European Archives of Psychiatry and Clinical Neuroscience
https://doi.org/10.1007/s00406-024-01761-8

ORIGINAL PAPER

Dampened motivation in schizophrenia: evidence from a novel effort-based decision-making task in social scenarios

Yu-Xin Shao[1,2,3] · Ling-Ling Wang[4] · Han-Yu Zhou[5] · Zheng-Hui Yi[6] · Shuai Liu[1,2] · Chao Yan[1,2]

Received: 23 September 2022 / Accepted: 13 January 2024

Abstract

Apathy represents a significant manifestation of negative symptoms within individuals diagnosed with schizophrenia (SCZ) and exerts a profound impact on their social relationships. However, the specific implications of this motivational deficit in social scenarios have yet to be fully elucidated. The present study aimed to examine effort-based decision-making in social scenarios and its relation to apathy symptoms in SCZ patients. We initially recruited a group of 50 healthy participants (16 males) to assess the validity of the paradigm. Subsequently, we recruited 45 individuals diagnosed with SCZ (24 males) and 49 demographically-matched healthy controls (HC, 25 males) for the main study. The Mock Job Interview Task was developed to measure effort-based decision-making in social scenarios. The proportion of hard-task choice and a range of subjective ratings were obtained to examine potential between-group differences. SCZ patients were less likely than HC to choose the hard task with strict interviewers, and this group difference was significant when the hard-task reward value was medium and high. More severe apathy symptoms were significantly correlated with an overall reduced likelihood of making a hard-task choice. When dividing the jobs into two categories based on the levels of social engagement needed, SCZ patients were less willing to expend effort to pursue a potential offer for jobs requiring higher social engagement. Our findings indicated impaired effort-based decision-making in SCZ can be generalized from the monetary/nonsocial to a more ecologically social dimension. Our findings affirm the critical role of aberrant effort allocation on negative symptoms, and may facilitate the development of targeted clinical interventions.

Keywords Schizophrenia · Effort-based decision-making · Apathy · Social function

Introduction

Apathy, manifested in daily life as reductions in motivation to participate in social activities and establish social relationships has profound effects on schizophrenia (SCZ) patients' social functioning [1, 2]. Reduced motivation and goal-directed behavior are prominent characteristics of negative symptoms in SCZ [3]. Among the core subdomains of negative symptoms, apathy exhibits a higher prevalence and greater persistence in the early stages of the disease, in comparison to reduced expression [4, 5]. Moreover, recent research has highlighted the significance of apathy as a predictor of functional outcome in chronic SCZ, surpassing the contribution of cognitive deficits, diminished expression, and other symptom dimensions [6]. However, treatments are not sufficiently effective to alleviate this symptom, partly due to the poor understanding of the neuropsychological mechanisms underlying impaired motivation [7]. To facilitate the development of targeted treatments, there is growing

✉ Chao Yan
cyan@psy.ecnu.edu.cn

1 Key Laboratory of Brain Functional Genomics (MOE and STCSM), Affiliated Mental Health Center (ECNU), School of Psychology and Cognitive Science, East China Normal University, Room 413, Building Junxiu, 3663 North Zhongshan Road, Shanghai 200062, China

2 Shanghai Changning Mental Health Center, Shanghai, China

3 Leshan Hi-Tech Zone Jiaxiang Foreign Languages School, Sichuan, China

4 School of Psychology, Shanghai Normal University, Shanghai, China

5 Shanghai Key Laboratory of Mental Health and Psychological Crisis Intervention, School of Psychology and Cognitive Science, East China Normal University, Shanghai, China

6 Shanghai Mental Health Center, Shanghai Jiao Tong University School of Medicine, Shanghai, China

Published online: 28 February 2024

interest in clarifying the mechanisms of motivational impairment in psychiatric disorders.

Motivation is a multidimensional construct, comprising hedonic experience, reward prediction, reward valuation, and effort valuation [2]. The ability to accurately weigh energy requirements against potential benefits (i.e., effort-based decision-making) is critical for optimal goal-directed behaviors, and alterations in this function are believed to be a core component of motivational disorders, such as apathy in SCZ [8]. Effort-based decision-making involves a psychological computational process where individuals estimate the amount of effort needed to obtain rewards [9–11]. On one hand, we compute the value of a reward ("value computation"). On the other hand, we compute how much effort it takes to get this reward ("effort computation"). These two components combined are called "cost – benefit analysis", the result of which determines whether we choose to take actions. In both human and animal models of schizophrenia, it has been determined that the mechanisms by which rewards are processed to motivate behavior are impaired [12, 13]. And these mechanisms can be conceptualized within the framework of effort-based decision-making for rewards, that is, how the potential benefit or reward for performing an activity is evaluated with respect to the cost in effort required to attain it [14].

Effort-based decision-making has emerged as a promising paradigm in the recent years, bridging the gap between preclinical models of cost – benefit analysis and the motivational deficits in SCZ. This translational approach leverages extensive preclinical research focused on quantifying motivation through assessing individuals' willingness to invest varying levels of effort for different rewards [15]. Paradigms examining motivational processes in patients can systematically manipulate the benefits and costs of actions to quantitatively evaluate potential deficits in effort-based decision-making. For example, Effort-Expenditure for Rewards Task (EEfRT) and its variant versions (such as the Effort-Cost Computation Task, the Effort Discounting Task, the Progressive Ratio task etc.) were developed to measure effort-based decision-making by determining how much physical (e.g., motoric or strength-based) or cognitive effort (e.g., mathematic calculation) a person is willing to exert for a given level of reward [8, 16–24].

Studies based on the physical effort – cost valuation found that chronic SCZ patients and first-episode psychosis patients were less willing to expend effort for monetary reward when compared with healthy controls (HC), especially in trials with the most certain and highest reward [8, 16–22]. Similarly, studies based on the cognitive effort found greater effort aversion in clinical SCZ groups [23, 24]. Many of these studies also found significant negative correlations between indicators of effort-based decision-making tasks and the severity of negative symptoms [8, 16–18, 21, 23, 24]. The results of these studies preliminary indicated an internal link between abnormal effort-based decision-making functions and motivational disorders in SCZ. Furthermore, neuroimaging studies involving physical effort found that the neural response in the nucleus accumbens (NAcc), the posterior cingulate cortex and the left medial frontal gyrus in SCZ patients were significantly weaker than HC [25], and reduced BOLD activation in the bilateral VS was associated with higher levels of negative symptoms [24].

Previous research has focused on monetary rewards and the results were largely consistent, reflecting the unwillingness of SCZ patients to exert efforts in pursuit of rewards and suggesting a strong correlation between this deficit and the severity of negative symptoms. However, monetary rewards lack social information, thus the above findings add little to our understandings of social dysfunction in SCZ, especially apathy in social contexts. Social dysfunction in SCZ is pervasive, and the apathy symptom may lead to impaired social functioning including limited quantity (e.g., few number and contacts of friends) and quality (e.g., diminished social skills) of interpersonal exchanges and relationships [26]. Therefore, expanding effort-based decision-making paradigms to social scenarios could further illuminate the causes of apathy in SCZ. Some studies have suggested that the processing mechanism for rewards with social information may be different from that for rewards without social information. For example, distinct neural correlates have been found for social and object preferences [27]. Moreover, despite showing a similar preference for monetary rewards, SCZ patients exhibited significantly lower preferences for social rewards, specifically genuine smiles, when compared with HC [28]. Therefore, the findings from monetary rewards studies are not necessarily replicable to explain the social dimension of apathy symptoms in SCZ.

The current study aimed to investigate effort allocation to obtain social approval in SCZ patients and its relationship with apathy symptoms. Social approval is a kind of reward with social information, which refers to the acceptance or recognition by the general public (e.g., the recognition by a company or interviewers during job interviews) [29]. Effort-based decision-making in such social situations is referred to as social effort-based decision-making. Based on the previous literature, we hypothesized that (1) SCZ patients would show lower willingness to expend effort for large rewards (i.e., social approval), and this impairment would be more severe in trials requiring higher social engagement; (2) SCZ patients with more severe apathy symptoms and social anhedonia would show a reduced likelihood of making a hard-task choice, which was further associated with lower levels of social function.

Methods

Participants

Forty-five SCZ patients aged from 15 to 40 years old were recruited from the outpatient clinic of the Shanghai Mental Health Centre in Shanghai of China. All patients met the diagnostic criteria for SCZ according to DSM-5 [30]. Patients who met the following criteria were excluded from the study: (1) history of any neurological disorders (2) history of past and present substance misuse (e.g., cannabis, cocaine etc.); (3) have other mental illnesses, such as depression, obsessive – compulsive disorder, etc.; (4) IQ < 80. All the recruited patients were prescribed second generation antipsychotic medications at the time of study enrolment (risperidone: 28%; olanzapine: 60%; amisulpride: 40%; aripiprazole: 40%; quetiapine: 11%; paliperidone: 15%) except for one who was taking a first-generation antipsychotic (haloperidol) without any change in the preceding four weeks.

Ninety-nine healthy subjects were recruited for the study, with 50 individuals selected to test the validity of the task and the remaining 49 serving as HC for the SCZ patients. Recruitment was conducted from both the university campus and the local community in Shanghai. The recruitment process involved advertising through social media platforms. These HC participants were carefully matched with the SCZ patients in terms of age, sex, and IQ. Importantly, they had no personal or family history of any psychiatric disorders, as confirmed by self-report assessments.

Mock job interview task

We developed the Mock Job Interview Task (MJIT) to examine participants' willingness to expend effort (i.e., in a highly intense and challenging interview context) to obtain rewards (i.e., job offer). The MJIT was developed with reference to the Effort-Expenditure for Rewards Task (EEfRT) [31]and Trier Social Stress Test (TSST) [32]. We measured participants' willingness to expend effort in pursuit of social approval to examine effort-based decision-making functions in social scenarios.

Briefly, participants were presented with a series of trials where they needed to make a decision between two options of either a less challenging job interview mission for small magnitude of reward (i.e., smaller probability of interview acceptance) or a more challenging interview mission for large values of reward (i.e., greater probability of interview acceptance). The easy task (i.e., less challenging interview) contains an interview with a friendly (i.e., smiling face) interviewer and participants had two minutes to prepare for questions posed by the reviewer, but no bonus point was offered. During the hard task (i.e., more challenging interview tasks), participants were interviewed by three strict interviewers characterized by stern expressions. Participants were allotted only one minute to prepare for the questions. However, they were informed that they had the opportunity to receive one of three levels of bonus points (low: 5/medium: 15/high: 25). These bonus points held the potential to enhance the likelihood of securing a job offer. Each participant was given a duration of 60 s to introduce themselves and respond to the interview questions. During the phase of feedback, they were provided with the interview score with extra points, corresponding rankings and the interview results (i.e., whether they received the job offer or not). The probability of receiving positive feedback was 10% for the easy task and 50% to 90% for the hard task (increasing with bonus points). Participants were subsequently required to provide ratings of their perceived stress level and subjective level of effort expenditure on a seven-point Likert scale, and pleasure valence and arousal experience on a nine-point Likert scale (See Fig. 1).

The 12 jobs were divided into two categories according to whether they required individuals to work with people or computers/other objects: six jobs requiring high levels of social engagement (e.g., journalist) and six jobs requiring low levels of social interactions (e.g., librarian), so that we could examine the influence of the social attributes of the job on the participants' willingness to expend effort. Jobs requiring high levels of social engagement are those whose job content requires more communication with other people, including human resource management, kindergarten teachers, property management staff, tour guides, insurance sales, and journalists. Jobs requiring low levels of social interactions are those that do not require interaction with other people, and to some extent require fewer social skills, including accountants, game engineers, literary magazine editors, architects, librarians, and interior designers. The proportion of hard tasks options selected were recorded, reflecting the willingness of effort allocation. A larger proportion represents stronger willingness to expend effort.

Clinical and cognitive assessments and questionnaires

Positive and negative symptoms of SCZ patients were evaluated by psychiatrists using the Positive and Negative Syndrome Scale (PANSS) [33] and the Scale for the Assessment of Negative Symptom (SANS) [34]. In addition, all participants underwent Intelligence Quotient (IQ) testing using the short form of the Chinese version of the Wechsler Adult Intelligence Scale-Revised (WAIS-R). The Anticipatory

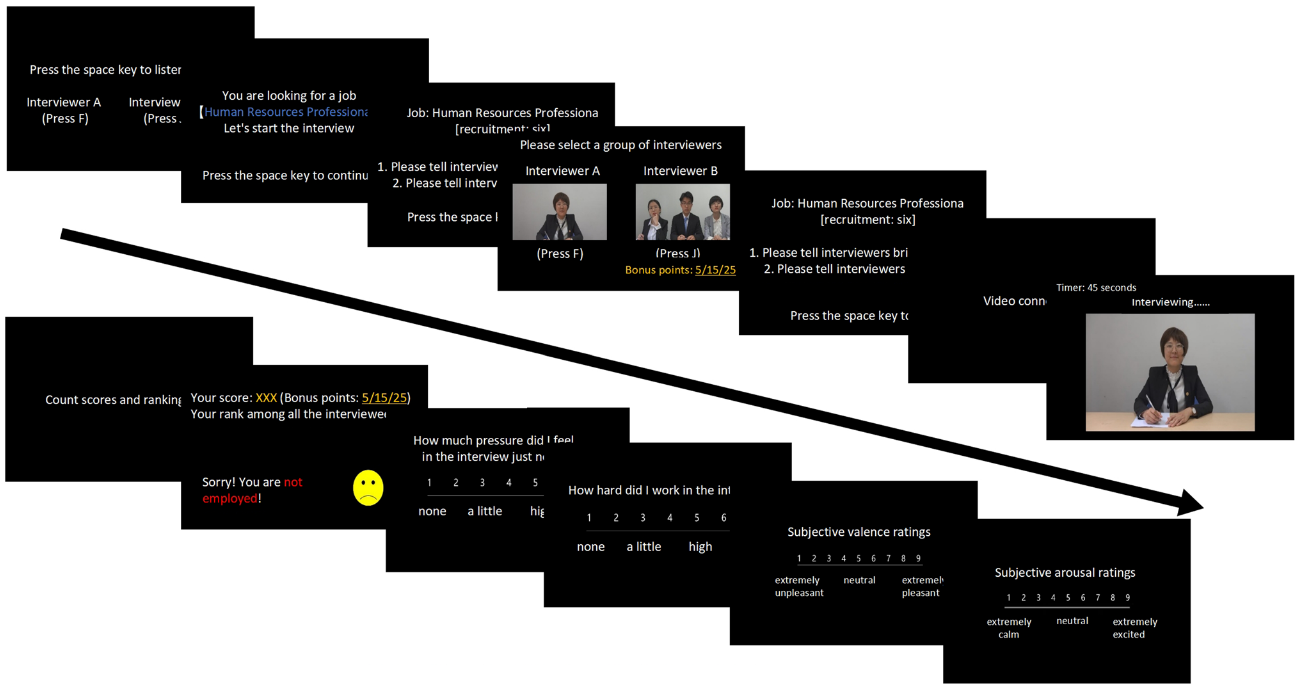


Fig. 1 The Mock Job Interview Task scheme. Participants first saw the job description and interview questions, and they choose whether to execute easy task or difficult task after seeing the amount of reward they would obtain. Next, participants had 60 s to make a self-introduction and responded to the questions for each job. Participants then saw the outcome of the interaction and rated their perceived stress level and subjective effort level for the interaction, rated their pleasure valence and arousal experience for the interaction outcome

and Consummatory Interpersonal Pleasure Scale (ACIPS) [35] was used to measure trait dispositions in anticipatory and consummatory pleasure experience regarding social domains, and higher scores on the ACIPS indicate lower levels of social anhedonia. The Revised Chapman Social Anhedonia Scale (RCSAS) was used to measure participants' pleasure experience from interpersonal interactions (e.g., “Getting together with old friends has been one of my greatest pleasures”), with higher scores on the RCSAS indicating less pleasure from social interactions [36]. The Social Functional Scale (SFS) was used to measure participants’ social function (e.g., "I think it easy to interact with authority"), and higher scores on the SFS represent better social functioning [37].

Statistical analysis

Independent-group t test was applied to examine group differences in age, years of education, estimated IQ and questionnaire scores between the SCZ and HC groups. Group difference in sex ratio was compared by conducting chi-square analysis.

Regarding the MJIT, we initially assessed the validity of this newly developed paradigm. To accomplish this, we conducted a series of repeated-measure analyses of variance (ANOVA) on an additional 50 healthy control participants. These analyses aimed to investigate the impact of reward magnitude on the mean proportions of hard-task choices. Furthermore, we explored the influence of task difficulty on subjective ratings of perceived stress level and effort level. Additionally, we examined the effects of interview ranking levels and outcomes on participants' subjective ratings of emotional experience.

Subsequently, a mixed analysis of variance (ANOVA) was conducted to explore group differences in the proportion of hard-task choices across different reward magnitudes. This analysis involved a 2 (Group: SCZ and HC) × 3 (Reward magnitude of hard tasks: low, medium, and high) design. In addition, we examined the impact of the social engagement level of jobs on the proportion of hard-task choices using a 2 (Group: SCZ and HC) × 3 (Reward magnitude of hard tasks: low, medium, and high) × 2 (Social engagement level of jobs: low and high) mixed ANOVA.

To investigate group differences in perceived stress level and subjective effort level across tasks, we performed 2 (Group: SCZ and HC) × 2 (Task: easy and hard) mixed ANOVA analyses. Furthermore, we explored the effects of the interview results on valence rating and arousal rating using a 2 (Group: SCZ and HC) × 2 (Result: failure and success) mixed ANOVA.

To examine the effect of negative symptom severity, patients were separated into two subgroups based on their

PANSS scores. Specifically, SCZ patients whose PANSS negative subscale score was at least 6 points higher than the PANSS positive subscale score were classified as SCZ patients with high-negative symptom (HNS), while the remaining participants were classified as low-negative symptom (LNS) group [38]. The negative symptoms in HNS patients (18.42 ± 3.50) were more severe than those in LNS patients (11.19 ± 2.01) (t_{42} = 8.59, p = 0.014), and there was no difference in the score of positive symptoms between these two groups (t_{42} = 0.29, p = 0.75). A mixed analysis of variance (ANOVA) was performed, incorporating a 3 (Subgroup: HC, LNS patients, and HNS patients) × 3 (Reward magnitude of hard tasks: low, medium, and high) design. To address the issue of multiple comparisons, Bonferroni correction was applied during the ANOVA analysis. Additionally, Cohen's d was calculated to provide an estimation of effect size, aiding in the interpretation of the observed differences.

Finally, we employed four Generalized Estimating Equation (GEE) models to examine the factors influencing effort-based decision-making within the SCZ group. GEE is a generalized regression model that is well-suited for investigating continuous or logistic outcome variables characterized by correlated residuals. In our study, the dependent measure was the dichotomous outcome of choosing either the hard or easy task, while independent variables encompassed reward magnitude, sex, age, clinical symptoms, and self-report scale scores. Notably, GEE models permit trial-by-trial modeling of time-varying parameters, such as changes in reward magnitude for each trial, in addition to incorporating fixed effects, such as scores on apathy symptoms and social anhedonia. Statistical significance was determined at α < 0.05 (two-tailed), and all statistical analyses were conducted using the Statistical Package for Social Science (SPSS, v23.0).

Table 1 Demographic and clinical characteristics of study sample

	SCZ group (n = 45)	HC group (n = 49)	t/χ^2	p
Sex (Male/Female)	24/21	25/24	0.05	.83
Age, mean(SD), years	22.31(4.47)	21.94(4.31)	0.41	.68
Education, year	13.27(2.68)	14.27(2.41)	− 1.90	.06
IQ Estimates	100.81(11.24)	104.96(9.54)	− 1.94	.06
TEPS_ant_abstract	18.07(4.07)	18.29(3.76)	− 0.27	.79
TEPS_ant_concrete	20.00(3.57)	18.58(4.68)	1.63	.11
TEPS_con_abstract	26.76(4.98)	27.06(5.05)	− 0.30	.77
TEPS_con_concrete	16.73(3.35)	17.45(3.73)	− 0.98	.33
TEPS_total	84.96(13.47)	85.16(14.51)	− 0.07	.94
ACIPS	71.40(16.02)	73.41(14.86)	− 0.63	.53
RCSAS	16.18(7.08)	13.45(7.94)	1.75	.08
SFS	89.36(17.67)	94.10(19.46)	− 1.23	.22
DOI, month	36.93(39.04)			
DOT, month	21.79(23.36)			
CPZ Equivalents	214.51(235.32)			
SANS_total[1]	21.19(10.50)			
SANS_apathy[1]	8.65(5.03)			
SANS_affective flattening[1]	5.63(4.05)			
PANSS_total[2]	53.93(11.23)			
PANSS_positive[2]	11.11(3.88)			
PANSS_negative[2]	13.16(4.09)			
PANSS_general[2]	29.66(7.56)			

SCZ Schizophrenia, *HC* Healthy control, *TEPS* Temporal Experience Pleasure Scale, *ant* anticipatory pleasure, *con* consummatory pleasure, *ACIPS* Anticipatory and Consummatory Interpersonal Pleasure Scale, *RCSAS* Revised Chapman Social Anhedonia Scale, *SFS* Social Functional Scale, *DOI* Duration of illness, *DOT* Duration of treatment, *CPZ* Chlorpromazine dosage, *SANS* Scale for the Assessment of Negative Symptom, Apathy consisted of items of Avolition-apathy and Anhedonia-asociality subscales on the SANS, *PANSS* Positive and Negative Syndrome Scale; 1: sample size of SCZ patients was 43; 2: sample size of SCZ patients was 44

Results

Sample characteristics

Demographic and clinical characteristics are presented in Table 1. The analysis revealed no significant differences between SCZ and HC in terms of sex ratio ($\chi^2 = 0.05$, $p = 0.83$), age ($t_{92} = 0.41$, $p = 0.68$), years of education ($t_{92} = -1.90$, $p = 0.06$) or estimated IQ ($t_{92} = -1.94$, $p = 0.06$). In addition, there were no significant differences between SCZ and HC on the total scores of TEPS ($t_{92} = -0.07$, $p = 0.94$), the ACIPS ($t_{92} = -0.63$, $p = 0.53$), and the SFS ($t_{92} = -1.23$, $p = 0.22$). However, patients with SCZ exhibited a tendency to report higher scores in the RCSAS when compared with HC ($t_{92} = 1.75$, $p = 0.08$).

Validity of the mock job interview task

A significant main effect on reward magnitude was observed ($F_{2,48} = 35.859$, $p < 0.001$, partial$\eta^2 = 0.60$, see Fig. 2a), indicating that participants were more inclined to choose the high-effort option as the reward magnitude increased. Participants who selected the high-effort option also reported higher levels of perceived stress ($t_{39} = -6.406$, $p < 0.001$, see Fig. 2b) and effort allocation ($t_{39} = -3.372$, $p = 0.002$, see Fig. 2b). In terms of valence rating and arousal rating, significant main effects were found for rankings (valence: $F_{2,23} = 12.484$, $p < 0.001$, partial$\eta^2 = 0.52$; arousal: $F_{2,23} = 12.422$, $p < 0.001$, partial$\eta^2 = 0.52$; see Fig. 2c) and interview outcomes (valence: $t_{49} = -5.6440$, $p < 0.001$; arousal: $t_{49} = -5.250$, $p < 0.001$; see Fig. 2d), indicating that all participants experienced increased happiness and excitement when the ranking was higher and the feedback was positive.

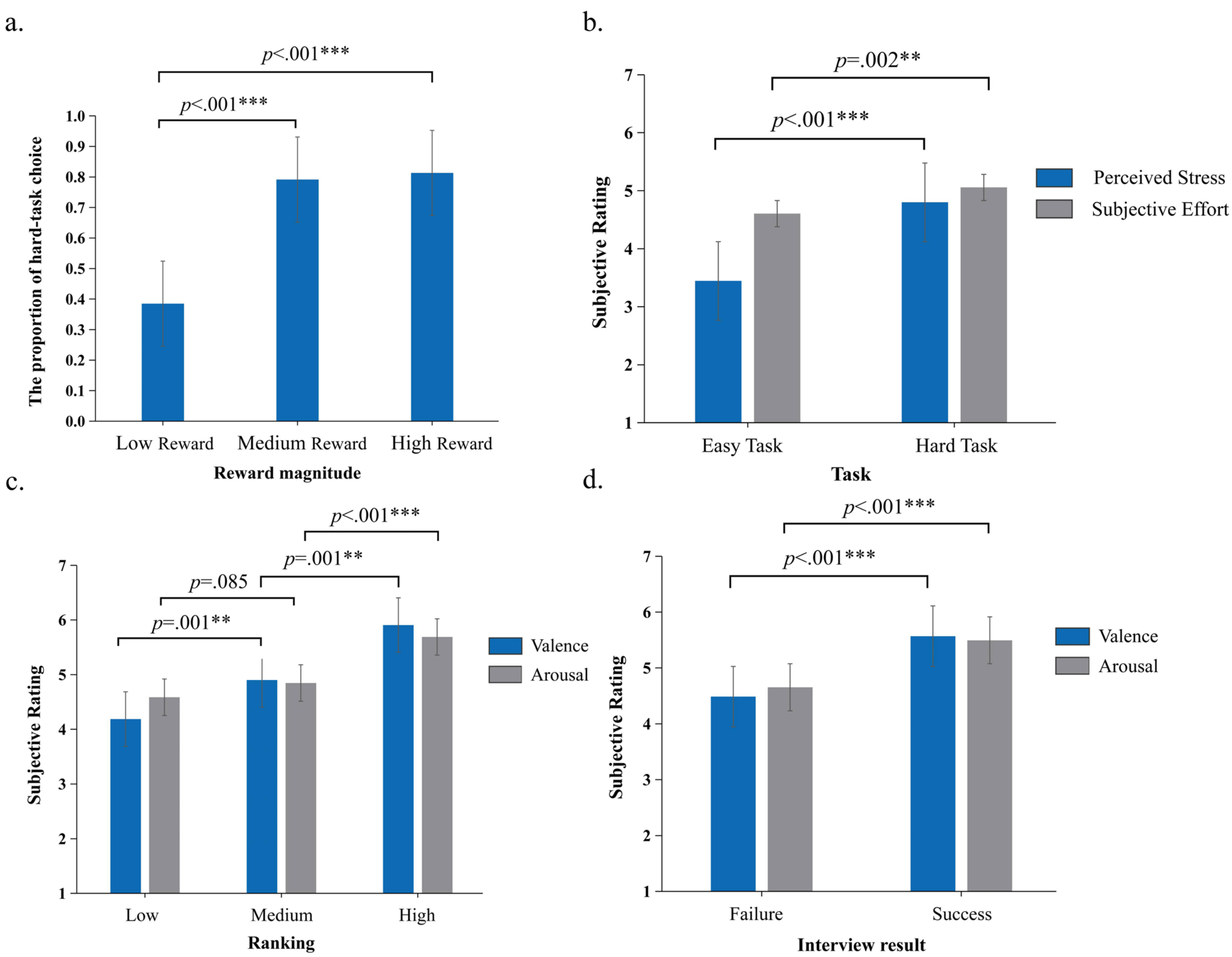
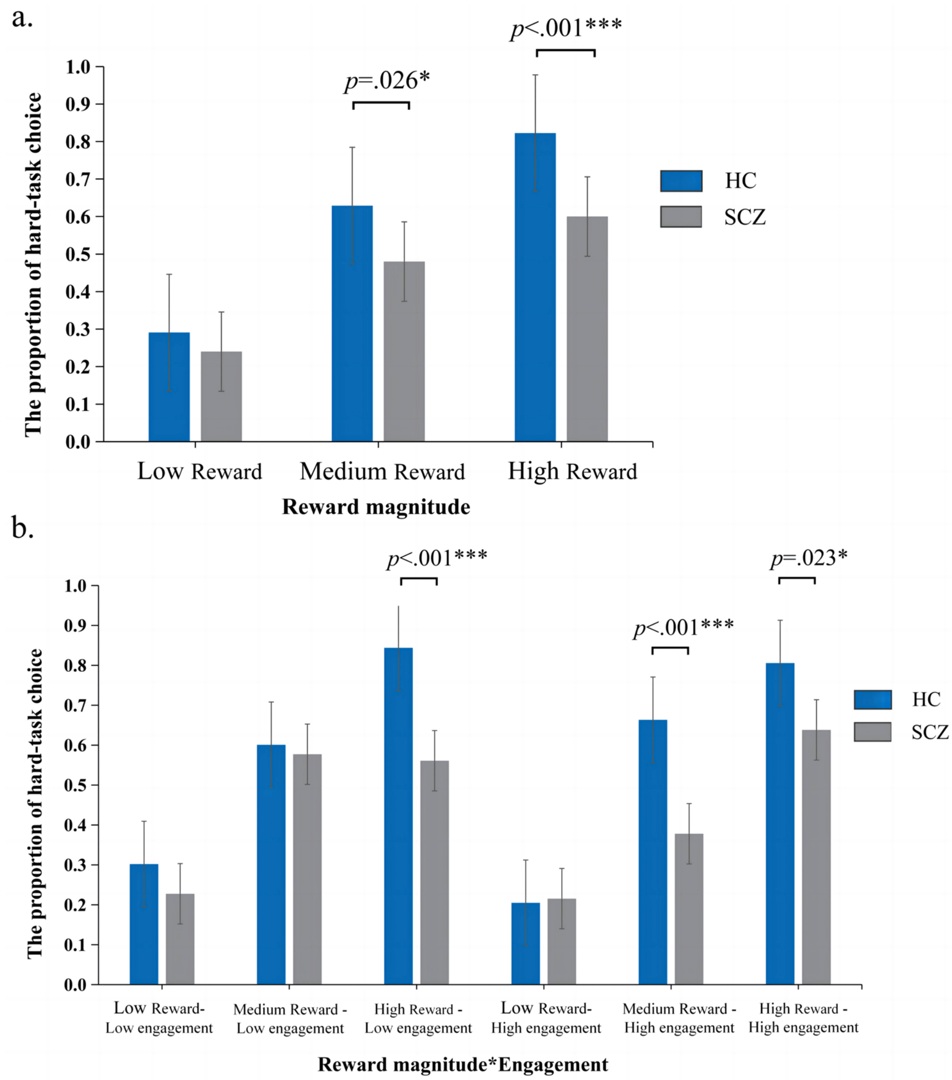


Fig. 2 Validity of the Mock Job Interview task. **a** Effect of reward magnitude; **b** Effect of task; **c** Effect of ranking; **d** in Effect of interview result

Fig. 3 Group difference in proportion of hard-task choice. **a** Effect of reward magnitude; **b** Effect of reward magnitude*engagement



Group differences in the proportion of hard-task choice

As shown in Fig. 3a, both the main effect of Group ($F_{1,92} = 7.632$, $p = 0.007$, partial$\eta^2 = 0.08$) and the Group × Reward interaction ($F_{2,184} = 3.768$, $p = 0.025$, partial$\eta^2 = 0.04$) were significant for the proportion of hard-task choice. Simple effect analyses revealed that SCZ patients exhibited a lower likelihood of choosing the hard-task in the medium-rewards condition ($F_{1,92} = 5.148$, $p = 0.026$, partial$\eta^2 = 0.05$) and high-rewards conditions ($F_{1,92} = 12.874$, $p < 0.001$, partial$\eta^2 = 0.12$) when compared with HC. However, the two groups demonstrated similar proportions of hard-task choice in the low-rewards condition. ($F_{1,92} = 0.820$, $p = 0.367$, partial$\eta^2 = 0.01$). Similar results were observed when controlling for CPZ equivalents levels. Specifically, both the main effect of Group ($F_{1,92} = 4.312$, $p = 0.041$, partial$\eta^2 = 0.05$) and the Group × Reward interaction ($F_{2,184} = 6.724$, $p = 0.002$, partial$\eta^2 = 0.07$) demonstrated statistical significance in relation to the proportion of hard-task choice.

Furthermore, as depicted in Fig. 3b, we observed a significant main effect of Group ($F_{1,87} = 7.181$, $p = 0.009$, partial$\eta^2 = 0.08$) and Group × Reward × Engagement interaction ($F_{2,174} = 4.407$, $p = 0.014$, partial$\eta^2 = 0.05$), whilst the main effect of Engagement was not significant ($F_{1,87} = 1.640$, $p = 0.204$, partial$\eta^2 = 0.02$). Simple effect analyses indicated that for jobs requiring low levels of social engagement, SCZ patients exhibited lower willingness when compared with HC to allocate more effort only in the high-rewards condition ($F_{1,87} = 11.203$, $p < 0.001$, partial$\eta^2 = 0.11$) whereas the proportion of hard-task choice was similar between groups when the reward values were low and medium. Regarding high social engagement jobs, SCZ patients were more inclined to choose the easy task in both the medium-rewards ($F_{1,87} = 11.239$, $p < 0.001$, partial$\eta^2 = 0.11$) and high-rewards ($F_{1,87} = 5.380$, $p = 0.023$, partial$\eta^2 = 0.06$) conditions. However, when controlling for

CPZ Equivalents levels, there were no significant interaction effects observed for Group × Engagement ($F_{1,86}=1.065$, $p=0.305$, partial$\eta^2=0.01$) or Group × Reward × Engagement ($F_{2,172}=1.047$, $p=0.353$, partial$\eta^2=0.01$).

The main effect of Sex ($F_{1,90}=0.088$, $p=0.767$, partial$\eta^2=0.001$) and the Group × Reward × Sex interaction ($F_{2,180}=2.628$, $p=0.075$, partial$\eta^2=0.03$) were not significant, suggesting that sex had a negligible influence on the proportion of hard-task choice.

Group differences in perceived stress level, effort level and emotional experience

As shown in Fig. 4a, there were no significant main effects of Group on perceived stress level ($F_{1,33}=0.228$, $p=0.636$, partial$\eta^2=0.007$) and subjective effort level ($F_{1,33}=0.0002$, $p=0.990$, partial$\eta^2=0.001$). Furthermore, the Group × Task interaction did not reach significance for perceived stress rating ($F_{1,33}=1.244$, $p=0.273$, partial$\eta^2=0.04$) and subjective effort rating ($F_{1,33}=2.296$, $p=0.139$, partial$\eta^2=0.07$). Similar results were observed when controlling for CPZ equivalents levels.

Regarding the different interview outcomes, as depicted in Fig. 4b, both the main effect of Group ($F_{1,91}=2.082$, $p=0.152$, partial$\eta^2=0.02$) and the Group × Result interaction ($F_{1,91}=1.359$, $p=0.247$, partial$\eta^2=0.02$) were not significant on valence ratings. However, for arousal ratings, the main effect of Group was significant ($F_{1,91}=4.11$, $p=0.046$, partial$\eta^2=0.04$), indicating that SCZ patients experienced higher levels of arousal than HC regardless of interview outcomes. There was no significant Group × Result interaction effect on the subjective ratings ($F_{1,91}=1.141$, $p=0.288$, partial$\eta^2=0.01$). Similar results were observed when controlling for CPZ equivalents levels.

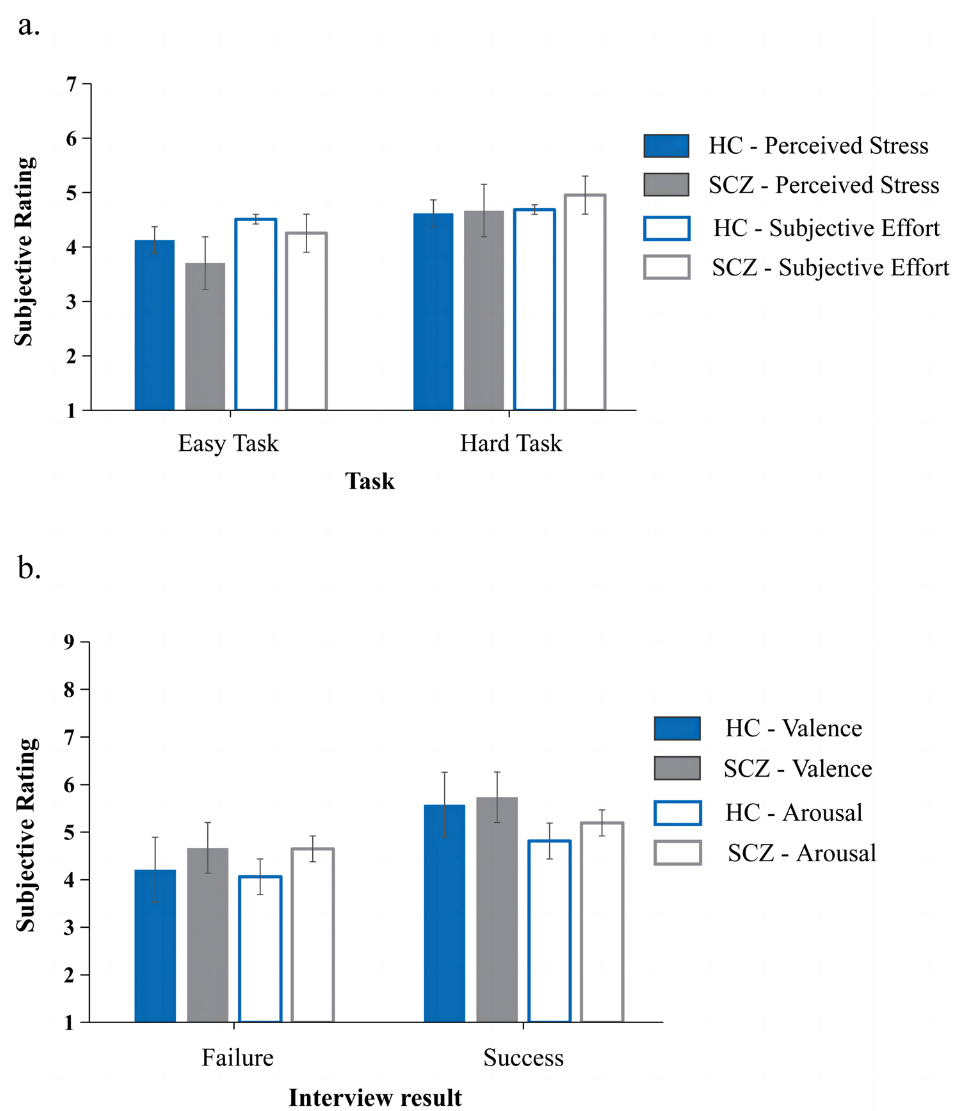


Fig. 4 Group difference in perceived stress level, effort level and emotional experience. **a** Effect of task; **b** Effect of interview result

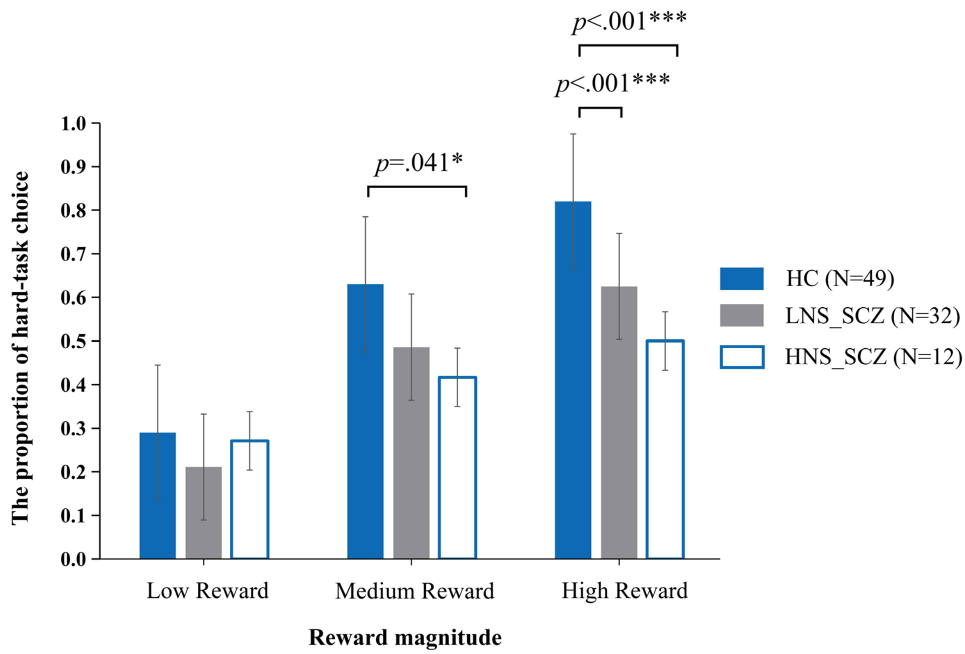


Fig. 5 The effect of negative symptoms on proportion of hard-task choice

The effect of negative symptoms on the proportion of hard-task choice

As depicted in Fig. 5, we observed significant main effects for Subgroup ($F_{2,90} = 4.559$, $p = 0.013$, partial$\eta^2 = 0.09$) and Subgroup × Reward interaction ($F_{4,180} = 2.726$, $p = 0.031$, partial$\eta^2 = 0.06$) in relation to the proportion of hard-task choice. Simple effect analyses revealed that SCZ patients with HNS were less likely to choose the hard task in both the medium rewards ($p = 0.041$, $d = -0.85$) and high rewards ($p < 0.001$, $d = -1.18$) conditions when compared with HC. SCZ patients with LNS were less likely to choose the hard task only in the high rewards condition as compared to HC ($p < 0.001$, $d = -0.63$). Furthermore, the Subgroup × Reward × Engagement interaction ($F_{4,170} = 1.797$, $p = 0.132$, partial$\eta^2 = 0.04$) was not significant. When controlling for CPZ Equivalents levels, we observed similar results. Specifically, there was no significant main effect of Subgroup ($F_{2,89} = 2.939$, $p = 0.058$, partial$\eta^2 = 0.06$). However, the Subgroup × Reward interaction remained significant ($F_{4,178} = 4.239$, $p = 0.004$, partial$\eta^2 = 0.09$) for the proportion of hard-task choice.

Relationship between apathy and anhedonia symptoms, social function and proportion of hard-task choice

We conducted four separate models using generalized estimating equations (GEE) to examine various factors influencing the proportion of hard-task choices in SCZ patients [39] (Table S1 in the supplementary materials).

In Model 1, we examined the main effects of reward magnitude, clinical symptoms, and self-report scale scores. We observed that SCZ patients were more likely to make hard-task choices as the reward magnitude increased ($b = 0.092$, $p < 0.001$). Furthermore, we found a negative correlation between the proportion of hard-task choices and social anhedonia, as measured by the RCSAS ($b = -0.069$, $p = 0.006$) and a positive correlation between the proportion of hard-task choices and social functioning, as measured by the SFS ($b = 0.029$, $p = 0.008$). In addition, we found a negative correlation between the proportion of hard-task choices and apathy symptoms ($b = -0.091$, $p = 0.006$).

In Model 2, we tested for an interaction between apathy symptoms and reward magnitude. The results revealed a significant interaction ($b = -0.006$, $p = 0.038$). Specifically, we found a negative correlation between apathy symptoms and hard-task choices in trials with medium reward magnitude ($b = -0.118$, $p = 0.038$) and high reward magnitude ($b = -.099$, $p = 0.005$), but not in trials with low reward magnitude ($b = 0.000$, $p > 0.05$).

In Models 3 and 4, we tested for potential interaction effects between reward magnitude and two predictors: social anhedonia (measured by the RCSAS) and social functioning (measured by the SFS). However, we did not find any evidence of interaction effects between reward magnitude and these two indicator ($ps > 0.05$).

Discussion

In the current study, we developed a novel paradigm to behaviorally measure effort-based decision-making in social scenarios among SCZ patients and examine its relationship with apathy symptoms. There were two major findings emerging from our analyses. First, SCZ patients exhibited altered effort allocation with less willingness to expend effort for social rewards with high reward magnitude as compared to HC. Second, such reduction in effort expenditure for rewards was most pronounced in patients with high levels of negative symptoms. What's more, reduced likelihood of making a hard-task choice was associated with more severe apathy symptoms, social anhedonia and impaired social functioning.

Our results indicated that SCZ patients were less willing than controls to allocate cognitive effort in social scenarios for high rewards (substantially increased likelihood of interview acceptance). This is consistent with prior studies on effort-based decision-making using monetary rewards, which found greater effort aversion in SCZ group [8, 16–23, 40]. A prior study also explored the effort-based decision-making function of patients in a social scenario, using the Modified Trust Task to examine changes in decisions to trust, and effort expenditure over the course of repeated interactions with positive or negative outcomes. They found patients with schizophrenia-spectrum disorders anticipated less pleasure from social interaction, expected more difficulty in reward learning and therefore expended less physical effort (number of keystrokes) to increase the likelihood of future interactions with positive outcomes (i.e., friendly faces) [41]. Consistent with this finding, our study found SCZ patients had a reduced willingness to exert effort in the pursuit of social approval in the mock situations of job interview. In addition, our paradigm is unique in that we set up a social scenario closer to real life situations, where people undergo interpersonal expectation stress and exert cognitive effort rather than physical effort (e.g., motoric or strength-based) in pursuit of social-related rewards. We strongly believe that our paradigm, which possesses higher ecological validity, provides a more accurate reflection of the impact of apathy symptoms on patients' daily lives. Previous studies utilizing the EEfRT have also reported similar findings, indicating that individuals diagnosed with SCZ exhibit less willingness to exert effort for rewards comparable to HC under low-reward conditions [16, 17]. These findings further support the idea that SCZ patients are not inherently averse to effort, but rather exhibit inefficient allocation of effort by not selecting high-effort choices to maximize rewards [20]. Collectively, these findings lend support to the theory that SCZ patients experience impairments in the computation of cost – benefit for motivation [9], irrespective of the reward types being nonsocial or social in nature.

Regarding the neural substrates of insufficient effort allocation for pursuing high rewards, accumulating evidence suggested that interference with dopamine transmission produces a low-effort bias (reviewed in [42], while stimulation of dopamine release increased willingness to exert effort [43, 44]. Although dopamine release in the striatum was not reduced in SCZ patients, decrease in effort expenditure in SCZ may be due to a variety of possibilities such as increased tonic striatal dopamine transmission and dopaminergic responses to d-amphetamine [45], an overexpression of post-synaptic D2 receptors [46] or erratic burst firing of dopamine neurons experienced in SCZ patients [47]. In addition to neurotransmitters, atypical brain functions related to reward and motivation, including decreased activation in the prefrontal cortex, the anterior cingulate cortex, the ventral striatum, etc., as well as the functional disconnections between these brain regions may also contribute to apathy/amotivation in SCZ [46, 48–50]. Given these brain regions are also strongly linked to social cognition and processing [51], this may serve as a direction for future research to explore the neural mechanisms behind socially relevant effort-based decision making.

Our results showed that such reduction in effort expenditure for rewards was most pronounced in patients with high levels of negative symptoms. This is consistent with several previous studies which demonstrated that SCZ patients with high levels of negative symptoms or apathy symptoms were the least willing to increase physical effort for higher value reward [8, 21, 22]. Of note, consistent with some evidence from previous studies, the present study found that more severe apathy symptoms were associated with an overall reduced likelihood of making a hard-task choice [8, 16, 18, 20]. This correlation clearly points to an important role of effort allocation on the apathy symptoms of SCZ, which suggested that impaired effort-based decision-making may be a potential contributory mechanism for motivational impairment in SCZ. These results provided hope that it might be possible to develop treatments targeted to components of effort-based decision making for reward. Such efforts might be relevant to psychological therapies as well. Future investigations are warranted to further elucidate the specific cognitive mechanisms that contribute to alterations in effort-based decision-making. This pursuit may advance the development of targeted therapeutic interventions.

We also observed that increased social functioning levels significantly predicted an overall increased likelihood of making a hard-task choice in SCZ patients, suggesting that poor social functioning may contribute to patients' avoidance of activities with high social engagement. Such withdrawal from social activities may in turn lead to the deterioration of social functioning. Future longitudinal studies are needed to further examine the bidirectional relationships between motivational deficits and social dysfunction in SCZ populations.

Moreover, we found no group differences in valence rating and arousal rating when participants received interview outcomes. The intact ability to experience in-the-moment pleasure upon obtaining the reward in SCZ patients is consistent with previous findings [52–54]. Although SCZ patients valued the reward similarly to the HC, they showed impairments in effort-based decision-making and engaged in fewer reward-seeking behaviors. This supports the current hypothesis of the separation of "liking" and "wanting" [9]. Specifically, consummatory pleasure is intact in SCZ, but the translation of reward information into motivated behavior is hampered when cognitive components such as anticipatory pleasure and effort computation are involved, because these cognitive processes are severely impaired in SCZ patients [9]. Another interpretation to explain the apparent disconnect between liking and wanting is that the ability to learn from positive feedbacks may be impaired in SCZ [41]. SCZ patients experienced as much positive emotion as HC, but were unable to increase the possibility of subsequent efforts based on this positive feedback, thus leading to fewer choices of hard-tasks. Future research should explore the exact mechanism underlying altered effort-based decision-making by separately examining the role of anticipatory pleasure, effort computation, and reward learning in SCZ.

This study had several limitations. First, all the SCZ patients in the present study were taking antipsychotic medications at the time of assessment. Although our analyses and previous studies revealed no significant correlation between antipsychotic dosage and task performance [8, 16, 20, 21], it is difficult to exclude the effect of dopamine D2 receptor antagonists on effort allocation given the evidence in rats that D2 receptor antagonists can reduce the willingness to make an effort for rewards [55, 56]. Recruiting medication-naive patients or high-risk groups can help to clarify the effect, if any, of antipsychotic medications on motivational behaviors. Second, although the Mock Job Interview Task in the present study was conducted in a social scenario, we only presented the rewards of social approvals in the text forms to the participants. In addition, the experimental scenario may be influenced by stressful situations, which may interfere with the measurement of social motivation. To improve the ecological validity of this paradigm, future studies could include audiovisual social feedbacks such as dynamic facial expressions with verbal comments. Third, anticipatory pleasure and estimation of effort expenditure were not assessed before participants were asked to make choices, which prevented us from separating the two components of value computation and effort computation in the cost – benefit analysis. Both an underestimation of the reward value and an overestimation of the cost of effort can lead to reduced willingness of effort exertion. Future research should clarify the precise mechanisms underlying aberrant effort allocation in SCZ. Fourth, it is important to acknowledge that our study did not include measurements of depression or anxiety symptom levels. Depressive symptoms can potentially confound the assessment of negative symptoms, including apathy, and social anxiety can have a significant impact on one's willingness to expend effort for social rewards. Therefore, future research should aim to assess and control for these potential confounders to better understand their influence on the effort-based decision making.

Conclusions

Our results suggest that SCZ patients show impairments in social cost – benefit analysis when seeking social approval, which may contribute to more severe apathy symptoms. This study extends effort-based decision-making in SCZ from nonsocial dimensions to social dimensions, and deepens our understanding of the mechanisms behind motivational deficits.

Acknowledgements This study was supported by grants from the Natural Science Foundation of Shanghai (21ZR142000), the National Natural Science Foundation of China (32171084) and the MOE (Ministry of Education in China) Project of Humanities and Social Sciences (20YJC190025). We appreciated all the participants who agreed to participate in the project, as well as research assistants (L. Zhou; H.R. Zhang; Y. Fan; S.N. Huang) and technical specialist (Dr. Z.T. Chen) for their great assistance.

Author contributions Y-XS and CY collaboratively generated the idea and conceptualized the aims and hypotheses of the study. Z-HY conducted clinical assessments and transferred patients to our study. Y-XS, L-LW and CY designed and programmed the experimental paradigm. Y-XS recruited participants and collected data with the assistance of our research assistants. Y-XS conducted data analysis and completed the manuscript. CY, Han-YZ and SL provided feedback on the concept and the text of the manuscript.

Data availability The datasets are only available from the corresponding author on reasonable request.

Declarations

Conflicts of interest The authors declare that there were no conflicts of interest with respect to the authorship or the publication of this article.

Ethical standards The study was approved by the Ethics Committees of the East China Normal University (HR2015/03003). All participants gave written informed consent before the commencement of the study. Details that might disclose the identity of the subjects under study were be omitted.

References

1. Brown RG, Pluck G (2000) Negative symptoms: the "pathology" of motivation and goal-directed behaviour. Trends Neurosci 23(9):412–417

2. Strauss GP, Bartolomeo LA, Harvey PD (2021) Avolition as the core negative symptom in schizophrenia: relevance to pharmacological treatment development. NPJ Schizophr 7(1):16. https://doi.org/10.1038/s41537-021-00145-4
3. Foussias G, Remington G (2010) Negative symptoms in schizophrenia: avolition and Occam's razor. Schizophr Bull 36(2):359–369. https://doi.org/10.1093/schbul/sbn094
4. Fervaha G, Foussias G, Agid O, Remington G (2015) Motivational deficits in early schizophrenia: prevalent, persistent, and key determinants of functional outcome. Schizophr Res 166(1–3):9–16. https://doi.org/10.1016/j.schres.2015.04.040
5. Messinger JW et al (2011) Avolition and expressive deficits capture negative symptom phenomenology: implications for DSM-5 and schizophrenia research. Clin Psychol Rev 31(1):161–168. https://doi.org/10.1016/j.cpr.2010.09.002
6. Chang WC, Hui CL, Chan SK, Lee EH, Chen EY (2016) Impact of avolition and cognitive impairment on functional outcome in first-episode schizophrenia-spectrum disorder: a prospective one-year follow-up study. Schizophr Res 170(2–3):318–321. https://doi.org/10.1016/j.schres.2016.01.004
7. Saleh Y, Jarratt-Barnham I, Fernandez-Egea E, Husain M (2021) Mechanisms Underlying Motivational Dysfunction in Schizophrenia. Front Behav Neurosci. https://doi.org/10.3389/fnbeh.2021.709753
8. Hartmann MN et al (2015) Apathy but not diminished expression in schizophrenia is associated with discounting of monetary rewards by physical effort. Schizophr Bull 41(2):503–512. https://doi.org/10.1093/schbul/sbu102
9. Kring AM, Barch DM (2014) The motivation and pleasure dimension of negative symptoms: neural substrates and behavioral outputs. Eur Neuropsychopharmacol 24(5):725–736. https://doi.org/10.1016/j.euroneuro.2013.06.007
10. Wallis JD (2007) Orbitofrontal cortex and its contribution to decision-making. Annu Rev Neurosci 30:31–56. https://doi.org/10.1146/annurev.neuro.30.051606.094334
11. Barch DM, Dowd EC (2010) Goal representations and motivational drive in schizophrenia: the role of prefrontal−striatal interactions. Schizophr Bull 36(5):919–934. https://doi.org/10.1093/schbul/sbq068
12. Der-Avakian A, Barnes SA, Markou A, Pizzagalli DA (2016) Translational Assessment of Reward and Motivational Deficits in Psychiatric Disorders. Curr Top Behav Neurosci 28:231–262. https://doi.org/10.1007/7854_2015_5004
13. Barch DM, Pagliaccio D, Luking K (2016) Mechanisms Underlying Motivational Deficits in Psychopathology: Similarities and Differences in Depression and Schizophrenia. Curr Top Behav Neurosci 27:411–449. https://doi.org/10.1007/7854_2015_376
14. Husain M, Roiser JP (2018) Neuroscience of apathy and anhedonia: a transdiagnostic approach. Nat Rev Neurosci 19(8):470–484. https://doi.org/10.1038/s41583-018-0029-9
15. Horan WP et al (2015) Effort-Based Decision-Making Paradigms for Clinical Trials in Schizophrenia: Part 2—External Validity and Correlates. Schizophr Bull 41(5):1055–1065. https://doi.org/10.1093/schbul/sbv090
16. Fervaha G, Graff-Guerrero A, Zakzanis KK, Foussias G, Agid O, Remington G (2013) Incentive motivation deficits in schizophrenia reflect effort computation impairments during cost−benefit decision-making. J Psychiatr Res 47(11):1590–1596. https://doi.org/10.1016/j.jpsychires.2013.08.003
17. Treadway MT, Peterman JS, Zald DH, Park S (2015) Impaired effort allocation in patients with schizophrenia. Schizophr Res 161(2–3):382–385. https://doi.org/10.1016/j.schres.2014.11.024
18. Barch DM, Treadway MT, Schoen N (2014) Effort, anhedonia, and function in schizophrenia: reduced effort allocation predicts amotivation and functional impairment. J Abnorm Psychol 123(2):387–397. https://doi.org/10.1037/a0036299
19. McCarthy JM, Treadway MT, Bennett ME, Blanchard JJ (2016) Inefficient effort allocation and negative symptoms in individuals with schizophrenia. Schizophr Res 170(2–3):278–284. https://doi.org/10.1016/j.schres.2015.12.017
20. Chang WC et al (2019) Effort-based decision-making impairment in patients with clinically-stabilized first-episode psychosis and its relationship with amotivation and psychosocial functioning. Eur Neuropsychopharmacol 29(5):629–642. https://doi.org/10.1016/j.euroneuro.2019.03.006
21. Gold JM, Strauss GP, Waltz JA, Robinson BM, Brown JK, Frank MJ (2013) Negative symptoms of schizophrenia are associated with abnormal effort-cost computations. Biol Psychiatry 74(2):130–136. https://doi.org/10.1016/j.biopsych.2012.12.022
22. Wang J, Huang J, Yang XH, Lui SS, Cheung EF, Chan RC (2015) Anhedonia in schizophrenia: Deficits in both motivation and hedonic capacity. Schizophr Res 168(1–2):465–474. https://doi.org/10.1016/j.schres.2015.06.019
23. Culbreth A, Westbrook A, Barch D (2016) Negative symptoms are associated with an increased subjective cost of cognitive effort. J Abnorm Psychol 125(4):528–536. https://doi.org/10.1037/abn0000153
24. Culbreth A, Moran EK, Kandala S, Westbrook A, Barch DM (2020) Effort, avolition and motivational experience in schizophrenia: Analysis of behavioral and neuroimaging data with relationships to daily motivational experience. Clin Psychol Sci 8(3):555–568. https://doi.org/10.1177/2167702620901558
25. Huang J et al (2016) Neural substrates of the impaired effort expenditure decision making in schizophrenia. Neuropsychology 30(6):685–696. https://doi.org/10.1037/neu0000284
26. Fulford D, Campellone T, Gard DE (2018) Social motivation in schizophrenia: How research on basic reward processes informs and limits our understanding. Clin Psychol Rev 63:12–24. https://doi.org/10.1016/j.cpr.2018.05.007
27. Dubey I, Georgescu AL, Hommelsen M, Vogeley K, Ropar D, Hamilton AFC (2020) Distinct neural correlates of social and object reward seeking motivation. Eur J Neurosci 52(9):4214–4229. https://doi.org/10.1111/ejn.14888
28. Catalano LT, Heerey EA, Gold JM (2018) The valuation of social rewards in schizophrenia. J Abnorm Psychol 127(6):602–611. https://doi.org/10.1037/abn0000366
29. Makowski CS, Lepage M, Harvey PO (2016) Functional neural correlates of social approval in schizophrenia. Soc Cogn Affect Neurosci 11(3):445–457. https://doi.org/10.1093/scan/nsv125
30. APA (2013) Diagnostic and Statistical Manual of Mental Disorders, 5th ed. American Psychiatric Association
31. Treadway MT, Buckholtz JW, Schwartzman AN, Lambert WE, Zald DH (2009) Worth the "EEfRT"? The effort expenditure for rewards task as an objective measure of motivation and anhedonia. PLoS ONE. https://doi.org/10.1371/journal.pone.0006598
32. Kirschbaum C, Pirke KM, Hellhammer DH (1993) The 'Trier Social Stress Test'–a tool for investigating psychobiological stress responses in a laboratory setting. Neuropsychobiology 28(1–2):76–81. https://doi.org/10.1159/000119004
33. Kay SR, Abraham F, Opler LA (1987) The Positive and Negative Syndrome Scale (PANSS) for Schizophrenia. Schizophr Bull 2:2
34. Andreasen NC (1989) Scale for the Assessment of Negative Symptoms. SANS 13(7):49–58
35. Chan RCK, Yang ZY, Li Z, Xie DJ, Gooding DC (2016) Validation of the Chinese version of the Anticipatory and Consummatory Interpersonal Pleasure Scale. Psych Journal 5(4):238–244. https://doi.org/10.1002/pchj.139
36. Chan RCK et al (2012) A Study of Trait Anhedonia in Non-Clinical Chinese Samples: Evidence from the Chapman Scales for Physical and Social Anhedonia. PLoS ONE 7(4):6. https://doi.org/10.1371/journal.pone.0034275

37. Wang Y et al (2013) Social Functioning in Chinese College Students with and without Schizotypal Personality Traits: An Exploratory Study of the Chinese Version of the First Episode Social Functioning Scale. PLoS ONE 8(5):6. https://doi.org/10.1371/journal.pone.0061115
38. Olié JP, Spina E, Murray S, Yang R (2006) Ziprasidone and amisulpride effectively treat negative symptoms of schizophrenia: results of a 12-week, double-blind study. Int Clin Psychopharmacol 21(3):143–151. https://doi.org/10.1097/01.yic.0000182121.59296.70
39. Chaves AC, Seeman MV, Mari JJ, Maluf A (1993) Schizophrenia: impact of positive symptoms on gender social role. Schizophr Res 11(1):41–45. https://doi.org/10.1016/0920-9964(93)90036-i
40. Wolf DH et al (2014) Amotivation in schizophrenia: integrated assessment with behavioral, clinical, and imaging measures. Schizophr Bull 40(6):1328–1337. https://doi.org/10.1093/schbul/sbu026
41. Campellone TR, Truong B, Gard D, Schlosser DA (2018) Social motivation in people with recent-onset schizophrenia spectrum disorders. J Psychiatr Res 99:96–103. https://doi.org/10.1016/j.jpsychires.2018.01.006
42. Salamone JD, Correa M, Yang JH, Rotolo R, Presby R (2018) Dopamine, Effort-Based Choice, and Behavioral Economics: Basic and Translational Research. Front Behav Neurosci 12:52. https://doi.org/10.3389/fnbeh.2018.00052
43. Wardle MC, Treadway MT, Mayo LM, Zald DH, de Wit H (2011) Amping up effort: effects of d-amphetamine on human effort-based decision-making. J Neurosci 31(46):16597–16602. https://doi.org/10.1523/jneurosci.4387-11.2011
44. Treadway MT et al (2012) Dopaminergic mechanisms of individual differences in human effort-based decision-making. J Neurosci 32(18):6170–6176. https://doi.org/10.1523/jneurosci.6459-11.2012
45. Howes OD et al (2012) The nature of dopamine dysfunction in schizophrenia and what this means for treatment. Arch Gen Psychiatry 69(8):776–786. https://doi.org/10.1001/archgenpsychiatry.2012.169
46. Strauss GP, Waltz JA, Gold JM (2014) A review of reward processing and motivational impairment in schizophrenia. Schizophr Bull. https://doi.org/10.1093/schbul/sbt197
47. Heinz A, Schlagenhauf F (2010) Dopaminergic dysfunction in schizophrenia: salience attribution revisited. Schizophr Bull 36(3):472–485. https://doi.org/10.1093/schbul/sbq031
48. Karcher NR, Rogers BP, Woodward ND (2019) Functional Connectivity of the Striatum in Schizophrenia and Psychotic Bipolar Disorder. Biol Psychiatry Cogn Neurosci Neuroimaging 4(11):956–965. https://doi.org/10.1016/j.bpsc.2019.05.017
49. Fornito A, Yücel M, Dean B, Wood SJ, Pantelis C (2009) Anatomical abnormalities of the anterior cingulate cortex in schizophrenia: bridging the gap between neuroimaging and neuropathology. Schizophr Bull 35(5):973–993. https://doi.org/10.1093/schbul/sbn025
50. He Y et al (2020) Organized Resting-state Functional Dysconnectivity of the Prefrontal Cortex in Patients with Schizophrenia. Neuroscience 446:14–27. https://doi.org/10.1016/j.neuroscience.2020.08.021
51. Fujiwara H, Yassin W, Murai T (2015) Neuroimaging studies of social cognition in schizophrenia. Psychiatry Clin Neurosci 69(5):259–267. https://doi.org/10.1111/pcn.12258
52. Cohen AS, Minor KS (2010) Emotional experience in patients with schizophrenia revisited: meta-analysis of laboratory studies. Schizophr Bull 36(1):143–150. https://doi.org/10.1093/schbul/sbn061
53. Llerena K, Strauss GP, Cohen AS (2012) Looking at the other side of the coin: a meta-analysis of self-reported emotional arousal in people with schizophrenia. Schizophr Res 142(1–3):65–70. https://doi.org/10.1016/j.schres.2012.09.005
54. Ursu S et al (2011) Prefrontal cortical deficits and impaired cognition−emotion interactions in schizophrenia. Am J Psychiatry 168(3):276–285. https://doi.org/10.1176/appi.ajp.2010.09081215
55. Filla I et al (2018) Striatal dopamine D2 receptors regulate effort but not value-based decision making and alter the dopaminergic encoding of cost. Neuropsychopharmacology 43(11):2180–2189. https://doi.org/10.1038/s41386-018-0159-9
56. Simpson EH, Waltz JA, Kellendonk C, Balsam PD (2012) Schizophrenia in translation: dissecting motivation in schizophrenia and rodents. Schizophr Bull 38(6):1111–1117. https://doi.org/10.1093/schbul/sbs114