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Devaluation of Rewards for the Future Is Associated With Schizotypal Personality Features

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Objective: Empirical evidence has suggested that schizophrenia is associated with dysfunctions in the reward system and working memory. However, little is known about individuals at risk for schizophrenia. In particular, it is not known if those with schizotypal personality features will show similar deficits in these two domains. This study examined whether individuals with schizotypal personality disorder features will subjectively devalue potential rewards in the future and show changes in their decision-making behaviour, compared with healthy controls, and whether this devaluation is inversely associated with working memory performance.

Method: A total of 44 participants with schizotypal personality features and 22 healthy control participants without schizotypal personality features completed the Monetary-Choice Questionnaire, the Cambridge Gambling Task, and number and letter span tasks, which assessed delay-discounting rate, decision-making behaviour, and working memory, respectively.

Results: The results showed that participants with schizotypal personality features, especially those with negative features, valued delayed rewards in the future to a lesser extent than healthy control participants. However, there was no significant group difference in decision-making on the Cambridge Gambling Task. Moreover, the delay-discounting rate of individuals with schizotypal personality features correlated significantly with working memory performance.

Conclusion: The findings suggest that people with schizotypal personality features may be impaired in future reward perception and that this impairment is related to their working memory ability, although their capacity to make decisions is not affected.

Key words: decision-making; delayed discounting rate; gambling task; reward valuation; schizotypal personality features; working memory.

What is already known on this topic

1 Patients with schizophrenia have demonstrated higher delay-discounting rate than healthy people.
2 Working memory dysfunction correlates with delay-discounting rate in patients with schizophrenia.
3 Reward perception and decision-making processes in individuals at risk of schizophrenia has not been fully examined.

What this paper adds

1 Individuals with schizotypal personality features, especially those with negative schizotypal personality features, devalued future rewards more than healthy controls.
2 Deficits in reward perception in those with schizotypal personality features are related to working memory function and time perception.
3 The immediate decision-making process of people with schizotypal personality features is unclear.

Decision-making plays an essential role in everyday life. An integrated process of decision-making consists of three components: (a) evaluating several possible options and formulating the optimal choice, (b) choosing and executing the appropriate action while inhibiting other substitute actions, and (c) experiencing and/or appraising the consequence of the chosen option (Paulus, 2007). At the beginning of each decision, effective evaluation of the suitability of the available choice of rewards is especially important because this affects subsequent decision-making behaviour as well as the ultimate outcome of a decision. Both humans and animals commonly devalue future rewards that come with a delay, a behaviour that has been defined as delay discounting (Kirby, 1997; Kirby, Petry, & Bickel, 1999; Rosati, Stevens, Hare, & Hauser, 2007). For example, an individual may prefer an immediate reward instead of the same

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reward delivered after a few days. Delay discounting can, therefore, be a factor that influences the decision-making process.

To better understand the process of future reward devaluation, the delay-discounting rate κ was introduced. The delay-discounting rate is represented by a hyperbolic function characterised by the formula $V = A/(1 + \kappa D)$, where V equals the reward's subjective value, A, after a delay of D number of days (Mazur, 1987). The delay-discounting rate quantifies the degree to which a future reward is devalued by an individual and its value differs across individuals. For instance, people with a larger κ are suggested to devalue future rewards more steeply (Kirby, 1997; Kirby & Marakovic, 1996). Moreover, the delay-discounting rate has been found to be associated with impulsivity (Kirby et al., 1999). Hirsh, Morisano, and Peterson, (2008) proposed that the inhibition of instant lure and the emphasis of future goals are commonly related to many positive consequences, including better academic performance, healthier relationships, and better social functioning, all of which require a relatively low delay-discounting rate. Conversely, a higher delay-discounting rate may lead to suboptimal behaviour and adverse consequences in some patient populations. For example, the delay-discounting rate among heroin abusers is twice that of healthy controls (HCs) and is positively associated with their impulsivity (Kirby et al., 1999). Furthermore, the significantly higher delay-discounting rate observed in patients with schizophrenia, when compared with HCs, may account for the impaired decision-making behaviour sometimes observed in this population (Gold, Waltz, Prentice, Morris, & Heerey, 2008; Heerey, Bell-Warren, & Gold, 2008; Heerey, Robinson, McMahon, & Gold, 2007).

Previous research evidence suggests that the delay-discounting rate may be related to working memory function in that the better the working memory function, the slower the decrease in subjective value of future reward (Heerey et al., 2007). Empirical findings also suggest that delay discounting and working memory may share common neural substrates, including the dorsolateral prefrontal cortex (Bjork, Momenan, & Hommer, 2009; Li et al., 2013; Yu, 2012). Conversely, the relationship between the orbitofrontal cortex and value representation of future reward has been explored using the Cambridge Gambling Task (CGT), a task that is sensitive to both decision-making behaviour and orbitofrontal cortex functions (Rogers et al., 1999a,b). Using the CGT, Hutton et al. (2002) found that schizophrenia patients perform significantly poorer in decision-making behaviours than HCs. However, most of the aforementioned findings come from studies that recruited patients with chronic schizophrenia (Evans, Bowman, & Turnbull, 2005; Kester et al., 2006; Shurman, Horan, & Ntuechterlein, 2005; Turnbull, Evans, Kemish, Park, & Bowman, 2006). Therefore, it is not yet clear whether the deficits demonstrated in delay-discounting and decision-making behaviours are due to the psychopathology of the illness or due to medication side effects.

The study of patients with first-onset, medication-naïve schizophrenia or at-risk individuals prone to psychosis, such as individuals with schizotypal personality disorder (SPD) features, may provide a better alternative for the examination of delay-discounting and decision-making behaviours than the study of patients with chronic schizophrenia. Recent findings suggest that individuals with SPD features share similar, *albeit* milder, deficits in cognitive, emotional, and psychosocial functions to those observed in chronic schizophrenia (Barrantes-Vidal, Lewandowski, & Kwapil, 2010; Chan et al., 2011). Moreover, SPD features can be further divided into two subtypes, namely positive SPD features and negative SPD features (Vollema & Vandenbosch, 1995; Wang, Neumann, Shum, & Chan, 2012). Empirical findings suggest that individuals with positive and negative SPD features show different patterns of neurocognitive functioning, with negative SPD features individuals showing poorer neurocognitive functioning compared with individuals with positive SPD features and HCs (Shrira & Tsakanikos, 2009). However, little is known about delay discounting, decision-making, and working memory functions in these at-risk individuals.

The present study, therefore, aimed to investigate whether individuals with SPD features are impaired in their value representation of future rewards and decision-making behaviours, and whether these functions are associated with working memory performance. It was hypothesised that individuals with SPD features would (a) devalue future rewards more than HCs, (b) show impaired decision-making performance relative to HCs, and that (c) their delay-discounting rate would be inversely related to working memory function. The nature of SPD symptoms were also examined to determine whether there were any differences in the hypothesised effects between those with positive and those with negative SPD features.

Method

Participants

The Schizotypal Personality Questionnaire (SPQ; Chen, Hsiao, & Lin, 1997; Raine, 1991) was used to screen participants with and without SPD features among undergraduates at North China Electric Power University. Individuals who scored in the top 10% (SPQ score > 36) on the SPQ were classified as having SPD features and those scoring in the lower 10% (SPQ score < 17) were classified as HCs (Raine, 1991). Participants with a history of psychiatric and neurological disorders, head injury, or substance abuse were excluded. A total of 44 participants with SPD features and 22 HCs were recruited. This study was approved by the ethics committee of the Institute of Psychology, Chinese Academy Sciences, which conforms to the provisions of the Declaration of Helsinki. Written informed consent was obtained prior to participation. Each participant received ¥15 RMB after completing all the measurements.

The SPQ consists of three factors: cognitive-perceptual, interpersonal, and disorganised (Raine et al., 1994). A cluster analysis using the three factor scores of the SPQ was performed on the SPD features group to generate the two classification subtypes, a negative SPD features group, characterised by interpersonal difficulties, (N-SPD group) and a positive SPD features group, characterised by cognitive-perceptual difficulties and disorganised behaviour (P-SPD group; see Table 1). The short form of the Wechsler Adult Intelligence Scale—Chinese Version was applied to estimate the intelligence quotient (IQ) of the participants (Gong, 1992). Finally, all three groups were matched on age, education, gender, and IQ estimate (see Table 1).

Table 1 Demographic of Healthy Control and Participants with Schizotypal Personality Disorder

Variable	HC (n = 22)	P-SPD (n = 28)	N-SPD (n = 16)	Significant level[a]
Male, n (%)	9 (40.9%)	13 (46.4%)	6 (37.5%)	χ^2 (2) = 0.358, p = .836
Age, mean (*SD*),years	20.55 (2.11)	20.79 (1.50)	20.13 (1.70)	F(2) = 0.707, p = .497
Education, mean (*SD*),years	14.18 (1.76)	14.68 (1.39)	14.13 (1.63)	F(2) = 0.882, p = .419
Right-handedness, n (%)	22 (100%)	28 (100%)	16 (100%)	/
IQ, mean (*SD*)	126.82 (8.89)	128.82 (6.77)	126.06 (9.88)	F(2) = 0.666, p = .518
Schizotypal Personality Questionnaire				
SPQ score, mean (*SD*)	11.18 (3.95)	41.71 (4.25)	48.31 (6.42)	F(2) = 359.533, p < .0001
Cognitive-perceptional score, mean (*SD*)	5.50 (2.74)	20.46 (2.97)	21.5 (5.21)	F(2) = 135.922, p < .0001
Interpersonal score, mean (*SD*)	3.68 (2.88)	14.68 (3.12)	22.88 (3.03)	F(2) = 194.569, p < .0001
Disorganized score, mean (*SD*)	2.59 (1.59)	10.18 (2.31)	10.38 (2.96)	F(2) = 82.370, p < .0001
Working memory				
Digit forward, mean (*SD*)	9.36 (1.29)	9.14 (1.208)	8.75 (1.00)	F(2) = 1.235, p = .298
Digit backward, mean (*SD*)	7.64 (1.73)	7.54 (1.50)	7.19 (1.68)	F(2) = 0.377, p = .688
Digit total, mean (*SD*)	17.00 (2.45)	16.68 (2.23)	15.94 (2.38)	F(2) = 0.978, p = .382
LNS: correct counts, mean (*SD*)	18.64 (3.77)	18.46 (4.31)	17.94 (3.44)	F(2) = 0.154, p = .858
LNS: longest counts, mean (*SD*)	7.05 (1.21)	7.32 (2.16)	6.69 (1.14)	F(2) = 0.736, p = .483
Average Z-score, mean (*SD*)	0.10 (0.70)	0.05 (0.70)	–0.23 (–0.7)	F(2) = 1.122, p = .332

Note. HC, healthy controls; IQ, intelligence quotient; LNS, Letter–Number Span; N-SPD, participants with schizotypal personality disorders who had both higher positive semiotic score and higher negative semiotic score; P-SPD, participants with schizotypal personality disorders who had only higher positive semiotic score; *SD*, standard deviation; SPD score, score of schizotypal personality disorders.
[a]Two tailed.

Materials

The Monetary-Choice Questionnaire (MCQ)

The MCQ was used to measure the delay-discounting rate, κ, of various rewards in the future, reflecting the extent of devaluation of future rewards (Kirby et al., 1999). It consists of 27 questions, each containing two reward options: a smaller immediate reward (SIR), which can be obtained immediately; or a larger delayed reward (LDR), which would be delivered after several days delay (e.g., "Would you like to get ¥31 RMB instantly or ¥85 RMB after 7 days?"). To examine the effect of LDR magnitude to the discount rate κ, three kinds of LDRs (large: ¥75~85 RMB; medium: C50~60 RMB; and small: ¥25~35 RMB) were measured using the MCQ, whereas the SIRs ranged between ¥11 RMB and ¥80 RMB. The delay-discounting rate of the three LDRs were calculated by the algorithm suggested by Kirby (2000).

The CGT

The CGT is a standardised task designed to examine decision-making (Rogers et al., 1999a,b). In each trial, 10 red or blue boxes were displayed on a touchscreen, and the participant was asked to guess which box a yellow ball was hidden in beforehand and to touch the corresponding box colour. Meanwhile, the participants were required to place a bet on their choice according to five fixed percentiles (5, 25, 50, 75, 95) based on their temporal points. These percentiles appeared in either a sort ascending or sort descending order. If the participant wins, he would receive the points, but if he loses, he would lose the points.

The three indices measured in the CGT were deliberation time, quality of decision-making, and risk adjustment (Hutton et al., 2002). Deliberation time was defined as the speed of decision-making. Quality of decision-making was defined as the proportion of the colour leading to a win, which was chosen by the participants. Risk adjustment was defined as the average ratio that the participants bet based on their current score.

Working Memory

Number span in reverse order

The number span in reverse order of the Wechsler Adult Intelligence Scale—Chinese version was applied. Nine trials were contained in this task. Each trial consisted of several numbers ranging from 1 to 9 displayed in random order. The number of digits increases in each trail. The longest trial contains all the nine numbers. Participants were asked to repeat each string of numbers in reverse order after hearing them (Gong, 1992).

Letter–Number Span (Chinese version)

For this task, participants were required to listen to a string of characters composed of several digits and Chinese characters, which were used for the calendar in ancient China, with each one read out at a separate time point. Participants were then required to repeat the numbers first in numerical order, followed by the characters in chronological order. Unlike the original English version (Gold, Carpenter, Randolph, Goldberg, & Weinberger, 1997), the version used in the current study replaced the English letters with the 10 Heavenly Stems of Chinese era, a Chinese calendar method (Chan et al., 2008). The 10 Heavenly Stems contain 10 Chinese characters (Jia, Yi, Bing, Ding, Wu, Ji, Geng, Xin, Ren, Kui) that are used to set the order, analogous to "A–F." For example, the correct order of the sequence "Ding 8 Yi 2" is "2 8 Yi Ding." The entire task consisted of eight levels, and each level contained four items. If a participant fails to repeat all four items of a level, the task would be terminated and the total number of correct trials as well as the longest sequence attained by the participant would be counted as the final score.

Data Analysis

Demographics of the three participant groups were compared using one-way analyses of variance (ANOVAs) for continuous variables and chi-square tests for categorical variables to ensure matching between the three groups. Z-scores for each index of working memory were calculated and averaged. The delay-discounting rate, κ, was compared among groups using a 3×3 mixed analysis of covariance (ANCOVA), with group status (HC vs positive SPD vs negative SPD) as the between-groups factor, LDR size (small vs medium vs large) as the within-subjects factor, and working memory performance (the average Z-score of each index) as the covariate. A $3 \times 2 \times 4$ mixed ANOVA, with group status as the between-groups factor, and the order of bet change (ascending vs descending) and the decision (blue or red box) ratio (6:4 vs 7:3 vs 8:2 vs 9:1) as the within-subjects factors, was conducted to compare the three groups on the three indices of the CGT. If Mauchly's test of sphericity is significant, the Greenhouse–Geisser method would be used to adjust the degrees of freedom. For *post hoc* pairwise comparisons, the Bonferoni correction method was used (corrected *p*-values are reported). Spearman's correlation coefficients between κ and working memory performance, as well as Pearson's correlation coefficients between delay-discounting rate and performance on the CGT were computed, respectively. The delay-discounting rate, κ, was log-transformed to improve the data's normality prior to the ANCOVA. Finally, all analyses were conducted using SPSS 17.0 (IBM, Armonk, NY, USA).

Results

Delay-discounting Rate

The results of the 3×3 mixed ANCOVA demonstrated that both the main effects of group status ($F[2, 62] = 4.44$, $p = .016$, $\eta = 0.13$) and LDR size ($F[1.69, 104.91] = 69.35$, $p < .001$, $\eta = 0.53$) were significant, whereas their interaction was not ($F[3.38, 104.91] = 1.99$, $p = .110$, $\eta = 0.06$).

For the small LDR size, *post hoc* analysis revealed that the delay-discounting rate of the HC group was significantly smaller than the positive SPD features group ($p = .017$, Cohen's $d = 0.68$) and the negative SPD features group ($p = .028$, Cohen's $d = 0.75$). However, for the medium LDR size, the delay-discounting rate of the negative SPD features group was significantly larger than the HC group ($p = .02$, Cohen's $d = 0.86$), whereas the positive SPD features group was not different to the HC group. Finally, for the large LDR size, the delay-discounting rates, κ, of the three groups were not significantly different (see Figure 1).

The correlations between working memory performance and delay-discounting rate are shown in Table 2. The reverse digit score, the number of correct counts, and the longest count attained in the Letter–Number Span were significantly and positively correlated with the delay-discounting rate for the small LDR size in the negative SPD features group. The longest count was negatively correlated with the delay-discounting rate for the medium LDR size and large LDR size in the positive SPD features group. Importantly, there were no significant correlations between working memory and delay-discounting rate for the HCs.

Deliberation Time

The results of the $3 \times 2 \times 4$ ANOVA demonstrated that no significant main or interaction effects, except for a main effect of ratio ($F[3, 189] = 8.76$, $p < .001$), were found for deliberation time (see Table 3). Nonetheless, to investigate possible difference between people with schizotypal personality features and HC, a $2 \times 2 \times 4$ mixed ANOVA, which included the group (SPD vs HC) as between-groups factor, the order of bet change (ascending vs descending), and the decision (blue or red box) ratio (6:4 vs 7:3 vs 8:2 vs 9:1) as the within-subjects factors, was conducted. Results demonstrated that the whole SPD group (all the participants with SPD features, $n = 44$) took a longer time to make a decision than the HCs ($F[1, 64] = 4.09$, $p = .047$, $\eta = 0.06$).

Quality of Decision

Averaging over groups, the results demonstrated that the higher the decision ratio was (e.g., 9:1 was preferable than 6:4), the higher the proportion of the option with the most likely outcome ($F[3, 189] = 24.86$, $p < .001$, $\eta = 0.28$). Moreover, the HCs performed similarly on quality of decision to the participants with positive and negative SPD features ($F[2, 65] = 0.42$, $p = .657$, $\eta = 0.01$). No significant interaction effect was found (refer to Table 3).

Risk Adjustment

The results showed that all individuals bet more of their points under higher ratios than under lower ratios ($F[3, 189] = 124.96$, $p < .001$, $\eta = 0.67$), and in descending rather than ascending conditions ($F[1, 189] = 53.61$, $p < .001$, $\eta = 0.46$). The main effect of group was not significant ($F[2, 65] = 1.40$, $p = .255$, $\eta = 0.04$), and no significant interaction effect was found (refer to Table 3).

All participants tended to bet smaller amounts depending on the current total points on sort ascending ($F[1, 59] = 4.21$, $p = .045$, $\eta = 0.07$). The effect of order condition (ascending vs descending) did not seem to interact with group (HC vs P-SPD vs N-SPD), $F(2, 59) = 0.05$, $p = .995$, $\eta = 0.002$). Consequently, the bet model of "impulsive" or "risk-taking" occurred on a similar frequency across all groups. Finally, the choice preference of the SPD feature participants and its two subgroups resembled HCs in the immediate gambling task ($F[2, 59] = 0.55$, $p = .583$, $\eta = 0.02$).

Correlations Between the Delay-discounting Rate and the CGT

As shown in Table 4, the correlation pattern between the delay-discounting rate and the performance on the CGT was different

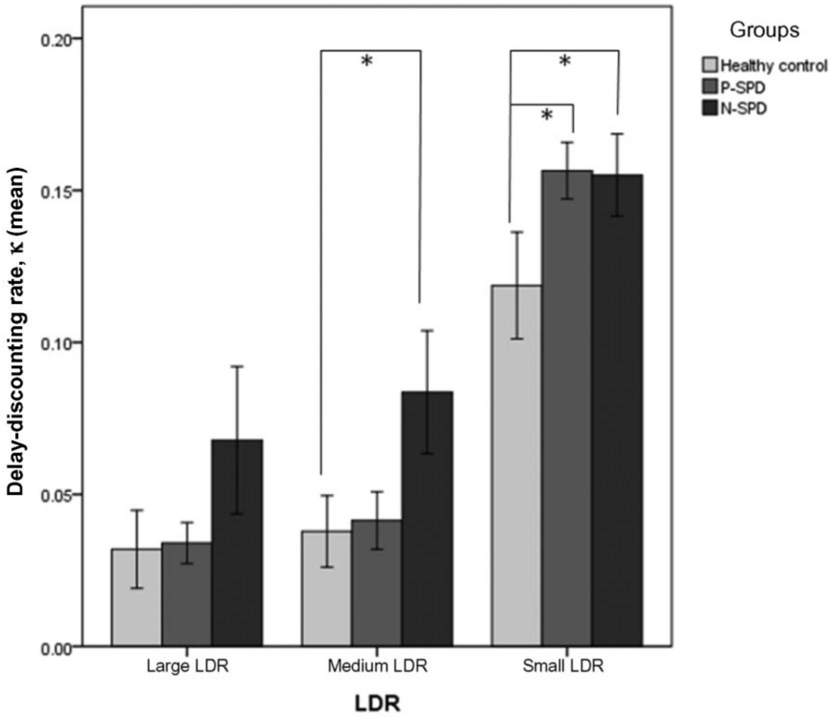

Figure 1 Delayed-discounting Rate (Raw Data) of Participants on Three LDR Conditions. For the Small LDR, the Delayed-discounting Rate, κ, of Both SPD Feature Subgroups Was Higher Than That of the Healthy Controls, Whereas for the Medium LDR, the κ of Participants with Negative SPD Features Was Higher Than That of the Healthy Controls. Error Bars Represent the Standard Error of the Mean. **p* < .05. LDR, Larger Delayed Reward; N-SPD, Participants With Schizotypal Personality Disorders Who Had Both Higher Positive Semiotic Score and Higher Negative Semiotic Score; P-SPD, Participants With Schizotypal Personality Disorders Who Had Only Higher Positive Semiotic Score; SPD, Schizotypal Personality Disorder.

Table 2 The Correlation of Delayed Discount Rate and Working Memory

Group	DDR	Digit forward	Digit backward	Digit total	LNS: correct counts	LNS: longest counts	Average Z-score
HC = 22	L-κ	–0.015	0.082	0.059	0.141	0.028	0.107
	M-κ	0.323	0.022	0.168	0.309	0.209	0.31
	S-κ	0.375	–0.011	0.223	0.117	–0.111	0.22
P-SPD = 28	L-κ	0.172	0.014	0.101	–0.343	–0.401*	–0.164
	M-κ	0.046	0.123	0.068	–0.34	–0.481*	–0.213
	S-κ	0.168	0.11	0.194	–0.181	–0.172	0.031
N-SPD = 16	L-κ	0.401	–0.187	–0.04	0.405	0.22	0.048
	M-κ	0.365	–0.01	0.04	0.29	0.163	0.121
	S-κ	0.573*	0.18	0.358	0.635**	0.559*	0.488

Note. DDR, delay-discounting rate; HC, healthy controls; L-κ, DDR of large delayed reward; M-κ, DDR of medium delayed reward; N-SPD, participants with schizotypal personality disorders who had both higher positive semiotic score and higher negative; P-SPD, participants with schizotypal personality disorders who had only higher positive semiotic score; semiotic score; S-κ, DDR of small delayed reward.
**p* < .05, ***p* < .01.

between the three groups. In the HCs, the delay-discounting rate to the small reward positively correlated with the risk adjustment index of the CGT. Furthermore, the delay-discounting rate of the positive SPD features group positively correlated with the indices of the CGT. However, the negative SPD features group showed a negative correlation with the delay-discounting rate.

Discussion

In this study, we found that individuals with SPD features, especially those with negative SPD features, had a higher delay-discounting rate, κ, compared with HCs for the small and medium LDR size, although the interaction between group and LDR size was not significant. The delay-discounting rate, κ, of

Table 3 The Performances of Cambridge Gambling Task Among the Three Groups

Indices of Cambridge Gambling Task	HC (*n* = 22)	P-SPD (*n* = 28)	N-SPD (*n* = 16)	Significant level[a]
Deliberation time (ascending, 6:4)	1863.24 (744.49)	2341.21 (1131.55)	2185.57 (858.49)	F(2,63) = 2.034, *p* = .139
Deliberation time (ascending, 7:3)	1809.34 (622.59)	2042.76 (767.44)	2077.7 (830.36)	
Deliberation time (ascending, 8:2)	1834.57 (698.44)	2239.32 (957.36)	2149.45 (751.54)	
Deliberation time (ascending, 9:1)	1727.77 (533.66)	1991.96 (692.78)	1870.94 (762.39)	
Deliberation time (descending, 6:4)	1995.24 (794.19)	2201.04 (939.41)	2505.52 (1321.32)	
Deliberation time (descending, 7:3)	1827.25 (682.46)	1977.93 (981.15)	2079.06 (827.04)	
Deliberation time (descending, 8:2)	1748.64 (520.03)	2053.71 (1068.56)	2053.56 (753.58)	
Deliberation time (descending, 9:1)	1645.26 (422.9)	1800.74 (728.83)	1998.65 (760.25)	
Quality of decision-making (ascending, 6:4)	0.85 (0.18)	0.84 (0.22)	0.87 (0.22)	F(2,63) = 0.422, *p* = .657
Quality of decision-making (ascending, 7:3)	0.93 (0.11)	0.88 (0.21)	0.95 (0.08)	
Quality of decision-making (ascending, 8:2)	0.96 (0.1)	0.92 (0.15)	0.96 (0.09)	
Quality of decision-making (ascending, 9:1)	0.97 (0.09)	0.95 (0.13)	0.98 (0.04)	
Quality of decision-making (descending, 6:4)	0.91 (0.14)	0.89 (0.14)	0.84 (0.18)	
Quality of decision-making (descending, 7:3)	0.96 (0.1)	0.91 (0.17)	0.91 (0.14)	
Quality of decision-making (descending, 8:2)	0.97 (0.06)	0.97 (0.08)	0.95 (0.1)	
Quality of decision-making (descending, 9:1)	0.98 (0.06)	0.99 (0.05)	0.97 (0.06)	
Risk adjustment (ascending, 6:4)	0.3 (0.13)	0.31 (0.18)	0.26 (0.14)	F(2,63) = 1.398, *p* = .255
Risk adjustment (ascending, 7:3)	0.4 (0.14)	0.42 (0.18)	0.37 (0.18)	
Risk adjustment (ascending, 8:2)	0.5 (0.16)	0.53 (0.2)	0.48 (0.2)	
Risk adjustment (ascending, 9:1)	0.58 (0.22)	0.66 (0.27)	0.54 (0.27)	
Risk adjustment (descending, 6:4)	0.48 (0.24)	0.47 (0.19)	0.42 (0.17)	
Risk adjustment (descending, 7:3)	0.58 (0.22)	0.62 (0.17)	0.54 (0.18)	
Risk adjustment (descending, 8:2)	0.69 (0.19)	0.73 (0.15)	0.67 (0.17)	
Risk adjustment (descending, 9:1)	0.76 (0.19)	0.82 (0.17)	0.75 (0.18)	

Note. HC, healthy controls; N-SPD, participants with schizotypal personality disorders who had both higher positive semiotic score and higher negative semiotic score; P-SPD, participants with schizotypal personality disorders who had only higher positive semiotic score.
[a]Two tailed; only the main effect of group was displayed here.

Table 4 The Correlations Between Delayed-discounting Rate κ and the Performances of Cambridge Gambling Task Among the Three Groups

	L-κ	M-κ	S-κ	
Risk adjustment (ascending, 6:4)	0.516*	0.404	0.327	HC = 22
Quality of decision-making (ascending, 8:2)	–0.465*	–0.304	–0.179	
Risk adjustment (descending, 6:4)	0.088	0.102	0.504*	
Risk adjustment (descending, 7:3)	0.068	0.066	0.507*	
Risk adjustment (descending, 8:2)	0.088	0.023	0.481*	
Risk adjustment (descending, 9:1)	0.338	0.406	0.479*	
Quality of decision-making (ascending, 6:4)	–0.508**	–0.796**	–0.372	P-SPD = 28
Deliberation time (ascending, 6:4)	0.392*	0.519**	0.549**	
Deliberation time (ascending, 7:3)	0.401*	0.488**	0.472*	
Deliberation time (ascending, 8:2)	0.411*	0.228	0.279	
Deliberation time (ascending, 9:1)	0.374	0.421*	0.430*	
Risk adjustment (ascending, 6:4)	–0.509*	–0.580*	–0.204	N-SPD = 16
Risk adjustment (ascending, 7:3)	–0.479	–0.519*	–0.009	
Deliberation time (descending, 9:1)	–0.443	–0.528*	–0.408	

Note. HC, healthy controls; L-κ, DDR of large delayed reward; M-κ, DDR of medium delayed reward; N-SPD, participants with schizotypal personality disorders who had both higher positive semiotic score and higher negative; P-SPD, participants with schizotypal personality disorders who had only higher positive semiotic score; S-κ, DDR of small delayed reward.
*$p < .05$, **$p < .01$; only the significant correlated coefficients were displayed here.

individuals with SPD features correlated significantly with their working memory, mainly in the Letter–Number Span Test, whereas this pattern was not observed in HCs. Nonetheless, individuals with SPD features did not perform more poorly on the CGT relative to HCs, except for a slightly but significantly slower decision-making time.

A higher delay-discounting rate suggests that individuals with SPD features value future rewards to a lesser extent than HCs, which may lead to more myopic or impulsive behaviour. This finding is consistent with those found in individuals with schizophrenia, but appears to be less severe in size (Heerey, Matveeva, & Gold, 2011; Heerey et al., 2007). Our findings add to prior research by suggesting that this problem may already be present, to some extent, prior to the onset of schizophrenia in high-risk individuals.

On one hand, the devaluation of future rewards in the SPD features group may be due to their tendency to dampen the pleasure of future reward. The lack of motivation seen in schizophrenia patients on effort–cost computation lends some support to this view (Fervaha et al., 2013; Gold et al., 2013). Furthermore, prior reports have demonstrated that individuals with SPD features exhibit deficits on pleasure function, especially anticipatory pleasure (Chan et al., 2012; Gooding & Pflum, 2012; Shi et al., 2012).

On the other hand, the delay-discounting rate was also related to working memory, which is poor in individuals with SPD features (Siever et al., 2002). Indeed, a previous study has shown that working memory training can be effective in decreasing the delay-discounting rate of participants (Bickel, Yi, Landes, Hill, & Baxter, 2011). Empirical findings suggest that working memory is associated with the functions of the dorsolateral cortex, which integrates time and value information for decision-making (Gold et al., 2008). Moreover, higher delay-discounting rates and preference for immediate gratification have been linked to dysfunctions of the frontal lobe, especially the dorsolateral prefrontal cortex (Bjork et al., 2009; Li et al., 2013; Yu, 2012).

Individuals with SPD features have been found to exhibit general deficits in working memory performance (Mitropoulou et al., 2005; Park & McTigue, 1997; Siever et al., 2002); however, our results did not reveal any difference in working memory function between individuals with SPD features and HCs. This discrepancy may be partially explained by the small sample size and non-comprehensive measurement of working memory in the current study. Nevertheless, a significant negative correlation was found between working memory and delay-discounting rate in individuals with positive SPD features, which was not observed in HCs. Thus, the preference for immediate gratification may be partly related to working memory dysfunction in individuals with positive SPD features. This finding is consistent with the correlations observed in previous studies on patients with schizophrenia (Heerey et al., 2007, 2011; Wing, Moss, Rabin, & George, 2012). This correlation lends support to the perspective that the larger delay-discounting rate of individuals with SPD features may be affected by their working memory.

The current study failed to find any significant difference between the SPD feature groups and the HCs on the CGT, although all the participants with SPD features performed significantly slower than the HC group. It may be the case that a performance difference between groups would be found if the deliberation time was held constant across groups or if the SPD feature groups were required to make a decision under a time pressure. As stated above, the limitation of this study is the small sample size, which may have led to the non-significant results. However, it should be noted that the immediate gambling task employed in the present study measures the complete decision-making process that is supposed to engage cognitive resources. Hence, the decision-making process of the SPD groups may be relatively intact or slightly impaired when given enough time to make the deliberation, whereas the subprocesses such as future reward representation may suffer from a deficit.

Contrary to our a priori hypothesis, the delay-discounting rate of the negative SPD group positively correlated with working memory. However, this result is consistent with a previous study in which prominent negative symptoms in schizophrenia patients were associated with higher delay-discounting rate and better working memory (Heerey et al., 2007). Moreover, the present study showed that the correlation between delay-discounting rate and performance on the CGT among the negative SPD group is also negative, meaning that a higher delay-discounting rate was related to better decision-making. This correlation pattern parallels the correlation between the delay-discounting rate and the working memory among the negative SPD group. However, it should be mentioned that larger delay discounting may not only be influenced by better working memory, but also by the deficits in affect and emotion, which are related to negative schizophrenia symptoms and negative SPD features. Shi et al. (2012) found that participants with negative SPD features suffered deficits in anticipatory pleasure, whereas participants with positive features had normal or better anticipatory pleasure compared with HCs. Anhedonia and other emotion problems that are absent in this study of the negative SPD group may be a cause of this correlation pattern, which should be taken into consideration in future research.

Conclusion

In conclusion, our results demonstrated that individuals with SPD features, especially those with negative SPD features, devalued future rewards more than HCs. These deficits are related to working memory function and time perception. However, the decision-making process of people with SPD features appears to be relatively intact.

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References

Barrantes-Vidal, N., Lewandowski, K. E., & Kwapil, T. R. (2010). Psychopathology, social adjustment and personality correlates of schizotypy clusters in a large nonclinical sample. *Schizophrenia Research*, *122*(1–3), 219–225. doi:10.1016/j.schres.2010.01.006

Bickel, W. K., Yi, R., Landes, R. D., Hill, P. F., & Baxter, C. (2011). Remember the future: Working memory training decreases delay discounting among stimulant addicts. *Biological Psychiatry*, *69*(3), 260–265. doi:10.1016/j.biopsych.2010.08.017

Bjork, J. M., Momenan, R., & Hommer, D. W. (2009). Delay discounting correlates with proportional lateral frontal cortex volumes. *Biological Psychiatry*, *65*(8), 710–713. doi:10.1016/j.biopsych.2008.11.023

Chan, R. C. K., Wang, Y., Deng, Y. Y., Zhang, Y. N., Yiao, X. L., & Zhang, C. (2008). The development of a Chinese equivalence version of Letter–Number Span Test. *Clinical Neuropsychologist*, *22*(1), 112–121. doi:10.1080/13825580601025957

Chan, R. C. K., Wang, Y., Yan, C., Zhao, Q., McGrath, J., Hsi, X. L., & Stone, W. S. (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), doi:10.1371/journal.pone.0034275

Chan, R. C. K., Yan, C., Qing, Y. H., Wang, Y., Wang, Y. N., Ma, Z., . . . Yu, X. (2011). Subjective awareness of everyday dysexecutive behavior precedes "objective" executive problems in schizotypy: A replication and extension study. *Psychiatry Research*, *185*(3), 340–346. doi:10.1016/j.psychres.2010.06.009

Chen, W. J., Hsiao, C. K., & Lin, C. C. H. (1997). Schizotypy in community samples: The three-factor structure and correlation with sustained attention. *Journal of Abnormal Psychology*, *106*(4), 649–654. doi:10.1037/0021-843x.106.4.649

Evans, C. E. Y., Bowman, C. H., & Turnbull, O. H. (2005). Subjective awareness on the Iowa Gambling Task: The key role of emotional experience in schizophrenia. *Journal of Clinical and Experimental Neuropsychology*, *27*(6), 656–664. doi:10.1080/13803390490918354

Fervaha, G., Graff-Guerrero, A., Zakzanis, K. K., Foussias, G., Agid, O., & Remington, G. (2013). Incentive motivation deficits in schizophrenia reflect effort computation impairments during cost–benefit decision-making. *Journal of Psychiatric Research*, *47*(11), 1590–1596. doi:10.1016/j.jpsychires.2013.08.003

Gold, J. M., Carpenter, C., Randolph, C., Goldberg, T. E., & Weinberger, D. R. (1997). Auditory working memory and Wisconsin Card Sorting Test performance in schizophrenia. *Archives of General Psychiatry*, *54*(2), 159–165. doi:10.1001/archpsyc.1997.01830140071013.

Gold, J. M., Strauss, G. P., Waltz, J. A., Robinson, B. M., Brown, J. K., & Frank, M. J. (2013). Negative symptoms of schizophrenia are associated with abnormal effort–cost computations. *Biological Psychiatry*, *74*(2), 130–136. doi:10.1016/j.biopsych.2012.12.022

Gold, J. M., Waltz, J. A., Prentice, K. J., Morris, S. E., & Heerey, E. A. (2008). Reward processing in schizophrenia: A deficit in the representation of value. *Schizophrenia Bulletin*, *34*, 835–847. doi:10.1093/schbul/sbn068

Gong, Y. X. (1992). *Manual of Wechsler adult intelligence scale—Chinese version*. Changsha, China: Chinese Map Press.

Gooding, D. C., & Pflum, M. J. (2012). The nature of diminished pleasure in individuals at risk for or affected by schizophrenia. *Psychiatry Research*, *198*(1), 172–173. doi:10.1016/j.psychres.2011.07.029

Heerey, E. A., Bell-Warren, K. R., & Gold, J. M. (2008). Decision-making impairments in the context of intact reward sensitivity in schizophrenia. *Biological Psychiatry*, *64*, 62–69. doi:10.1016/j.biopsych.2008.02.015

Heerey, E. A., Matveeva, T. M., & Gold, J. M. (2011). Imagining the future: Degraded representations of future rewards and events in schizophrenia. *Journal of Abnormal Psychology*, *120*(2), 483–489. doi:10.1037/a0021810

Heerey, E. A., Robinson, B. M., McMahon, R. P., & Gold, J. M. (2007). Delay discounting in schizophrenia. *Cognitive Neuropsychiatry*, *12*(3), 213–221. doi:10.1080/13546800601005900

Hirsh, J. B., Morisano, D., & Peterson, J. B. (2008). Delay discounting: Interactions between personality and cognitive ability. *Journal of Research in Personality*, *42*, 1646–1650. doi:10.1016/j.jrp.2008.07.005

Hutton, S. B., Murphy, F. C., Joyce, E. M., Rogers, R. D., Cuthbert, I., Barnes, T. R. E., . . . Robbions, T. W. (2002). Decision making deficits in patients with first-episode and chronic schizophrenia. *Schizophrenia Research*, *55*, 249–257. doi:10.1016/S0920-9964(01)00216-X

Kester, H. M., Sevy, S., Yechiam, E., Burdick, K. E., Cervellione, K. L., & Kumra, S. (2006). Decision-making impairments in adolescents with early-onset schizophrenia. *Schizophrenia Research*, *85*(1–3), 113–123. doi:10.1016/j.schres.2006.02.028

Kirby, K. N. (1997). Bidding on the future: Evidence against normative discounting of delayed rewards. *Journal of Experimental Psychology: General*, *126*(1), 54–70. doi:10.1037/0096-3445.126.1.54

Kirby, K. N. (2000). *Instructions for inferring discount rates from choices between immediate and delayed rewards*. Unpublished manuscript. Williamstown, MA: Williams College.

Kirby, K. N., & Marakovic, N. N. (1996). Delay-discounting probabilistic rewards: Rates decrease as amounts increase. *Psychonomic Bulletin & Review*, *3*(1), 100–104. doi:10.3758/bf03210748

Kirby, K. N., Petry, N. M., & Bickel, W. K. (1999). Heroin addicts have higher discount rates for delayed rewards than non-drug-using controls. *Journal of Experimental Psychology. General*, *128*, 78–87. doi: http://dx.doi.org/10.1037/0096-3445.128.1.78

Li, N., Ma, N., Liu, Y., He, X. S., Sun, D. L., Fu, X. M., . . . Zhang, D. R. (2013). Resting-state functional connectivity predicts impulsivity in economic decision-making. *Journal of Neuroscience*, *33*(11), 4886–4895. doi:10.1523/jneurosci.1342-12.2013

Mazur, J. E. (1987). An adjusting procedure for studying delayed reinforcement. In M. L. Commons, J. E. Mazur, J. A. Nevin, & H. Rachlin (Eds.), *The effect of delay and of intervening events on reinforcement value* (pp. 55–73). Hillsdale, NJ: Lawrence Erlbaum Associates.

Mitropoulou, V., Harvey, P. D., Zegarelli, G., New, A. S., Silverman, J. M., & Siever, L. J. (2005). Neuropsychological performance in schizotypal personality disorder: Importance of working memory. *American Journal of Psychiatry*, *162*(10), 1896–1903. doi:10.1176/appi.ajp.162.10.1896

Park, S., & McTigue, K. (1997). Working memory and the syndromes of schizotypal personality. *Schizophrenia Research*, *26*(2–3), 213–220. doi:10.1016/s0920-9964(97)00051-0

Paulus, M. P. (2007). Decision-making dysfunctions in psychiatry- altered homeostatic processing? *Science*, *318*, 602–606. doi:10.1126/science.1142997

Raine, A. (1991). The SPQ—a scale for the assessment of schizotypal personality based on DSM-III-R criteria. *Schizophrenia Bulletin*, *17*(4), 555–564. doi:10.1093/schbul/17.4.555

Raine, A., Reynolds, C., Lencz, T., Scerbo, A., Triphon, N., & Kim, D. (1994). Cognitive-perceptual, interpersonal, and disorganized features of schizotypal personality. *Schizophrenia Bulletin*, *20*(1), 191–201. doi:10.1093/schbul/20.1.191

Rogers, R. D., Everitt, B. J., Baldacchino, A., Blackshaw, A. J., Swainson, R., Wynne, K., . . . Robbins, T. W. (1999a). Dissociable deficits in the decision-making cognition of chronic amphetamine abusers, opiate abusers, patients with focal damage to prefrontal cortex, and tryptophan-depleted normal volunteers: Evidence for monoaminergic mechanisms. *Neuropsychopharmacology*, *20*, 322–339. doi:10.1016/S0893-133X(98)00091-8

Rogers, R. D., Owen, A. M., Middleton, H. C., Williams, E. J., Pickard, J. D., Sahakian, B. J., & Robbins, T. W. (1999b). Choosing between small, likely rewards and large, unlikely rewards activates inferior and orbital prefrontal cortex. *Journal of Neuroscience*, *19*(20), 9029–9038.

Rosati, A. G., Stevens, J. R., Hare, B., & Hauser, M. D. (2007). The evolutionary origins of human patience: Temporal preferences in chimpanzees, bonobos, and human adults. *Current Biology*, *17*(19), 1663–1668. doi:10.1016/j.cub.2007.08.033

Shi, Y. F., Wang, Y., Cao, X. Y., Wang, Y., Wang, Y. N., Zong, J. G., . . . Chan, R. C. K. (2012). Experience of pleasure and emotional expression in individuals with schizotypal personality features. *PLoS ONE*, *7*(5), e34147. doi:10.1371/journal.pone.0034147

Shrira, A., & Tsakanikos, E. (2009). Latent inhibition as a function of positive and negative schizotypal symptoms: Evidence for a bi-directional model. *Personality and Individual Differences*, *47*(5), 434–438. doi:10.1016/j.paid.2009.04.015

Shurman, B., Horan, W. P., & Ntuechterlein, K. H. (2005). Schizophrenia patients demonstrate a distinctive pattern of decision-making impairment on the Iowa Gambling Task. *Schizophrenia Research*, *72*(2–3), 215–224. doi:10.1016/j.schres.2004.03.020

Siever, L. J., Koenigsberg, H. W., Harvey, P., Mitropoulou, V., Laruelle, M., Abi-Dargham, A., . . . Buchsbaum, M. (2002). Cognitive and brain function in schizotypal personality disorder. *Schizophrenia Research*, *54*(1–2), 157–167. doi:10.1016/s0920-9964(01)00363-2

Turnbull, O. H., Evans, C. E. Y., Kemish, K., Park, S., & Bowman, C. H. (2006). A novel set-shifting modification of the Iowa Gambling Task: Flexible emotion-based learning in schizophrenia. *Neuropsychology*, *20*(3), 290–298. doi:10.1037/0894-4105.20.3.290

Vollema, M. G., & Vandenbosch, R. J. (1995). The multidimensionality of schizotypy. *Schizophrenia Bulletin*, *21*(1), 19–31. doi:10.1093/schbul/21.1.19

Wang, Y., Neumann, D., Shum, D. H. K., & Chan, R. C. K. (2012). A cross-validation study of clustering of schizotypy using a non-clinical Chinese sample. *Psychiatry Research*, *200*(1), 55–58. doi:10.1016/j.psychres.2012.03.026

Wing, V. C., Moss, T. G., Rabin, R. A., & George, T. P. (2012). Effects of cigarette smoking status on delay discounting in schizophrenia and healthy controls. *Addictive Behaviors*, *37*(1), 67–72. doi:10.1016/j.addbeh.2011.08.012

Yu, R. J. (2012). Regional white matter volumes correlate with delay discounting. *PLoS ONE*, *7*(2), e32595. doi:10.1371/journal.pone.0032595