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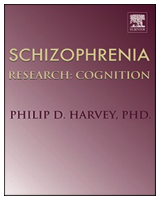

Research Paper

Decision-making under risk and its correlates in schizophrenia

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ABSTRACT

Schizophrenia spectrum disorders (SSD) are associated with pervasive cognitive impairments, including deficits in decision-making under risk. However, there is inconclusive evidence regarding specific mechanisms underlying altered decision-making patterns. In this study, participants (33 SSD and 28 non-SSD) completed the Columbia Card Task, an explicit risk-taking task, to better understand risk preference and adjustment in dynamic decision-making. We found that while there is no group difference in overall risk-taking, risk preference, or optimal decision-making, risk adjustment to contextual factors (e.g., loss probability) is blunted in SSD. We also found associations between risk-taking/suboptimal decision-making and disorganized symptoms, excited symptoms, and role functioning, but no associations between decision-making and working memory. These results suggest that during a complex, dynamic risk-taking task, individuals with SSD exhibit less adaption to changing information about risk, which may reflect risk imperception.

1. Introduction

Cognitive impairment is a core feature of schizophrenia spectrum disorders (SSD) and a key determinant of functional outcomes (Halverson et al., 2019; Kahn and Keefe, 2013; Kharawala et al., 2022; McCleery and Nuechterlein, 2019). One way in which these cognitive impairments manifest is in aspects of decision-making (Evans et al., 2015; Kurtz, 2005; Mosiołek et al., 2016; Sterzer et al., 2019). Particularly, considerable evidence suggests that decision-making under risk, an important aspect of cognitive functioning, is altered in schizophrenia (see Purcell et al., 2022 for review). In this context, *risk* refers to the degree of variance in all potential outcomes of a decision (Schonberg et al., 2011; Trepel et al., 2005). Mathematically, a normatively superior decision would entail maximizing the *expected value (EV)* of an outcome, calculated as the probability of a state occurring multiplied by the outcome of such a state (Trepel et al., 2005). However, leading decision theories suggest that individuals do not strictly adhere to normative EV maximization when evaluating choices (Kahneman and Tversky, 1979; Tversky and Kahneman, 1992). Rather, differences emerge in *risk preferences*, a latent construct depicting how risk-seeking or risk-averse an individual is (Dave et al., 2010; Pennings and Garcia, 2001; Weber and Milliman, 1997). While there is evidence of an association between cognitive abilities and risk preference differences, some studies suggest that this correlation may be spurious, and can be accounted for by the relationship between cognition and decision errors, such as choice inconsistency and randomness (Andersson et al., 2016; Mechera-Ostrovsky et al., 2022; Olschewski et al., 2018).

Likewise, empirical research has yielded mixed findings regarding whether schizophrenia is characterized by increased risk-seeking or risk-averse attitudes, suggesting that other mechanisms may underlie risky decision-making in schizophrenia (Purcell et al., 2022). A recent, novel theory—the risk imperception hypothesis—attempts to reconcile these mixed findings by positing that schizophrenia is characterized by *risk imperception*, a relative inability to integrate risk-related information to make optimal decisions, which precedes the formation of risk preferences (Purcell et al., 2022). Converging empirical evidence substantiates this notion (Albrecht et al., 2016; Hutton et al., 2002; Li et al., 2021; Pedersen et al., 2017). Specifically, many studies reported a difference in risk adjustment between groups. For instance, in one study, individuals with both chronic and first-episode psychosis adjusted their bets to a lesser extent in response to changing probability compared to controls (Hutton et al., 2002). Another study found that individuals with

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adolescent-onset schizophrenia made fewer optimal choices and adjusted their behavior less according to negative outcomes on the previous decision (Li et al., 2021).

Despite this work, much remains unknown about risky decision-making in schizophrenia. For example, to what extent are differences in risk-taking due to risk imperception versus other factors (e.g., risk preference)? How are risky decision-making deficits related to psychotic symptoms and functioning? Towards better understanding these issues, here, we aimed to examine patterns of risky decision-making among individuals with and without an SSD. To do so, we used the "hot" version of the Columbia Card Task (CCT), a risk-taking task developed by Figner et al. (2009), which to our knowledge, has not been used before with an SSD sample. Importantly, the CCT has several advantages compared to other risky decision-making paradigms, in that (1) as an explicit risk-taking task, no learning is involved in the CCT, and all risk-taking parameters are known or calculable; (2) different factors affecting risky decision-making, including probability and magnitude of loss, are analytically decomposable and unconfounded; (3) the task disentangles risk-taking from optimal normative choice, where choices with higher EV are not necessarily riskier (Figner et al., 2009). In addition, in the hot version of the CCT, risk dynamically increases with actions taken, and skin conductance responses suggest that the task elicits prevailingly affective—rather than purely deliberative—decision-making processes, which are associated with need-for-arousal and are largely independent of executive functioning (Figner et al., 2009).

Furthermore, in the current study, we aimed to evaluate correlates of risky decision-making, including working memory, psychotic symptom severity, and global functioning. We expected to replicate findings from Heerey et al. (2008) that degraded working memory in SSD might be associated with decreased ability to weigh probability information during risky decision-making. Past research using the CCT in non-SSD samples has also shown that decreased working memory is associated with increased risk-seeking (Buelow, 2015; Figner et al., 2009), thus creating an opportunity to test this in a clinical sample. Concurrently, in line with the *risk imperception* hypothesis, we hypothesized that disorganization, a symptom domain strongly linked to information synthesis (Minor and Lysaker, 2014; Ventura et al., 2010), would be associated with altered risk-taking in SSD. Moreover, consistent with other work examining risk-taking and SSD (Boka et al., 2020), we expected that excitement symptom severity—considering its association with increased impulsivity and treatment non-adherence—would be related to increased risk-taking (Sumich et al., 2013). Finally, for exploratory aims, we examined the association between real-world functioning and risky decision-making. Impairments in decision-making under risk are linked to deficits in future planning and various maladaptive risk-taking behaviors, including increased substance use, which are often observed in SSD and associated with negative health outcomes (Buelow, 2020). In the current study, we sought to explore whether differences in risk-taking patterns might be associated with functional outcomes, namely social and role functioning.

2. Methods

2.1. Participants

Participants were 33 SSD and 28 non-SSD individuals between the ages of 18–65 years (Table 1; see Supplemental for additional participant information). SSD participants met criteria for schizophrenia or schizoaffective disorder as determined with the Structured Clinical Interview for DSM-5 Disorders (SCID-5; First et al., 2015). All participants were clinically stable and had no medication change in the month prior to the study. Non-SSD participants were screened with SCID-5 and did not have any current psychiatric disorder, any current/past psychotic disorder, prior psychiatric hospitalization, or first-degree relatives with SSDs. This study was approved by the University of Rochester's Research Subjects Review Board.

Table 1
Participant characteristics.

Variable	SSD $N = 33$ M (SD) or n (%)	Non-SSD $N = 28$ M (SD) or n (%)	Group difference statistics
Age	41.4 (13.2)	38.1 (14.8)	$t(55) = -0.90$, $p = .374$
Diagnosis			
Schizophrenia	21 (64)	–	–
Schizoaffective (depressive type)	8 (24)	–	–
Schizoaffective (bipolar type)	4 (12)	–	–
Sex			$\chi^2(1, N = 61) = 3.67$, $p = .055$
Male	21 (64)	10 (36)	
Female	12 (36)	18 (64)	
Gender identity			$\chi^2(3, N = 61) = 7.12$, $p = .068$
Man	20 (61)	9 (32)	
Woman	13 (39)	16 (57)	
Non-binary	0	3 (11)	
Race			$\chi^2(5, N = 61) = 11.97$, $p = .035$*
East Asian	0	4 (14)	
South Asian	0	2 (7)	
Black	11 (33)	4 (14)	
Central or South American	1 (3)	0	
White	19 (58)	18 (64)	
Not reported	2 (6)	0	
Ethnicity			$\chi^2(2, N = 61) = 3.63$, $p = .163$
Non-Hispanic/Latino	29 (88)	28 (100)	
Hispanic/Latino	3 (9)	0	
Not reported	1 (3)	0	
IQ	102.5 (15.2)	109.5 (15.1)	$t(58) = 1.79$, $p = .079$
Digit span			
Backward	8.1 (2.0)	9.5 (2.7)	$t(49) = 2.30$, $p = .026$*
Sequencing	8.6 (2.6)	10.0 (2.1)	$t(59) = 2.40$, $p = .020$*
Global functioning			
Social functioning	6.1 (1.6)	8.0 (1.7)	$t(56) = 4.45$, $p < .001$*
Role functioning	5.6 (2.1)	8.8 (1.0)	$t(47) = 7.85$, $p < .001$*
PANSS			
Positive	13.9 (5.6)	–	–
Negative	18.9 (7.6)	–	–
Disorganized	15.7 (6.4)	–	–
Excited	7.3 (3.0)	–	–
Depressed	14.5 (5.4)	–	–

Note. $Ps < 0.05$ are marked with an asterisk (*). IQ = Wechsler Abbreviated Scale of Intelligence Full Scale Intelligence Quotient. PANSS = Positive and Negative Syndrome Scale.

2.2. Measures

2.2.1. Columbia Card Task

Decision-making under risk was assessed with the "hot" Columbia Card Task (Figner et al., 2009). During each of 24 trials, participants were presented with 32 face-down cards on the screen and instructed to maximize points by selecting "gain" cards and avoiding "loss" cards. Throughout each trial, participants were shown how much gain cards were worth (+10 or + 30), how much loss cards were worth (−250 or −750), and how many loss cards were present (1 or 3). These three parameters were randomized independently across trials. Each trial ended when participants voluntarily terminated the trial or if a loss card was selected, in which case the trial automatically ended, and the loss amount was subtracted from points earned in the current trial.

Following other work using the CCT (Schaefer et al., 2022), we

evaluated two outcomes. First, we quantified overall risk-taking as the number of cards turned over each trial. Second, because the number of cards selected do not directly speak to optimal decision-making given trial parameters, following Schaefer et al. (2022), we calculated trial-by-trial deviation from the optimal number of cards to turn over (hereafter, "deviation") that would maximize EV (based on the normative solution described in Figner et al., 2009[1]). A deviation score of 0 indicates that the optimal number of cards were selected; a positive-going score suggests more cards were selected than optimal, indicating risk-seeking; and a negative-going score suggests fewer cards were selected than optimal, indicating risk-aversion (Schaefer et al., 2022).

2.2.2. Cognitive and clinical measures

We assessed working memory with the WAIS-IV digit span task (backwards and sequencing scores) (Wechsler, 2008); social and role functioning in the past month with the Global Functioning Scales Social and Role Scale (Cornblatt et al., 2007); and symptoms in the SSD group with the Positive and Negative Syndrome Scale (PANSS; Kay et al., 1987). See Supplemental for details.

2.3. Data analysis

Data were analyzed in R Statistical Software (R Core Team, 2022) and RStudio (RStudio Team, 2020). Following others who have used the CCT in various applications (e.g., Schaefer et al., 2022; Somerville et al., 2019), the two outcomes—number of cards turned over and deviation—were analyzed at the trial level with group, gain amount, loss amount, loss probability, and all two-way interactions between group and the three task variables as predictors. Categorical variables were sum-to-zero contrast coded. To account for the repeated-measures nature of the dataset, we analyzed the data using Bayesian mixed-effects models with maximal random effects structure (i.e., including a random intercept for participant, random slopes for all within-subjects effects, and all random covariance terms; Barr et al., 2013). To account for the fact that the data were right-censored in that trials ended when a participant selected a loss card even though they may have turned over additional cards if a loss card was not selected, we used the censoring function in *brms*. Regression coefficients were considered statistically significant when the 95 % credibility interval (CI) did not include zero. Since data were right-censored, we report estimated marginal means (EMM) and their 95 % CI from the respective models. We note that these model-predicted values generally align with the raw data. See Supplemental for additional details.

Next, we evaluated whether the two task outcomes were associated with symptoms (the five PANSS dimensions), working memory (digit span backwards and sequencing), and functioning (Global Functioning Scales Social and Role score). To do so, we conducted similar Bayesian mixed-effects model previously described that also included a term for each of the variables described above (in separate models), their interaction with group (except for models that included the five PANSS dimensions since it was only administered to SSD participants), their interaction with each of the task variables, and a three-way interaction with group and each task variable. Continuous variables were *z*-scored in all models.

[1] The normative solution to maximize expected value is calculated as $n_{optimal} = 32 - \frac{n_{loss\ cards} * (g_{gain\ amount} + l_{loss\ amount})}{g_{gain\ amount}}$. To derive the deviation score used in the analyses, we subtracted the actual number of cards selected from the optimal number of cards to turn over that would maximize expected value ($n_{optimal}$), and multiplied that value by −1.

3. Results

3.1. Number of cards turned over

All participants turned over fewer cards during trials with higher probability of losing (Table 2). There was no significant effect of gain amount or loss amount on number of cards turned over.

There was no statistically significant difference between the number of cards turned over by non-SSD and SSD participants (Table 2). That said, we observed an interaction between group and probability of loss (Fig. 1). Both non-SSD and SSD participants turned over more cards when 1 versus 3 loss cards were present (Table 3). However, the magnitude of this difference was greater in non-SSD—27.7 % reduction of cards turned over with greater probability of loss—versus SSD participants—15.4 % reduction in cards turned over with greater probability of loss—suggesting increased behavioral adjustment to changing loss probability in non-SSD participants. There were no group differences in the number of cards turned over when there were either 1 or 3 loss cards. We observed no other interactions between group and task variables.

3.2. Deviation from optimal decision-making

Consistent with other studies (Schaefer et al., 2022), all participants were risk-seeking, turning over more cards than optimal in terms of maximizing EV. On average, participants made less optimal decisions when the probability of loss was higher, when the gain amount was lower, and when the loss amount was higher (see Supplemental).

There was no statistically significant difference in optimal decision-making between non-SSD and SSD participants (Table 4). However, the two groups differed significantly in their degree of risk-seeking depending on loss probability and loss amount (Table 3). Both groups demonstrated less optimal decision-making when the probability of loss was higher versus lower (Fig. 2A), and when the loss amount was higher (Fig. 2B). However, risk preference was more stable across both task parameters for non-SSD participants (a 26.6 % increase in deviation from low to high probability of loss, and a 40.7 % increase in deviation from low to high loss amount) than it was in SSD participants (a 47.4 % increase in deviation from low to high probability of loss, and a 53.8 % increase in risk-seeking from low to high loss amount), meaning that as task parameters changed, risk preference shifted more drastically in SSD participants.

3.3. Correlates of risk-taking

Regarding symptoms, greater disorganization was associated with more cards turned over and less optimal decision-making (Supplemental materials). In addition, we observed a two-way interaction between

Table 2
Number of cards turned as a function of group, task variables, and their interaction.

Predictor	*B*	Est. error	Lower 95 % CI	Upper 95 % CI
Intercept	**14.26**	**0.95**	**12.42**	**16.14**
Group	0.30	0.92	−1.49	2.12
Loss probability	**1.74**	**0.24**	**1.27**	**2.24**
Gain amount	−0.24	0.22	−0.66	0.21
Loss amount	0.36	0.23	−0.09	0.81
Group * loss probability	**0.59**	**0.22**	**0.14**	**1.03**
Group * gain amount	−0.24	0.20	−0.64	0.17
Group * loss amount	0.35	0.21	−0.08	0.76

Note. *B* = estimated regression coefficient; Est. error = estimated standard error; lower 95 % CI = lower boundary of the 95 % credibility interval; upper 95 % CI = upper boundary of the 95 % credibility interval; bolded rows indicate statistically significant effects.

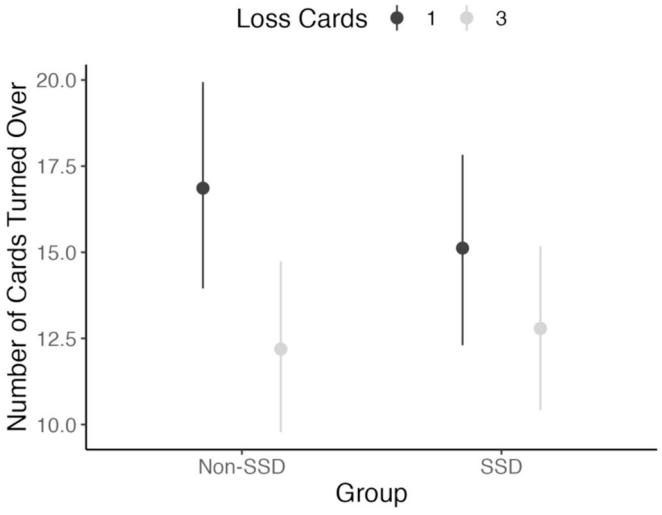

Fig. 1. Group by loss probability interaction in predicting number of cards turned over.
Note. Interaction $B = 0.59$, SE = 0.22, 95 % CI [0.14, 1.03]. Dots represent estimated marginal means for the non-SSD group (left) and SSD group (right) when the probability of loss was low (1 loss card; black dot/lines) and high (3 loss cards; gray dot/lines). Error bars represent 95 % CI.

disorganization and gain amount, such that the association between disorganization and number of cards turned over was only significant in 30-point-gain conditions, $B = 3.28$, 95 % CI [0.57, 6.07]. We observed similar associations with excited symptoms, such that greater excitement was associated with more cards turned over, and less optimal decision-making (Supplemental materials). Notedly, while both research engagement characteristics (i.e., hostility and uncooperativeness) and impulsiveness (i.e., excitement and poor impulse control) were associated with increased risk-taking, we only observed a two-way interaction between loss probability and impulsiveness, $B = 0.62$, 95 % CI [0.11, 1.14].

Regarding functioning, risk preference was associated with a two-way interaction between group and role functioning (Supplemental materials). The two-way interaction was characterized by a non-significant, positive association between role functioning and risk preference for non-SSD participants, $B = 4.79$, 95 % CI [−2.56, 11.82], and a non-significant, negative association between role functioning and risk preference for SSD participants, $B = -3.04$, 95 % CI [−6.01, 0.04].

We observed no other associations or interactions with digit span scores or social functioning (Supplementary materials).

4. Discussion

In the present study, we examined risky decision-making with the Columbia Card Task in a sample of SSD and non-SSD individuals. Collapsing across task parameters, we observed no group differences in risk-seeking. Rather, group differences in *risk adjustment* emerged. While both groups selected more cards when loss probability was lower, the degree of this adjustment was significantly larger in non-SSD participants. Notedly, as past research has often found an association between cognitive abilities and altered risk-taking in SSD (Albrecht et al., 2016; Benke et al., 2021), in the current study, SSD and non-SSD groups did not demonstrate differences in IQ, eliminating an important potential confound. Concurrently, when comparing risk-taking separately during 1-loss-card and 3-loss-card conditions, we observed no group differences in either risk-taking or risk preference. This suggests SSD participants were still sensitive—although to a lesser extent compared to non-SSD participants—to trial variations and changing task parameters, highlighting that risk adjustment, but not risk preference or general task comprehension, may contribute to altered decision-making in SSD.

Our findings were largely consistent with past studies regarding altered risk adjustment in schizophrenia, such that SSD participants demonstrated impairments in integrating probability information during decision-making (Heerey et al., 2008; Hutton et al., 2002; Martin et al., 2015). In past studies using uncertain dynamic risk-taking tasks (e.

Table 4
Deviation from optimal decision-making as a function of group, task variables, and their interaction.

Predictor	*B*	Est. error	Lower 95 % CI	Upper 95 % CI
Intercept	**11.01**	**1.09**	**8.89**	**13.16**
Group	0.19	1.08	−1.96	2.30
Loss probability	**−2.54**	**0.33**	**−3.18**	**−1.90**
Gain amount	**3.48**	**0.30**	**2.90**	**4.08**
Loss amount	**−3.40**	**0.31**	**−4.02**	**−2.79**
Group * loss probability	**0.82**	**0.30**	**0.23**	**1.40**
Group * gain amount	−0.49	0.27	−1.02	0.05
Group * loss amount	**0.58**	**0.29**	**0.01**	**1.15**

Note. *B* = estimated regression coefficient; Est. error = estimated standard error; lower 95 % CI = lower boundary of the 95 % posterior credible interval; upper 95 % CI = upper boundary of the 95 % posterior credible interval; bolded rows indicate statistically significant effects.

Table 3
Interaction effects.

Outcome	Variable	Level	Non-SSD, EMM [95 % CI]	SSD, EMM [95 % CI]	Non-SSD versus SSD contrast, estimate [95 % CI]	Non-SSD within variable contrast, estimate [95 % CI]	SSD within variable contrast, estimate [95 % CI]
Number of cards turned over	Loss probability	1 loss card	16.86 [13.95, 19.94]	15.12 [12.30, 17.83]	1.75 [−2.23, 5.80]	**4.65 [3.32, 6.03]**	**2.30 [1.07, 3.60]**
		3 loss cards	12.19 [9.78, 14.73]	12.79 [10.42, 15.17]	−0.060 [−3.93, 2.79]		
Deviation from optimal decision-making	Loss probability	1 loss card	9.46 [6.20, 12.94]	7.44 [4.39, 10.69]	2.04 [−2.41, 6.84]	**−3.45 [−5.26, −1.71]**	**−6.74 [−8.44, −5.05]**
		3 loss cards	12.89 [9.94, 16.10]	14.15 [11.25, 17.10]	−1.27 [−5.46, 2.92]		
	Loss amount	250 points	8.37 [5.42, 11.59]	6.82 [3.97, 9.70]	1.56 [−2.74, 5.65]	**−5.62 [−7.34, −3.89]**	**−7.96 [−9.53, −6.23]**
		750 points	13.99 [10.88, 17.63]	14.77 [11.66, 18.02]	−0.80 [−5.47, 3.72]		

Note. Bold values indicate a statistically significant between-group or within-group effect.

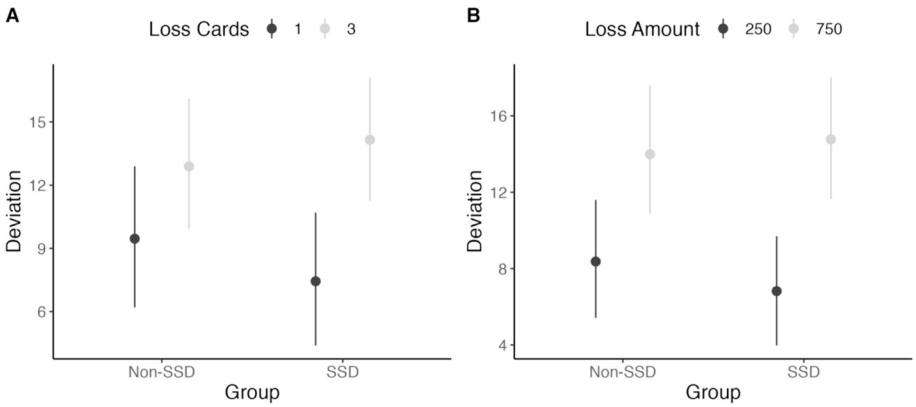

Fig. 2. Group by loss probability and loss amount interaction in predicting deviation.
Note. Interaction of group and loss probability (A, interaction $B = 0.82$, SE = 0.30, 95 % CI [0.23, 1.40]) and group and loss amount (B, interaction $B = 0.58$, SE = 0.29, 95 % CI [0.01, 1.15]). Deviation score (y-axis) represents the overall distance between participant decisions and optimal decisions maximizing EV, where a greater deviation score indicates increased risk-seeking. Dots represent estimated marginal means for the non-SSD group (left) and SSD group (right). Error bars represent 95 % CI.

g., Balloon Analog Risk Task), risk aversion is mainly observed as SSD participants were less likely to select the riskier option with greater reward (e.g., Brown et al., 2015; Luk et al., 2021). It comes into question whether there is a true alteration of risk preference, or if SSD participants are risk avoidant due to placing decreased value on uncertain choices (Hart et al., 2019), which might reflect a relative inability to accurately learn and weigh risk-related information (Purcell et al., 2022). In the current study, the CCT is uniquely equipped to disentangle risk-taking from optimal decision-making in task performance. Our findings suggest that SSD and non-SSD participants do not differ in overall risk-taking or risk preference. Rather, differences in the magnitude of adjustment to changing probability information emerged. Thus, our findings, in comparison to past uncertain risk-taking studies, lend support to the risk imperception hypothesis, suggesting that the integration of risk-related information—which precedes the formation of risk attitude—is impaired in SSD.

These findings add to the growing evidence that SSD is linked to a relative difficulty in integrating information and adjusting decisions accordingly (Sterzer et al., 2019). However, we note that in contrast to prior work using the "hot" CCT (Schaefer et al., 2022; Somerville et al., 2019), gain amount and loss amount information did not have a significant effect on participant decision-making in our sample. The lack of expected sensitivity to these variables suggests that caution is warranted in interpreting the findings related to these variables. Future studies should examine whether group differences exist in the degree of risk adjustment to the magnitude of gain and loss amount.

Contrary to prior work (Buelow, 2015; Figner et al., 2009), working memory was not associated with task performance. There are two potential explanations for this discrepancy. First, our sample may have behaved atypically. The apparent insensitivity to gain and loss amount might mean that our sample relied more on intuition during the CCT, thus reducing the impact of working memory load on decision-making. Second, the role of working memory in altered risky decision-making is largely unknown in SSD. Although past studies have found that digit span performance contributes to group differences in altered valuation of outcomes between SSD and non-SSD participants (Heerey et al., 2008; Martin et al., 2015), it is possible that motivational or affective processes, which we did not measure, may have had an impact on decision-making over and above any impact of working memory (Martinelli et al., 2018). Future studies are needed to examine the role of working memory, and other affective processes like motivation, more closely in relation to decision-making in SSD.

In subsequent analyses, we examined the relation between risky decision-making and psychotic symptoms. Disorganized and excited symptoms were significantly associated with increased risk-taking and less optimal decision-making during the CCT. Past empirical research suggests that disorganization is related to increased random exploration, which stems from impaired evidence integration in a changing environment (Cathomas et al., 2021). Similarly, our findings indicate that disorganization may be related to overall decision-making deficits, where individuals with more severe disorganized symptoms deviated further from optimal decisions in a complex, dynamic risk-taking task.

In addition, our findings suggest that altered risky decision-making in SSD may be related to functional outcomes, although in different ways depending on diagnostic status. Specifically, the SSD group showed a negative-going association (better role functioning associated with more optimal decision-making characterized by less deviation), while the non-SSD group showed a positive-going association between deviation and role functioning. Although both slopes were not statistically significant, this could suggest that for SSD individuals, optimal decision-making under risk is associated with role functioning in a direct manner. Meanwhile, for non-SSD individuals, other important processes might be at play that mitigate the potential impact of risk-seeking on functioning (e.g., cognitive ability, motivation, social skills).

There are several limitations to the current study. First, because this is a novel use of the CCT, we performed a large number of tests, increasing the possibility of false positives. As such, it would be important to replicate these findings especially with larger samples. Second, we did not account for mood state on the day of testing. Past work suggest that mania is associated with suboptimal decision-making and altered learning from negative outcomes (Adida et al., 2008; Minassian et al., 2004; Murphy et al., 2001). Thus, future research should account for the potential influence of mood (and mania in particular). Third, in the current study, we extrapolated psychological processes (e.g., risk preference) from task variables, but we would need other forms of data to confirm this speculation. Lastly, while no participants qualified for current alcohol or substance use disorder in the 6 months prior to assessment, individuals may have qualified for lifetime alcohol or substance use disorder. Future studies should more closely examine the effect of lifetime substance use on risky decision-making patterns.

In conclusion, findings from the current study suggest that risk adjustment, but not risk preference, is altered in SSD, providing tentative support for the risk imperception hypothesis (Purcell et al., 2022). Further, risky decision-making may hold real-world clinical and functional implications in schizophrenia. Greater understanding of the underlying mechanisms involved in risky decision-making may help to identify treatment targets.

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CRediT authorship contribution statement

Xiaoyu Dong: Writing – original draft, Visualization, Project administration, Investigation, Formal analysis, Data curation. **Bridget Shovestul:** Writing – review & editing, Project administration, Investigation, Data curation. **Abhishek Saxena:** Writing – review & editing, Project administration, Investigation, Data curation. **Emily Dudek:** Writing – review & editing, Project administration, Investigation, Data curation. **Stephanie Reda:** Project administration, Investigation, Data curation. **J. Steven Lamberti:** Writing – review & editing, Supervision, Resources. **David Dodell-Feder:** Writing – review & editing, Supervision, Resources, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization.

Declaration of competing interest

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.scog.2024.100314.

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