognition, emotional prosody) (Leppanen et al., 2008; Najt et al., 2012; Scholten et al., 2005) and emotion expressivity (Kring and Moran, 2008). In the context of these previous findings, our results provide new evidence in understanding the role of sex in emotion dysfunctions in patients with schizophrenia spectrum disorders.

Finally, SCZ patients displayed attenuated anticipatory and consummatory negative affect, which is inconsistent with previous meta-analytic studies reporting at least comparable levels of aversive emotion to negative stimuli in SCZ patients (Cohen and Minor, 2010). It is possible that the inconsistent findings may be related to the difference in negative symptoms severity in SCZ patients in different studies. The severity of negative symptoms in SCZ has been reported to be inversely correlated with affective experience (Dowd and Barch, 2010) and ventral striatal and amygdala activities when processing affective stimuli (Dowd and Barch, 2010; Taylor et al., 2005). In the present study, we also observed that negative symptoms severity was inversely correlated with anticipatory arousing experience to losses in SCZ patients. Interestingly, HS individuals demonstrated higher levels of anticipatory and consummatory negative affect, which is consistent with previous evidence reporting higher levels of experienced emotion across a range of sensory domains in individuals with positive and disorganized schizotypy (Cohen et al., 2015; Phillips and Seidman, 2008). In addition, neuroimaging studies have reported exaggerated neural activity in the medial prefrontal cortex, the anterior cingulate cortex and the amygdala

in response to emotionally arousing pictures and fearful faces in schizotypal individuals or those at high familial risk of developing psychosis (van Buuren et al., 2011), indicating these individuals may be sensitive to negative emotional events. Taken together, the pattern of negative emotion in response to monetary losses appears to be different in SCZ patients and HS individuals.

This study has several limitations. First, only monetary reinforcements were used to elicit participants' affect, which might restrict the generalization of our results. In view of the differential neural correlates of monetary and social reward anticipation (Spreckelmeyer et al., 2009), further investigation is needed to clarify whether SCZ patients and HS individuals exhibit similar anticipatory pleasure dysfunction in the social domain. Secondly, subjective ratings were employed to measure affective experience, but the feeling reported could be distorted by the participants' awareness of being measured. Future studies should adopt objective measurements such as physiological arousal to address this issue. Lastly, the possible effect of antipsychotic medication on pleasure experience in SCZ patients should also be acknowledged. Since antipsychotic medications are thought to alleviate psychotic symptoms via D2 antagonism (Howes and Kapur, 2009), the consequent change in dopamine transmission may reduce/enhance neural activities in the ventral striatum involved in reward anticipation (Juckel et al., 2006; Schlagenhauf et al., 2008). Future studies should preferably recruit medication-naïve patients to avoid this confounding factor.

5. Conclusion

In conclusion, SCZ patients, especially male patients, exhibited selective impairment in anticipatory rather than consummatory pleasure towards high-rewards in terms of valence, partially supporting the anticipatory anhedonia hypothesis in SCZ. Individuals with HS demonstrated differential affective pattern in response to monetary rewards and punishments from SCZ patients. Furthermore, negative and positive dimensions of schizotypy were related to lower and higher levels of anticipatory pleasantness and arousing experience, respectively. Our findings may have implications for the developmental psychopathology of negative symptoms in SCZ.

Conflict of interest

The authors reported no conflicts of interest with this work.

Contributors

CY designed the study, collected and analyzed the data, and wrote up the first manuscript. SSYL, LQZ, CYW, FCZ, recruited clinical cases and made clinical diagnoses and clinical ratings on patients with schizophrenia. LQZ collected the subclinical data and conducted the assessments to all subclinical cases and healthy controls. EFC and DHKS made critical comments to the drafts of the manuscript. RCKC generated the idea, designed the study, interpreted the findings and commented critically to the drafts of the manuscript. All authors read and approved the final version of manuscript for submission.

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The funding agents had no further role in the study design; in the collection, analysis and interpretation of the data; in the writing of the manuscript; and in the decision to submit the paper for publication.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.schres.2018.12.003.

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