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Affective forecasting in individuals with social anhedonia: The role of social components in anticipated emotion, prospection and neural activation

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ABSTRACT

Background: Affective forecasting, or the ability to forecast emotional responses to future events, is essential to everyday life adaption. Previous research suggests that individuals with social anhedonia exhibit deficits in affective forecasting, but the pattern of these deficits and their neural correlates are not known.
Methods: Individuals with social anhedonia (n = 40) and healthy controls (n = 46) completed a social affective forecasting task and underwent resting-state fMRI scanning.
Results: Compared with healthy controls, social anhedonia individuals anticipated reduced pleasure especially in social conditions and their prospection contained less visualization, voice, taste, self-referential thoughts, other-referential thoughts and language communication. Moreover, anticipated pleasure (valence and arousal for positive events) was positively associated with effort level, especially in social conditions. The social anhedonia group also exhibited stronger functional connectivity between the retrosplenial cortex and the insula and reduced functional connectivity between the hippocampal formation and the parahippocampus. These altered functional connectivities were correlated with anticipated valence in social, but not non-social, conditions.
Conclusions: These findings suggest that individuals with social anhedonia anticipate less pleasure predominately in social conditions and impaired prospection may contribute to the reduced anticipated pleasure. Reduced anticipated pleasure may be a target to improve social motivation in social anhedonia individuals.

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1. Introduction

The ability to predict one's hedonic consequences in the future, or affective forecasting (AF), guides future-oriented behaviour and plays a key role in adaptive functioning (Gilbert and Wilson, 2007). Moreover, AF is meaningful for clinical research given that it serves as a fundamental role in anhedonia (Frost and Strauss, 2016) and influences the level of motivation (Morewedge and Buechel, 2013). Therefore, in together with its impact on future-oriented or goal-directed behaviour, AF may contribute to the display and the development of clinical symptoms, such as anhedonia or amotivation. Abnormal AF is observed in individuals with mental disorders, as well as those at risk for developing a disorder (Engel et al., 2016; Yang et al., 2018), such as social anhedonia. Social anhedonia refers to a trait-like reduced ability to experience pleasure during social activities (Blanchard et al., 2011), which is regarded as a risk factor of developing schizophrenia-spectrum disorders (Kwapil, 1998; Gooding et al., 2014). Individuals with high levels of social anhedonia are less motivated to develop interpersonal

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relationships (Mishlove and Chapman, 1985) and have more negative functional outcomes than individuals with low levels of social anhedonia (Hu et al., 2018). Given the crucial role of AF in clinical studies and the maladaptive functions of individuals with social anhedonia, it is worthwhile to investigate the pattern of AF in individuals with social anhedonia, not only because it may help to elucidate the underlying mechanism of anhedonia and amotivation, but also it may contribute to novel interventions to enhance social functioning.

Although a growing number of studies have investigated AF in people with mental disorders, it is often confused with "anticipatory pleasure" in these studies (Frost and Strauss, 2016). The conceptual relationship between AF and anticipatory pleasure is shown in Fig. 1. Specifically, *prospection* is the mental simulation of future events, *AF* is the ability to predict future feelings (i.e., anticipated emotion), and *anticipatory affect* is the in-the-moment feeling during prospection. According to Frost and Strauss (2016), these three components (prospection, AF, and anticipatory affect), as well as associative conditioning, are all a part of anticipatory pleasure. However, the AF component of anticipatory pleasure only refers to anticipated positive emotions, neglecting to consider anticipated negative emotions. Because recent research has suggested the importance of anticipated negative emotions in the social experience of individuals with social anhedonia (Moore et al., 2019), in this study, we aimed to investigate AF as measured by anticipated positive and negative emotions.

Prospection is one of the key processes of AF (Gilbert and Wilson, 2007). Relevant information is retrieved from different memory systems and is then used to simulate future scenarios. By integrating the in-the-moment feeling during prospection (e.g., anticipatory affect) with sematic information (e.g., beliefs), future emotions can be forecasted (i.e., anticipated emotion; Gilbert and Wilson, 2009). The medial temporal lobe (MTL), a sub-system of the Default Mode Network (DMN), has been shown to play a key role in prospection (Andrews-Hanna et al., 2010; Bellana et al., 2017). This finding is further supported by a meta-analytic study, which found all components of the MTL sub-system to be significantly activated during episodic future thinking (Stawarczyk and D'Argembeau, 2015). Moreover, the MTL sub-system is part of a "core network", which has been proposed as the key neural mechanism of episodic future thinking (Schacter et al., 2017). Therefore, the MTL-subsystem may be an important neural correlate of AF.

One way researchers have measured AF is using the Temporal Experience of Pleasure Scale (TEPS; Chan et al., 2012a; Gard et al., 2006). This widely-used self-report scale includes items measuring anticipated emotion and anticipatory affect. Studies using the TEPS have found that social anhedonia individuals reported less anticipatory pleasure than individuals without social anhedonia (Wang et al., 2016), but it is not clear whether the impairment is from the anticipated emotion or the anticipatory affect.

Another way researchers have measured AF is using the Incentive Delay task. Using this task, Xie et al. (2014) found that social anhedonia individuals anticipate less pleasure than controls when cues are social affective pictures instead of money, suggesting a social domain-specific impairment in AF in social anhedonia individuals. This hypothesis is supported by further imaging studies which found that compared with healthy controls, social anhedonia individuals show similar brain activation in the Monetary Incentive Delay task, but exhibit abnormal brain activation in the Affective Incentive Delay task (Chan et al., 2016b). Therefore, it is possible that social anhedonia individuals have social domain-specific deficits in AF, which has not been investigated in previous studies. At the same time, some evidence suggests that social anhedonia individuals may have altered anticipation of negative emotions. For

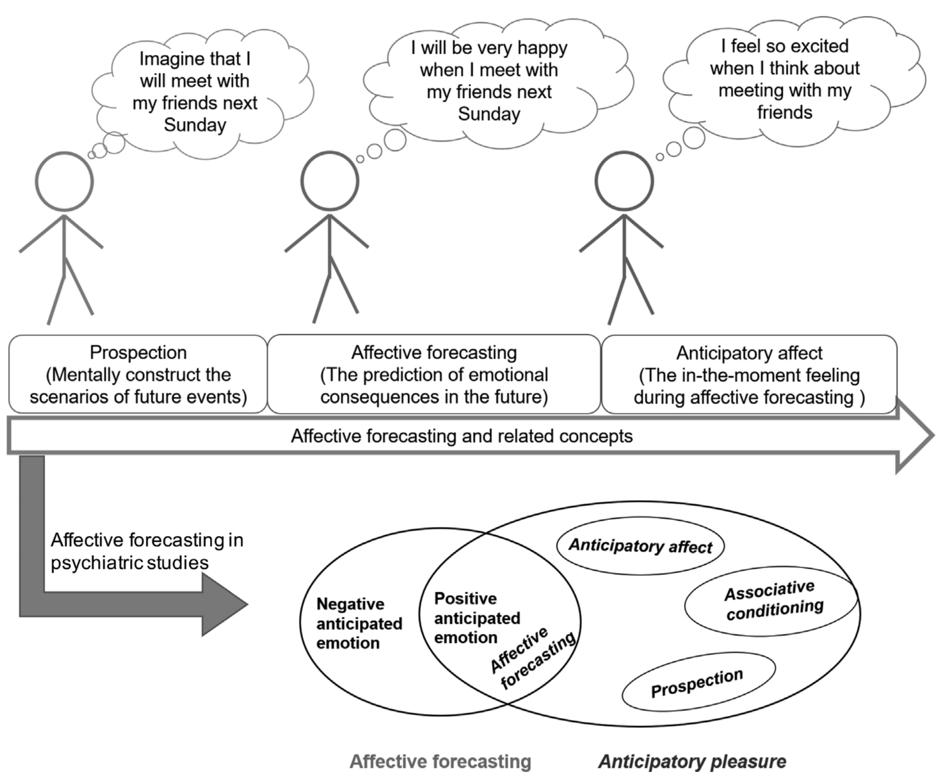

Fig. 1. Concept clarification of affective forecasting and its similar terminologies. Prospection is the ability to mentally simulate future scenarios and it is the basic process of affective forecasting. Affective forecasting is the ability to predict future emotions based on prospection and anticipated emotion is the main outcome of affective forecasting. Anticipatory affect is the in-the-moment feeling during prospection and it may interact with anticipated emotion. Anticipatory pleasure in psychiatric studies includes affective forecasting, prospection, anticipatory affect and associative conditioning. Affective forecasting in the anticipatory pleasure is overlapped with positive anticipated emotion. Please be noted that the pleasure in the concept clarification refers to all kinds of pleasure.

example, people with more subclinical negative symptoms anticipated more fear in both socially inclusive and exclusive situations compared with people with less subclinical negative symptoms (Engel et al., 2015). However, since most previous studies have only explored positive emotions (e.g., pleasure), little is known about the pattern of anticipated negative emotions.

In this study, we aimed to investigate the role of social components in AF in social anhedonia individuals, including both positive and negative anticipated emotions. We also investigated the behavioural and neural mechanism of the altered AF ability and tested the relationship between AF and motivation. So far, there is not a widely accepted imaging paradigm that can directly capture the cognitive processing of AF. Therefore, adopting the resting-state functional connectivity approach and conducting correlation analysis with AF performance at the behavioral level may be a practical way to explore the neural correlates of AF.

We hypothesized that 1) social anhedonia individuals would anticipate less positive emotions (lower valence and lower arousal) and more negative emotions (lower valence) than controls in social conditions but not in non-social conditions; 2) prospection of social anhedonia individuals would contain fewer details than that of controls in social conditions but not in non-social conditions; 3) impaired anticipated emotion would be associated with less detailed prospection features and reduced motivation (lower effort level); and 4) altered brain functional connectivity in social anhedonia individuals would be correlated with anticipated emotion in social conditions but not in non-social conditions. In addition, the pattern of anticipatory affect and motivation in social anhedonia individuals were also explored. To distinguish between anticipated emotion and anticipatory affect, we developed a novel task which could capture anticipated emotion and prospection features of positive and negative future events in social and non-social situations.

2. Materials and methods

2.1. Participants

Participants were selected from a large sample pool (n = 2247) from 130 cities in mainland China, based on their scores on the Chinese version of the Chapman Social Anhedonia Scale (CSAS; Chan et al., 2012b; Chapman et al., 1976). According to the criteria of previous social anhedonia study (Wang et al., 2016), participants with CSAS score higher than 1.5 standard deviations (SD, SD = 6.67) above the mean score (mean = 10, cut off score = 20) were recruited into the Social Anhedonia (SoA) group (n = 40), while participants with CSAS score lower than the mean score were recruited into the Healthy Control (HC) group (n = 46). Participants completed checklists to ensure that none of them had a history of brain injury, substance abuse, psychiatric disorders or other physical disorders. All participants completed a task specifically examining social affective forecasting and 26 participants from the SoA group and 30 participants from the HC group underwent resting-state functional magnetic resonance imaging scanning. IQ was estimated by the Chinese Version of the Wechsler Adult Intelligence Scale (WAIS-R; Gong, 1992), using the Information, Arithmetic, Similarity and Digit Span subscales. This study was approved by the Ethics Committee of the Institute of Psychology, the Chinese Academy of Sciences (certification number: H15031). All participants (age range: 18-31, mean score = 21.83, SD = 2.89) gave written informed consent.

2.2. Social affective forecasting task

The Social Affective Forecasting (SAF) Task is a self-developed behavioural task designed to assess the role of social components in AF. The SAF task utilizes a 2(social/non-social) * 2(positive/negative) design and consists of four conditions (positive social, positive non-social, negative social and negative non-social). Materials were rated on valence (1: very unhappy; 9: very happy) and sociality (1: no social interaction; 9: a lot of social interaction) by an independent sample of participants (See SI_Table 1 for demographic information). The mean valence of positive social, positive non-social, negative social, and negative nonsocial events was 7.58 (SD = 0.87), 7.32 (SD = 1.02), 2.19 (SD = 1.15) and 1.87 (SD = 0.82) respectively. The mean sociality of positive social, positive non-social, negative social, negative nonsocial events was 7.32 (SD = 1.14), 3.82 (SD = 2.09), 6.35 (SD = 1.80) and 3.06 (SD = 1.78) respectively. Repeated measures ANOVA analysis was performed and a significant difference was found between conditions in valence (Emotion main effect: $F_{emotion(1,30)} = 512.47$, $p < 0.001$, $\eta^2 = 0.945$) and sociality (Sociality main effect: $F_{sociality(1,30)} = 79.50$, $p < 0.001$, $\eta^2 = 0.726$). Each condition contains two daily events (e.g., "To have a cozy family reunion dinner"), giving a total of eight events in the whole task.

The procedure of the SAF task is presented in Fig. 2. In the formal session, participants first rated the current emotion ("How do you feel right now?") on valence (1: very unhappy; 9: very happy) and arousal (1: very peaceful; 9: very excited) before they began imagining. Afterwards, participants were asked to imagine future events according to the presented materials. They read the materials, imagined the event, and then described their simulation. Participants then rated their anticipated emotions and anticipatory affect on valence (1: very unhappy; 9: very happy) and arousal (1: very peaceful; 9: very excited). For positive events, participants also reported how much effort they would devote to make the described event happen on a nine-point scale (1: no effort; 9: all effort). Lastly, participants reported the phenomenological characteristics of their prospection on 7-point Likert scales: 1) sensory details including visualization, voice, smell, taste and touch (1: none; 7: many); 2) self-referential thoughts (1: none; 7: very detailed); 3) other-referential thoughts (1: none; 7: very detailed); and 4) communications (1: none; 7: very detailed). The order of presentation of the eight events was counterbalanced.

Before the formal experiment, a practice session was conducted to ensure that participants understood the requirement of each step and responded correctly. The practice session started with a concept clarification of anticipated emotions and anticipatory affect followed by a checking part to ensure they could correctly distinguish these two concepts. Details regarding materials selection, sample demographic information (SI_Table 1), concept clarification and the checking part can be found in supplementary information.

2.3. Measures

Participants completed the Chinese version of the Chapman Social Anhedonia Scale (CSAS; Chan et al., 2012b; Chapman et al., 1976). The CSAS is a 40-item questionnaire used to capture the

Table 1
Demographic information of SoA and HC.

	SoA		HC		T/χ2	*df*	*p*
	Mean	SD	Mean	SD			
Gender (Male/Female)	15/25		11/35		1.87	2	0.13
Age (Years)	20.70	4.52	21.87	2.61	-1.49	84	0.14
Length of Education (Years)	16.15	2.67	15.53	2.06	1.15	84	0.25
IQ	123.43	12.90	122.34	11.82	0.51	84	0.61
Mean FD	0.085	0.024	0.089	0.028	-0.42	50	0.68

Note: SoA: individuals with social anhedonia; HC: healthy controls; FD: framewise displacement. Group comparison in Mean FD was based on 23 SoA and 29 HC who included in final resting analysis.

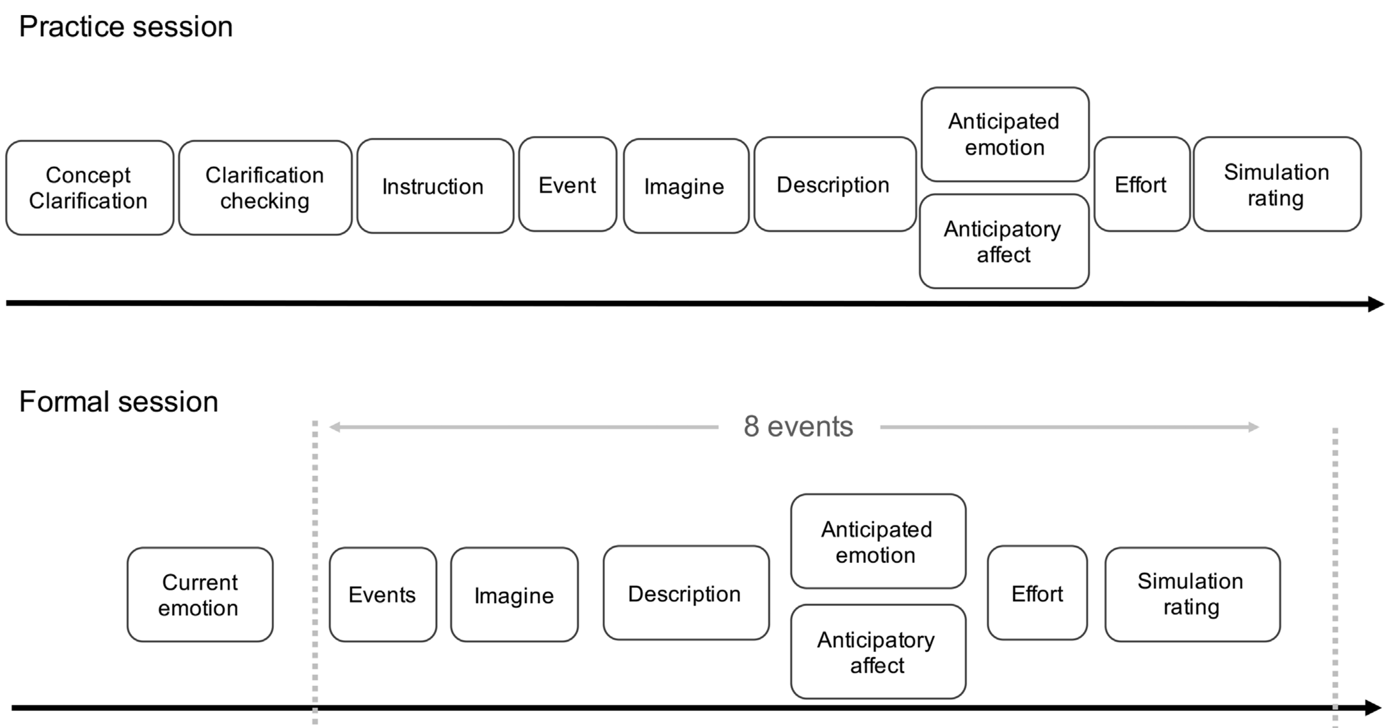

Fig. 2. The procedure of social affective forecasting task. Practice session starts with the clarification of anticipated emotion and anticipatory affect. After ensuring that participants can distinguish the two emotions correctly, instructions are presented. Participants are required to read materials, imagine the occurrence of the presented events and describe their simulations. Then participants rate their anticipated emotion and anticipatory affect on valence and arousal. In positive events, they are required to report their effort level. Finally, participants rate their prospection features. Formal session starts with a rating of state emotion on valence and arousal. After that, formal events are presented and participants imagine events accordingly and complete learned steps in practice session.

reduced ability to experience pleasure from social or interpersonal activities. Participants were required to respond to each item in a "true or false" format, according to their experience. The CSAS has a possible score range of 0 to 40, with higher scores indicating higher levels of social anhedonia. The CSAS has been shown to be valid across culture and the Chinese version of the CSAS possesses good psychometric properties (Chan et al., 2012b, 2016a; Hu et al., 2018).

Temporal Experience of Pleasure Scale (TEPS; Gard et al., 2006) is a 20-item questionnaire used to measure the ability to experience anticipatory pleasure and consummatory pleasure, with higher scores indicating better pleasure experiene. The Chinese version TEPS has a four-factor structure (anticipatory abstract, anticipatory contextual, consummatory contextual and consummatory abstract factors) and it has been shown good validity (Chan et al., 2012a)

Anticipatory and Consummatory Interpersonal Pleasure Scale (ACIPS; Gooding and Pflum, 2014) is 17-item questionnaire used to measure pleasure experience in social conditions and seven items were originally designed to capture anticipatory pleasure. The Chinese version of ACIPS has been widely applied in previous researches and satisfactory psychometric features were shown in previous studies (Chan et al., 2016c)

2.4. Image data acquisition and preprocessing

MRI data were obtained from a General Electric scanner at the Institute of Psychology, the Chinese Academic of Sciences. Functional resting-state imaging data were collected by the T2-weighted echo planar imaging sequence and 300 brain volumes were obtained for each participant. Parameters were as follows: repetition time (TR) = 2000 ms, echo time (TE) = 30 ms, slice number = 37, slice thickness = 3.5 mm, flip angel = 90°, matrix size = 64*64, field of view (FOV) = 220 mm, and voxel size = 3.4*3.4*4 mm. Structural MRI data were acquired by the T1-weighted MPRAGE (magnetization prepared rapid gradient echo) sequence, with parameters as follows: repetition time (TR) = 6.90 ms, echo time (TE) = 2.99 ms, slice number = 176, slice thickness = 1 mm, flip angel = 8°, matrix size = 256*256, field of view (FOV) = 256 mm, and voxel size = 1*1*1 mm. Participants were instructed to watch the "+" sign on the screen and try not to think of anything during scanning. A radiologist screened the images for incidental clinical abnormalities.

Preprocessing of resting-state data were conducted by the Data Processing Assistant for Resting-State FMRI (DPARSF) toolbox (Yan, 2010). The first 10 vol were removed and slice timing was conducted. Spatial head motion was corrected and the Friston-24-parameter model was used to calculate head motion parameters. Four participants (3 from SoA group; 1 from HC group) whose head motion was greater than 2 mm were excluded. Structural images were then co-registered manually and segmented into grey and white matter using the DARTEL toolbox (Ashburner, 2007). After that, functional images were co-registered to their own structural images and then normalized into the standard Montreal Neurological Institute space. Spatial smoothing was then performed with an 8-mm full-width at half maximum Gaussian kernel. Friston-24-parameter, white matter and cerebrospinal fluid were regressed out. Lastly, temporal band pass filtering was conducted ($0.01 < f < 0.1$).

2.5. Statistical analysis

2.5.1. Behavioural data

Group comparisons on gender, age, length of education, estimated IQ and head motion (mean Framewise Displacement; mean FD) were calculated by two-sample t tests and Chi-square tests. Normality testing was conducted and non-normally distributed data were normalized using blom transformation. Repeated measures ANOVA was used to calculate the group and interaction effect of anticipated emotions and prospection features. Correlation analysis was performed to examine the relationship between anticipated emotions, prospection features and effort levels. Paired-sample *t*-test was conducted to measure the difference between anticipated emotion and anticipatory affect. To explore the pattern of anticipatory affect and effort level, group effect and interaction effect were calculated with repeated measures ANOVA. In order to examine the convergent validity of SAF task, anticipated valence and anticipatory valence were correlated with anticipatory items of TEPS and ACIPS. All statistical analysis on behavioural data was performed using SPSS 20.

2.5.2. Imaging data

Seed-based functional connectivity (FC) analysis was conducted by DPARSF and SPM 8. Five regions from the MTL-subsystem were defined as regions of interest (ROI) with a 5 mm radius (See SI_Table 2; Andrews-Hanna et al., 2010). Seed-based FC of each ROI was calculated by correlation analysis between time series of each ROI and other remaining voxels. R maps of each ROI obtained from the formal step were transformed into Fisher z maps. Two-sample *t*-test was performed by SPM 8 to calculate the altered FC in the SoA group. In order to reduce motion-induced artefacts, mean FD was included in the statistical analysis as a covariate (Yan et al., 2013). False discovery rate (FDR) was used to correct for multiple comparisons and the significance threshold was set at $p < 0.005$ at the voxel level and $p < 0.05$ at the cluster level. FC values of regions showing significant group differences were extracted by MARSBAR (http://marsbar.sourceforge.net/) and further correlated with positive anticipated valence in both social and non-social conditions. To test whether the interaction of social and non-social conditions was correlated with FC, the interaction score was calculated by multiplying the score of social anticipated valence and the score of non-social anticipated valence and the interaction score were further correlated with the FC values.

3. Results

3.1. Demographic information and behavioural results

The SoA group and the HC group were matched in gender, age, length of education and estimated IQ (see Table 1).

For anticipated emotion, SoA individuals anticipated lower valence ($F_{(1,84)} = 25.18$, $p < 0.001$, $\eta^2 = 0.231$) and lower arousal ($F_{(1,84)} = 14.21$, $p < 0.01$, $\eta^2 = 0.125$) for positive events, which can be regarded as reduced anticipated pleasure. Moreover, SoA individuals anticipated less arousal ($F_{(1,84)} = 4.52$, $p = 0.037$, $\eta^2 = 0.051$) for negative events. A significant interaction effect was found only for anticipated valence ($F_{(1,84)} = 4.74$, $p = 0.032$, $\eta^2 = 0.053$) for positive events (see Table 2). Simple effect analysis showed that reduced anticipated positive valence in the SoA group was predominately found in social conditions, although reductions were found in both social ($p < 0.001$, $\eta^2 = 0.278$) and non-social conditions ($p = 0.038$, $\eta^2 = 0.051$).

For prospection features, significant group effects were found with the SoA group reporting significantly less visualization ($F_{(1,84)} = 5.04$, $p = 0.027$, $\eta^2 = 0.057$), less voice ($F_{(1, 84)} = 4.63$, $p = 0.034$, $\eta^2 = 0.052$), less taste ($F_{(1, 84)} = 6.74$, $p = 0.011$, $\eta^2 = 0.074$), fewer self-referential thoughts ($F_{(1,84)} = 5.96$, $p = 0.017$, $\eta^2 = 0.066$), fewer others-referential thoughts ($F_{(1,84)} = 10.30$, $p = 0.002$, $\eta^2 = 0.109$) and less language communication ($F_{(1,84)} = 8.61$, $p = 0.004$, $\eta^2 = 0.093$) (see Table 2). No significant interaction effect was found for any prospection features.

For the correlation between anticipated emotion and prospection features, anticipated valence in social conditions was positively correlated with visualization ($r = 0.238$, $p < 0.05$), self-referential thoughts ($r = 0.218$, $p < 0.05$), other-referential thoughts ($r = 0.263$, $p < 0.05$) and body communications ($r = 0.256$, $p < 0.05$). Anticipated valence in non-social conditions was positively correlated with visualization ($r = 0.232$, $p < 0.05$) and self-referential thoughts ($r = 0.254$, $p < 0.05$). Moreover, anticipated arousal was positively correlated with visualization ($r = 0.239$, $p < 0.05$) and others-referential thoughts ($r = 0.268$, $p < 0.05$) in social conditions. Anticipated arousal was also positively correlated with visualization ($r = 0.273$, $p < 0.05$) in non-social conditions. However, no correlation between anticipated emotion and prospection features survived Bonferroni correction. Anticipated emotions were positively correlated with effort level in both social (valence: $r = 0.602$, $p < 0.001$; arousal: $r = 0.597$, $p < 0.001$) and non-social (valence: $r = 0.282$, $p < 0.01$; arousal: $r = 0.378$, $p < 0.001$) conditions. Correlations between anticipated emotion and effort level remained significant after Bonferroni correction, except the correlation between anticipated valence and effort level in non-social conditions. Correlations between anticipated emotions, prospection features and effort levels can be found in Supplementary information (SI_Tables 3.1–3.3). Moreover, reduced anticipatory affect and effort levels were also observed in SoA individuals and detailed results can be found in supplementary information (SI_Table 4). Significant differences were found between anticipated emotion and anticipatory affect in valence and arousal in all conditions (SI_Table 5). Anticipated valence and

Table 2
Anticipated emotion and prospection features of SoA and HC.

		SoA(n = 40)				HC(n = 46)				F_{group}	F_{social}	F_{inter}
		Social		Non-social		Social		Non-social				
		Mean	SD	Mean	SD	Mean	SD	Mean	SD			
Anticipated emotion	Positive Valence	6.64	1.24	7.31	0.83	7.91	.92	7.74	.98	25.18***	0.04	4.74*
	Positive Arousal	6.29	1.17	6.60	0.97	7.26	1.20	7.04	1.21	14.21***	0.02	3.21
	Negative Valence	2.81	1.26	2.65	1.32	2.43	1.24	2.30	1.30	3.93	0.07	0.76
	Negative Arousal	5.93	1.66	6.08	1.91	6.52	1.71	6.93	1.68	4.52*	0.01	0.62
Prospection	Visualization	5.20	1.41	4.83	1.53	5.93	0.85	5.39	1.12	5.04*	0.02	0.86
	Voice	4.01	1.44	3.34	1.49	4.97	1.58	3.67	1.75	4.63*	33.55***	3.31
	Smell	2.84	1.31	1.69	0.99	3.46	1.80	1.85	0.96	2.81	0.24***	2.11
	Taste	2.96	1.37	1.52	0.87	3.63	1.55	1.78	0.99	6.74*	0.33***	0.82
	Touch	3.47	1.55	3.59	1.79	4.05	1.60	3.75	1.61	1.45	0.30	1.42
	Self-referential thoughts	4.16	1.43	3.91	1.75	4.89	1.53	4.72	1.71	5.96*	2.04	0.66
	Others-referential thoughts	3.83	1.43	2.45	1.38	4.46	1.39	3.50	1.63	10.30**	43.67***	1.41
	Language Communication	3.90	1.79	2.58	1.53	4.51	1.40	3.63	1.45	8.61**	41.26***	1.68
	Body Communication	3.24	1.47	2.10	1.39	3.78	1.59	2.71	1.50	3.14	0.10	0.001

Note: *: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$; SoA: Individuals with social anhedonia group; HC: healthy controls.

anticipatory valence were significantly correlated with scores on anticipatory subscales of TEPS and anticipatory items in ACIPS, supporting that the SAF task is a valid measure of affective forecasting (SI_Table 6).

3.2. Group effects in functional connectivity and its correlation with anticipated emotion

Compared with HC, the SoA group exhibited significantly stronger functional connectivity (FC) between the retrosplenial cortex (RsC) and the bilateral insula, and stronger FC between the RsC and the medial frontal gyrus (MFG). In addition, the SoA group showed significantly increased FC between the parahippocampal cortex (PHC) and the MFG, and reduced FC between the hippocampal formation (HF^+) and the PHC. Group effects in FC are shown in Supplementary information (SI_Table 7).

As shown in Fig. 3, the FC with significant group effects were only significantly correlated with anticipated valence in social conditions, but not in non-social conditions. After Bonferroni correction, anticipated valence in social conditions was significantly correlated with the FC between the RsC and the right insula ($r = -0.404$, $p = 0.003$) and the FC between the HF^+ and the right PHC ($r = 0.380$, $p = 0.006$). No significant correlation was found between the anticipated valence of interaction condition and FC with group effects.

4. Discussion

The present study investigated the role of social component in AF in individuals with SoA. We found that SoA individuals, compared with HC, anticipated less pleasure in positive future events, especially in social conditions. However, they anticipated similar levels of valence as HC for negative events. Further analysis found that during prospection, SoA individuals reported less visualization and fewer features about social interactions such as self-referential thoughts and others-referential thoughts and those features were correlated with anticipated valence in social conditions. Anticipated emotions were correlated with effort level, especially in social conditions. More importantly, we found that FCs with significant group effect were correlated with social, but not non-social, anticipated valence, suggesting that the social component may play as a key role in altered AF in SoA individuals.

For positive future events, compared with HC, SoA individuals anticipated less pleasure and the reduction in anticipated pleasure was mainly in social conditions, which is consistent with our hypothesis. This result is also consistent with previous studies which reported that SoA individuals anticipate less pleasure in response to socially-related cues but not in response to monetary cues (Xie et al., 2014). As suggested by Gilbert and Wilson (2007), prospection may contribute to this alteration. Our results found that more visualization, self-referential thoughts and others-referential thoughts were associated with higher anticipated pleasure, but SoA individuals reported less visualization, self-referential thoughts and others-referential thoughts in their prospection than HC, which may be the cause of their diminished anticipated pleasure. There are several potential explanations for the reduced prospection in SoA individuals. First, considering the hypothesis that impaired episodic memory in schizophrenia patients may reduce their prospection ability (Frost and Strauss, 2016), the diminished prospection features in SoA individuals may be potentially associated with poor episodic memory (Sahakyan and Kwapil, 2016). Second, past experience and beliefs may also contribute to reduced anticipated pleasure in social conditions. It has been reported that SoA individuals are happier when alone than interacting with others (Kwapil et al., 2009). This preference for being alone may lead to less memory about social interactions for SoA individuals to

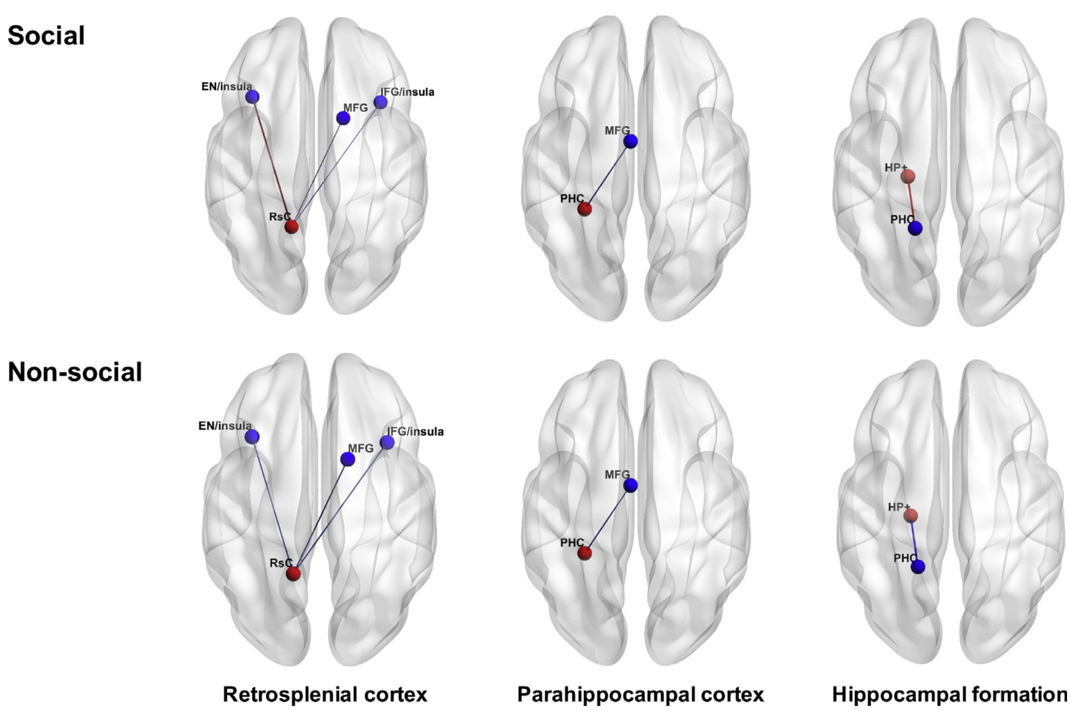

Fig. 3. Correlations of altered seed-based functional connectivity (FC) and anticipated valence of positive events. The first row represents correlations between altered FC and social anticipated valence and the second row represents correlations between altered FC and non-social anticipated valence. Red nodes are regions of interests (ROIs) and blue nodes are regions which functionally connected with ROIs which showed significant group effect. Lines between nodes represent the FC between two brain regions. FCs which significantly correlated with anticipated emotions are in red while FCs with no correlation with anticipated emotions are in blue. Significant correlation between FCs and anticipated emotions are only showed in the social condition. RsC: Retrosplenial cortex; PHC: Parahippocampal cortex; EN: Extra-Nuclear; MFG: Medial frontal gyrus; IFG: Inferior frontal gyrus; HF^+: Hippocampal formation. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

retrieve, resulting in their less detailed simulation. Third, Frost and Strauss (2016) proposed that "low pleasure beliefs" may be the reason that schizophrenia patients have problems in AF given that "low pleasure beliefs" affect non-current emotions. Interestingly, "low pleasure beliefs" have also been found in SoA individuals (Yang et al., 2018a). Therefore, the preference for being alone may generate "low pleasure beliefs" such as "social activities are not enjoyable", which may lead to reduced pleasure expectation from social activities.

As expected, higher levels of anticipated valence and anticipated arousal were correlated with higher effort levels, which is in line with previous findings that anticipated emotion may affect motivation (Morewedge and Buechel, 2013). This finding also supports the theoretical framework that reward prediction (anticipated emotions) would influence the computation of effort which further may impact the approach motivation and approach behaviour (Kring and Barch, 2013). Moreover, the correlation between effort level and anticipated emotion were stronger in social than in non-social conditions, suggesting that anticipated emotion in social conditions may be easier to translate into motivation than those in non-social conditions. Therefore, it is suggested that social components may be an influential factor in reward processing and future studies may consider targeting at enhancing social anticipated emotion to improve motivation in SoA individuals.

Our FC results also support the key role of the social component in altered AF in SoA individuals. FCs which were significantly different between SoA individuals and HC were significantly correlated with social anticipated valence but not with non-social anticipated valence. Compared with HC, SoA individuals showed stronger FC between the RsC and the insula which was correlated with reduced social anticipated valence. The role of the RsC in prospection has been reported in previous studies. For example, the RsC is part of the MTL-subsystem of the DMN, which is related to future-oriented thinking (Andrews-Hanna et al., 2010). Moreover, based on an ALE meta-analysis of previous studies, the RsC appears to be part of a "core network" that is specific to episodic simulation (Schacter et al., 2017). The insula is associated with emotional awareness and has been reported to be activated during emotional experience (Craig, 2009). Moreover, the insula has also been found to be related to risk predictions (Preuschoff et al., 2008). The stronger FC between the RsC and the insula may indicate more emotional awareness and risk prediction during mental simulation. Therefore, when simulating future scenarios, SoA individuals may be more likely to be aware of negative emotions and to forecast risks about these coming events, which may result in reduced anticipated pleasure. Another altered FC we found which was associated with social anticipated valence is the FC between the HF^+ and the PHC. As a part of the MTL sub-system, the HF^+ is involved in imagining future events (Andrews-Hanna et al., 2010). Similar to the HF^+, the PHC is activated when imagining the future and it is specific to the constructive process of simulation (Gaesser et al., 2013). Moreover, in a memory-prospection model proposed by Zheng et al. (2014), the PHC is situated in the overlap between memory and prospection which suggests the role of memory retrieval in the construction of future scenarios, especially in processing visual-spatial information. The reduced FC between the HF^+ and the PHC suggests an impaired constructive process during prospection and that SoA individuals may have problems in recalling past information to visually construct future events, which may lead to less pre-feelings and reduced anticipated pleasure.

This study has several limitations. The first limitation is that the scenario for the practice session was a positive event and it might have influenced the emotional state of the participants, even though most participants chose "peace" to describe their current emotional state before the experimental session. Moreover, it is possible that individuals can experience both positive and negative emotions in an event, but we captured anticipated emotion using a bipolar scale instead of separate unipolar scales for positive and negative emotions. This may limit the exploration of the Positive Offset Theory of anhedonia (Strauss et al., 2017). Further, we did not include infrequency items of the CSAS to exclude invalid answers.

Notwithstanding the abovementioned limitations, this is the first study that systematically explored AF pattern in SoA individuals using both behavioural and imaging approaches. This study directly tested the role of social components in altered AF in SoA individuals by developing a new behavioural paradigm, which is ecologically valid and could distinguish between anticipated emotion and anticipatory affect. The present study has both theoretical and practical implications with respect to the broader literature. Theoretically, it illustrated the AF deficits in SoA individuals are predominately in social conditions, and it further demonstrated that impaired prospection could be the key mechanism of AF deficits. Moreover, it supported that reward prediction may impact effort computation and suggested reward processing may be influenced by social components. In addition, it identified RsC, insula, HF^+ and PHC as important neural correlates of AF in social condition, which provides valuable information for future studies. Practically, the present study suggested that improving AF ability may benefit clinical outcomes (e.g., reducing anhedonia or amotivation symptoms), and social components may be targets for AF unmedical treatment. Future studies adopting task-based imaging paradigm to specifically explore the neural correlates of AF are indicated.

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Contributors

RTZ contributed data collection, data analysis and the manuscript writing; ZYY and YMW contributed data collection; YW contributed the critical comments for methods part; TXY, EFC and EM contributed to critical comments for the manuscript revision. RCKC generated the idea and design of the study, interpreted the findings, and commented critically on the various drafts of the manuscript.

Role of funding source

These 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.

Declaration of competing interest

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.schres.2019.10.006.

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