Journal of Psychopathology and Clinical Science

Differential Deficits in Social Versus Monetary Reinforcement Learning in Schizophrenia: Associations With Facial Emotion Recognition

Jaisal T. Merchant, Deanna M. Barch, Julia A. Ermel, Erin K. Moran, and Pamela D. Butler

Online First Publication, November 27, 2023. https://dx.doi.org/10.1037/abn0000869

AMERICAN PSYCHOLOGICAL ASSOCIATION

Journal of Psychopathology and Clinical Science

ISSN: 2769-7541

https://doi.org/10.1037/abn0000869

Differential Deficits in Social Versus Monetary Reinforcement Learning in Schizophrenia: Associations With Facial Emotion Recognition

Jaisal T. Merchant[1], Deanna M. Barch[1, 2], Julia A. Ermel[1, 3], Erin K. Moran[1], and Pamela D. Butler[3, 4]

[1] Department of Psychological & Brain Sciences, Washington University in St. Louis

[2] Department of Psychiatry, Washington University School of Medicine

[3] Department of Clinical Research, Nathan Kline Institute for Psychiatric Research, Orangeburg, New York, United States

[4] Department of Psychiatry, New York University Grossman School of Medicine

Despite evidence that individuals with schizophrenia (SZ) have an intact desire for social relationships, they have small social networks and report high levels of loneliness. Difficulty with reinforcement learning (RL), the ability to update behavior based on feedback, may inhibit the formation and maintenance of social relationships in SZ. However, impaired RL in SZ has largely been demonstrated via monetary tasks. Thus, it remains unclear whether SZ are similarly impaired in social and monetary RL, or whether social-specific factors may further inhibit their ability to learn from social feedback. Thirty-one individuals with SZ and 31 healthy controls (HCs) participated in a RL paradigm to test hypotheses about social versus monetary RL. SZ exhibited impaired RL compared to HCs in both social and monetary tasks. Further, a Group × Task interaction demonstrated that SZ was more impaired when learning from social than monetary reinforcement, $F(1, 59) = 5.99$, $p = .017$. This differential deficit to social RL was not accounted for by reported pleasure from social feedback, which did not differ between groups. Instead, SZ had poorer emotion recognition than HCs, $t(1, 60) = 4.80$, $p < .001$, particularly for negative emotions, and controlling for this eliminated the differential social RL impairment. These results suggest the possibility that difficulty recognizing social cues, especially those indicating negative feedback, may relate to a reduced ability to learn from others' feedback. Thus, future research could elucidate whether targeting these emotion recognition difficulties in treatment could serve as a potential mechanism for improving social functioning in SZ.

General Scientific Summary

Although monetary reinforcement learning (RL) deficits are well documented in schizophrenia (SZ), the nature of social RL in SZ remains unclear. The present study suggests that SZ may have greater deficits to social than monetary RL, and that this differential deficit relates to difficulty recognizing social feedback in the form of (negative) facial expressions. This provides a link between emotion recognition deficits and social functioning in SZ and could enhance clinical understanding of factors that may inhibit SZ from forming social relationships.

Keywords: schizophrenia, reinforcement learning, emotion recognition, social pleasure

Supplemental materials: https://doi.org/10.1037/abn0000869.supp

Jaisal T. Merchant https://orcid.org/0000-0002-9644-9915

This study was funded by NIMH R21 MH116422 provided to Pamela D. Butler. The authors thank the study participants for their time and contribution. The authors also thank Matthew Hoptman for conceptual input and assistance, Constance Shope for supervising clinical assessments, and Tarek Sobeih, Caroline Tobey, and Baerbel Allingham for developing the database and monitoring data entry. The authors have no disclosures to report. Materials and analysis code for this study are available by emailing the corresponding author (jaisalmerchant@wustl.edu). All data will also be available on the National Institute of Mental Health Data Archive upon overall study completion. This study was not preregistered.

Jaisal T. Merchant served as lead for writing–original draft and served in a supporting role for conceptualization and data curation. Deanna M. Barch served in a supporting role for conceptualization, data curation, formal analysis, and funding acquisition. Julia A. Ermel served as lead for project administration and served in a supporting role for investigation and methodology. Erin K. Moran served in a supporting role for conceptualization and data curation. Pamela D. Butler served as lead for conceptualization, data curation, funding acquisition, investigation, and methodology and served in a supporting role for writing–original draft. Jaisal T. Merchant and Pamela D. Butler contributed equally to formal analysis. Deanna M. Barch, Erin K. Moran, and Pamela D. Butler contributed equally to writing–review and editing.

Correspondence concerning this article should be addressed to Jaisal T. Merchant, Department of Psychological & Brain Sciences, Washington University in St. Louis, St. Louis, MO 63130, United States. Email: jaisalmerchant@wustl.edu

Recent evidence indicates that individuals with schizophrenia (SZ) and healthy controls (HCs) desire social relationships to a similar extent (Jetha et al., 2013; Spinzy et al., 2012). However, SZ tends to have small social networks and high levels of loneliness, which are associated with poor clinical and functional outcomes (Badcock et al., 2020; Culbreth et al., 2021). Thus, it is critical to identify factors that inhibit SZ from forming and maintaining social connections. Difficulty with social reinforcement learning (RL), the ability to learn and modify behavior based on social feedback, could impair the formation of social relationships in this population. Extensive research in SZ has documented RL deficits to monetary forms of feedback (Barch et al., 2017), but little work has examined the ability to learn from social feedback in SZ. Therefore, it is unclear whether impaired social RL in SZ is an extension of their general RL deficits, or whether SZ has greater impairments when learning from social than monetary feedback due to factors such as reductions in social pleasure or emotion recognition. Similarly, certain symptoms of SZ, such as negative symptoms, may be more associated with difficulties learning from social or monetary feedback. The goal of the current study was to investigate impairments in social versus monetary RL in SZ and assess their respective correlates. This information could elucidate the nature of these deficits and identify targets to improve social functioning in SZ.

RL Deficits in SZ

RL, the use of feedback from past behavior to inform upcoming behavior, is a critical skill to productively adapt to many domains in our daily lives. For example, the decision to continue to use the presentation strategy that was met with enthusiastic feedback from your boss (seeking social positive feedback) or to abandon the joke that was met with uncomfortable silence (avoiding social negative feedback) are small examples of the ways RL may arise day-to-day. RL deficits are well-documented in response to nonsocial (e.g., monetary) forms of reinforcement in SZ (see Barch et al., 2017 for a review). This RL literature consistently demonstrates that SZ have difficulty adapting their behavior to maximize positive feedback (i.e., winning money) with some inconsistent reports about the extent to which SZ are able to learn and modify their behavior to avoid negative feedback (i.e., losing money; Barch et al., 2017). RL deficits in SZ have also been linked to negative symptoms of the disorder (e.g., Moran et al., 2017). However, little work has examined social RL in SZ, so it is unclear how this may differ from monetary RL in this population.

To our knowledge, only three studies to date have directly compared social to monetary RL in SZ. Two of these studies, J. Lee et al. (2019) and Le et al. (2022) used a probabilistic RL (PRL) paradigm that included social and monetary RL tasks to compare performance in SZ versus HCs. In these tasks, participants chose between differently colored slot machines that were associated with high likelihoods of positive (smiling face, monetary gain, neutral (neutral face, no monetary change)) or negative (scowling face, monetary loss) outcomes. Results from these studies differed: one found that SZ had worse RL than HCs (Le et al., 2022) while the other found no behavioral differences between groups (J. Lee et al., 2019). Further, while one found that all participants had better learning from monetary rewards (J. Lee et al., 2019), the other found all participants, regardless of group, learned better from social rewards (Le et al., 2022). However, J. Lee et al. (2019), found that patients, but not controls, had reduced reward-related neural activation in response to social but not monetary reward.

The third social RL study in SZ (Catalano et al., 2018) used a smile valuation game to assess RL in response to rewards in the form of varying degrees of social (polite vs. genuine smiles) and monetary (lower vs. higher monetary gains) feedback. While groups did not differ in monetary RL, SZ were less likely than healthy participants to use social rewards in the form of genuine (but not polite) smiles to guide task decisions. This decreased RL from genuine smiles in SZ was not associated with difficulty discriminating between smile types.

Overall, the limited literature on social RL in SZ is mixed, with findings showing that either SZ show similar impairment to learning from social and monetary reinforcement, or that they are more impaired in their ability to learn from social than monetary feedback. If SZ shows similar patterns of impairment to social and monetary RL, difficulty learning from social feedback in SZ may simply be an extension of their general RL deficits. On the other hand, if SZ demonstrates more impairment to social RL, factors that may differentially impact the ability to learn from social feedback should be examined. For example, a greater social than monetary RL deficit could suggest that SZ have impaired emotional responses to social outcomes and/or that they have more difficulty recognizing the cues presented in social feedback.

Facial Emotion Recognition

There is consistent evidence that SZ is impaired in their ability to recognize others' facial expressions in an array of emotions (Edwards et al., 2002) with some work suggesting that SZ have more difficulty recognizing negatively valenced emotions such as anger than they do recognizing positively valenced emotions such as happiness (Kohler et al., 2003; E. Lee et al., 2006). However, the role that difficulty recognizing positive versus negative facial expressions may play in social RL in SZ is unclear and should be further examined (J. Lee et al., 2019).

Social Pleasure

The extent to which SZ have intact versus impaired pleasure (or displeasure) in response to social feedback could also impact their ability to learn from this feedback. Evidence on nonsocial pleasure has demonstrated that SZ and HCs consistently report comparable momentary pleasure in response to nonsocial stimuli (see Kring & Moran, 2008 for a review). Research on momentary responses to social stimuli is more limited and mixed. For example, research has found that SZ and HCs rate smiling faces as equally pleasant (and negative faces as equally unpleasant; Campellone & Kring, 2018) and have a similar tendency to approach smiling faces (Radke et al., 2015), consistent with the idea that SZ has intact social pleasure. However, other research has indicated that SZ is less likely to use facial expressions to modify decisions than controls (Csukly et al., 2011), suggesting they may have difficulty using these faces to guide behavior. In addition, while reduced motivation and pleasure (MAP) are a core component of negative symptoms of SZ (Horan et al., 2011), these negative symptoms may be more related to reduced anticipation vs. experience of pleasure (Merchant et al., 2022; Moran & Kring, 2018) and there is mixed evidence on how they relate specifically to pleasure from social experiences in SZ (Blanchard et al., 2015; McCarthy et al., 2018). There is less work

on negative emotional responses in SZ, but the existing data suggest that this may be intact or heightened in this population (Herbener et al., 2008; E. Lee et al., 2006).

As outlined, there is evidence that SZ are impaired in their ability to learn and modify their behavior based on feedback from their environment, with some evidence suggesting they may be more impaired when seeking positive feedback than when avoiding negative feedback. Most work on this topic has used monetary forms of reinforcement, and the limited research that compares monetary to social RL in SZ does not paint a clear picture of whether SZ is similarly or more impaired when learning from social feedback. Further, the extent to which factors such as difficulty with facial emotion recognition or social pleasure may play a role in social RL remains unclear. As such, it is important to examine differences in social versus monetary RL in SZ and assess whether individual difference factors in SZ relate differently to RL based on type (e.g., social vs. monetary) and valence (positive vs. negative) of feedback. Examining these questions could elucidate factors that impair motivated behavior and the ability to form social relationships in SZ.

Aims and Hypotheses

The primary aims of this work are to: (a) examine whether SZ have impairments in learning from social reward or punishment, (b) assess whether this impairment is similar to or greater than that for monetary RL, and (c) explore whether certain features of SZ (i.e., symptoms, emotion recognition, social pleasure) show differential relationships to social versus monetary RL. Our central hypothesis is that the pattern of social RL deficits in SZ is an extension of more general RL impairments in the population but that there may be additional impairments due to difficulties with emotion recognition or reduced social pleasure. More specifically, we hypothesize that (a) SZ will show impaired social RL that may exceed their overall RL impairments from monetary incentives, (b) there will be greater impairment when attempting to seek positive feedback than avoid negative feedback for both social and monetary tasks, (c) poorer social and monetary RL will be associated with severity of negative symptoms, and (d) impaired social but not monetary RL will be related to measures of social pleasure and/or facial emotion recognition.

Method

Overview

The data presented in the current study are the behavioral results from an magnetic resonance imaging (MRI) study in which participants took part in a PRL paradigm (described below) which was completed in the scanner. Participants also underwent clinical interviews (prior to the PRL) and assessments of social pleasure and facial emotion recognition (following the PRL). Participants were compensated at the end of the study and received additional payment in the amount of their earnings from the PRL. The current study focuses on behavioral results, while reports of brain activity and its relationship to behavior will be the focus of a future report.

Participants

Participants were 37 patients with the *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.; *DSM-IV*) SZ or schizoaffective disorder (SZ) and 33 HCs with no history of a Structured Clinical Interview for *DSM-V*-defined Axis I disorder. Patients were recruited from inpatient and outpatient clinics associated with the Nathan Kline Institute for Psychiatric Research (NKI). Diagnoses were obtained using the Structured Clinical Interview for *DSM-IV* (American Psychiatric Association, 2000). HCs were recruited through the volunteer recruitment pool at NKI. The groups were recruited to be as similar as possible on sex, age, race, parental education, and socioeconomic status (SES; Table 1). SES was measured using the four-factor Hollingshead Scale (Hollingshead, 1975). Participants were excluded from study participation if they were under 18 or over 60-year-old, had a neurological disorder that could affect performance, had a history of brain trauma with loss of consciousness for >10 min, or behavioral sequelae, met criteria for alcohol or substance abuse disorder in the past month, or had an intelligence quotient of less than 70 as measured via the Wide Range Achievement Test, Reading Subtest which provides an estimate of premorbid functioning (Harvey et al., 2006; Johnstone et al., 1996).

Data from six SZ and three HC participants were excluded from the study. Specifically, three SZ participants were excluded due to poor performance on the PRL practice trials and one HC participant was excluded for poor performance during the main task (see criteria below). In addition, three SZ participants chose to leave the MRI partway through the task and one control refused to enter the MRI. This yielded a final sample of size of 62: 31 HCs and 31 SZ (24 SZ, seven schizoaffective). All participants provided informed consent according to the Declaration of Helsinki. This study was approved by the NKI/Rockland Psychiatric Center Institutional Review Board.

RL Task

The PRL paradigm, adapted from tasks by Lin et al. (2012), allows assessment of learning in response to positive or negative feedback in structurally identical social and monetary learning tasks (Figure 1A). Both tasks involved a series of trials that started with a "choice" screen consisting of two different colored side-by-side cartoon slot machines. Each slot machine color was probabilistically associated with a specific reward outcome (positive, negative, or neutral) 80% of the time (Figure 1B) and slot machine colors differed between the social and monetary tasks. The positive and negative slot machines were always paired with the neutral slot machine, rather than presented together. At each choice screen, participants were directed to select one slot machine and then presented with the respective outcome. The monetary outcome showed a picture of either: (a) a nickel, indicating a win of 5 cents; (b) a nickel with a red slash, indicating a loss of 5 cents; or (c) a blank circle of nickel size, indicating a neutral outcome (neither win nor loss). The social feedback showed a picture of either: (a) a smiling face, indicating positive feedback, (b) an angry face, indicating negative feedback, or (c) a neutral face, indicating neither positive nor negative feedback. The included faces comprised four people showing each of three emotions (happy, angry, neutral) from the NimStim set of faces. These faces were counterbalanced to include two women (07F, 11F) and two men (27M, 38M) (one African-American and one European-American as described by Tottenham et al., 2009), for a total of twelve stimuli.

The PRL involved a total of 200 RL trials: 100 each for the social and the monetary RL tasks. The order of the social versus monetary task presentation was counterbalanced. Each of these RL tasks, included 50 trials in which it was possible to obtain a positive outcome and 50 in which it was possible to avoid a negative outcome.

Table 1
Participant Demographics and Clinical Characteristics

Characteristic	HCs ($n = 31$) *M* (*SD*)	SZ ($n = 31$) *M* (*SD*)	*p*
Age	40.2 (12.6)	41.8 (12.3)	.611
Sex (% female)	32	26	.780
Race (%)			
White	61	68	.603
Black/African American	26	23	.771
Asian	10	3	.562
Other	3	6	
Ethnicity (% Hispanic/Latinx)	13	19	.466
Education (years)	15.8 (2.12)	13.2 (1.85)	<.001*
Parental education	13.6 (2.29)	14.8 (2.05)	.040
SES	46.7 (10.1)	32.5 (10.5)	<.001*
Parental SES	42.4 (9.9)	46.5 (9.3)	.134
CPZ	—	580.31 (342.46)	—
Symptoms			
CAINS MAP	—	12.67 (7.65)	—
CAINS EXP	—	2.19 (3.29)	—
PANSS Positive	—	17.61 (5.74)	—

Note. HCs = healthy controls; SZ = schizophrenia; SES = four-factor Hollingshead socioeconomic status scale (note-parental SES data is missing for eight SZ participants); CPZ = chlorpromazine equivalent dose; CAINS MAP = clinical assessment interview of negative symptoms motivation and pleasure subscale; CAINS EXP = CAINS experience subscale; PANSS Positive = positive and negative syndrome scale positive subscale.
* $p < .05$.

Participants were told they would receive the money that they won (in addition to the payment for study participation) and they were given the money at the end of the session.

Prior to the PRL (conducted in the MRI), there was a practice session that included slot machine colors that differed from those in the main task and outcome associations of 90% (rather than 80% during the main task). Participants had to perform significantly above chance ($\geq$16 out of 20 trials) to continue to the main task and had up to five blocks (of 20 practice trials) to achieve this. For their data from the PRL to be included in the final data analysis, participants had to: (a) perform significantly above chance (i.e., $\geq$58 out of 100 correct) on either the monetary or social tasks, (b) respond to at least 80/100 monetary and social trials, (c) not be biased toward pressing only the right or left side of the keypad (i.e., could not have >80 right or >80 left presses on money or social), and (d) finish the task.

Clinical Assessments

Clinical assessments were conducted in the SZ group and included two clinician interview instruments. The positive symptoms factor of the positive and negative syndrome scale (PANSS Positive; Kay et al., 1987) was used to assess the positive symptom severity. The clinical assessment interview for negative symptoms (CAINS; Horan et al., 2011) was used to assess severity of motivation and pleasure negative symptoms (CAINS MAP), and their expressive negative symptoms (CAINS EXP). Clinical assessments were performed by research assistants with bachelor's degrees, under the supervision of PhD-level psychologists.

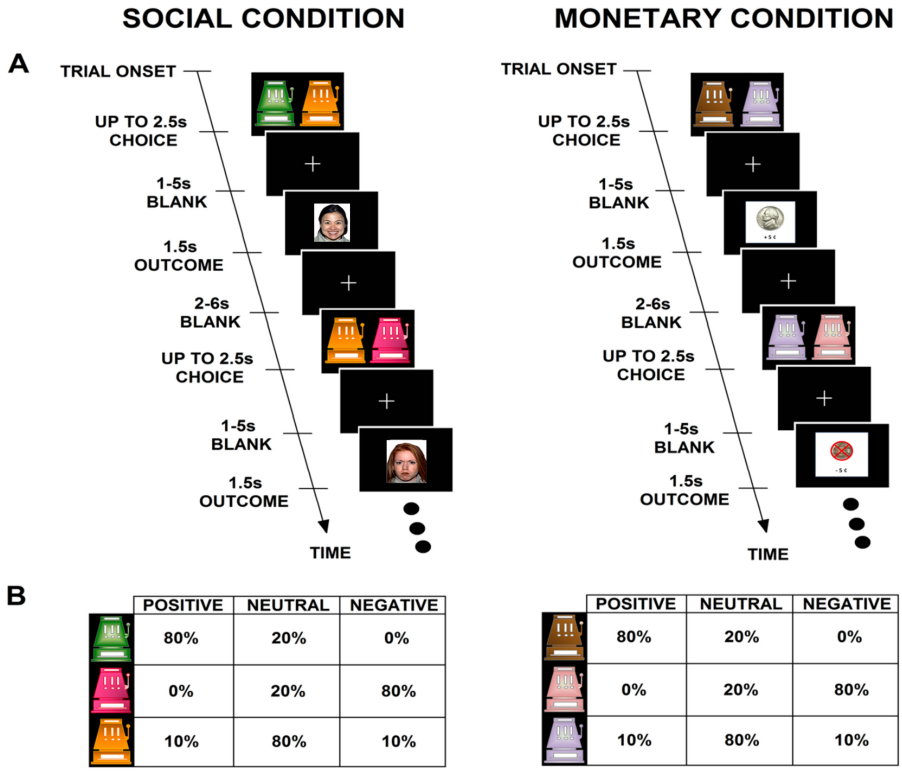
Facial Perception Tasks: Social Pleasure and Emotion Recognition

Following the PRL, participants completed three tasks to assess social pleasure and emotion recognition. First, emotion recognition (EmoDiscrim) and pleasantness (EmoRate) of faces, including those used in the PRL task, were assessed. Specifically, these tasks included static face photographs of four women (01F, 07F, 11F, 13F) and four men (27M, 37M, 38M, 42M) (two African-American and two European-American of each sex) from the NimStim faces (Tottenham et al., 2009). As in the PRL task, three emotions for each face were shown (happy, angry, neutral). There were a total of 24 stimuli for the EmoDiscrim and EmoRate tasks. For EmoRate, participants were asked how pleasant they found the face on a 7-point scale from *extremely unpleasant* to *extremely pleasant*. The scale was shown to the right of each face and the participant chose which box to click. The average rating of happy faces (EmoHappy) and angry faces (EmoAngry) were used as dependent variables of pleasantness. For EmoDiscrim, participants were asked to identify the facial expression of each picture from *happy*, *neutral*, and *angry*. These choices were shown to the right of each face. The total number correct was our dependent measure of emotion discrimination.

Participants also completed the Penn Emotion Recognition Task (ER40; Kohler et al., 2003) a widely used measure to assess facial emotion recognition. The ER40 includes photographs of eight individuals' faces, each expressing four basic emotions—happy, sad, angry, or fearful—and neutral expressions for a total of 40 trials. Thus, whereas EmoDiscrim task served to provide a more specific measure of the recognition of the faces and expressions used as social feedback in the PRL, the ER40, which includes a wider range of emotional expressions (and does not include the PRL faces), provided more generalizable data about broad facial emotion recognition deficits. As with the EmoDiscrim, our dependent variable for the ER40 was the total number correct. To conduct exploratory analyses assessing emotion recognition for distinct expressions we also calculated the number of correct responses for each of the distinct expressions in the EmoDiscrim (happy,

Figure 1

Schematic of Social and Monetary RL Tasks



Note. (A) Example social and monetary trials. Participants are presented with a pair of differently colored slot machines, asked to choose one, and then presented rewarding (positive), punishing (negative), or neutral feedback based on their choice. (B) There are three slot machine colors in each task; each is probabilistically associated with a specific reward outcome (80% likelihood of positive, negative, or neutral feedback). Positive and negative slot machines are always paired with neutral slot machines. RL = reinforcement learning. See the online article for the color version of this figure.

angry, neutral) and ER40 (happy, angry, neutral, fear, sad) tasks as dependent variables.

Statistical Analyses

Analyses were conducted using R statistical software, Version 1.4.1106 and SPSS statistical software, Version 27. To examine the effects of our primary variables: Group (SZ vs. HCs), Task (Social vs. Monetary), Valence (seek Positive vs. avoid Negative), and Block (blocks 1, 2, 3, 8, 9, and 10), we conducted a repeated measures analysis of variance (ANOVA). This model included Task, Valence, and Block as within-subjects factors and Group as our between-subjects factor to predict RL. We used the first and last three blocks for our analyses to capture changes in RL for the majority of the task while emphasizing early versus later task performance as RL improved.

We also conducted independent samples *t* tests to examine group differences in facial emotion recognition (EmoDiscrim, ER40) and social pleasure (EmoHappy, EmoAngry). To assess how our RL findings related to these face perception measures, we conducted four additional repeated measures ANOVAs, each of which included one of the above face variables as a covariate to our original repeated measures ANOVA model.

Lastly, we conducted exploratory correlational analyses in SZ to examine the relationship between clinical symptoms (CAINS MAP, CAINS EXP, PANNS Positive) or face perception measures (EmoDiscrim, ER40, EmoHappy, and EmoAngry) and monetary and social RL task performance (totaled across the six assessed blocks). False discovery rate (FDR) corrections were used for these exploratory analyses (Benjamini & Hochberg, 2000).

Study data were managed using acquire online data capture tools hosted at the NKI (Sobeih & Robinson, n.d.). Materials and analysis code for this study are available by emailing the corresponding author. All data will also be available on the National Institute of Mental Health Data Archive upon overall study completion. This study was not preregistered.

Results

Demographic Characteristics

Table 1 documents the participant demographics. Groups did not differ in age, sex, race, or ethnicity. However, as expected, HCs had significantly more years of education and higher SES than SZ, while the parents of SZ had significantly more years of education than

those of HCs. Parental SES did not differ between groups (but was nonsignificantly higher in SZ).

RL Across Participants

As reported in Table 2, RL across participants showed significant main effects of Block and Task, with Valence approaching significance. Specifically, RL improved across blocks such that performance in later blocks was better than that in earlier blocks. The main effect of Task demonstrated that monetary RL was better than social RL across participants. These main effects were modified by a Block × Task interaction, which indicated that participants learned more slowly for social than monetary RL (Figure 2). More specifically, participants' social and monetary RL differed most early on with similar task performance in later blocks (Figure 2).

The main effect of Valence approached significance and was modified by a Task × Valence interaction that also approached significance (Table 2). To parse this interaction, we computed simple effects tests comparing Valence within each task. These analyses showed that participants learned better when seeking positive feedback than they did when avoiding negative feedback in social, $F(1, 60) = 9.24$, $p = .004$, $\eta_p^2 = .13$, 90% confidence interval, CI [.03, .27], but not monetary, $F(1, 60) = 0.010$, $p = .942$, $\eta_p^2 = .00$, 90% CI [0, .01], RL conditions (Figure 2). However, participants were better at monetary than social RL when avoiding negative feedback, $F(1, 60) = 12.01$, $p = .001$, $\eta_p^2 = .17$, 90% CI [.05, .30], but not when seeking to receive positive feedback, $F(1, 60) = 0.38$, $p = .541$, $\eta_p^2 = .01$, 90% CI [0, .07].

Group Differences in RL

There was a significant main effect of Group, which was modified by significant Group × Task and Group × Block interactions (Table 2). We performed two simple effects tests to parse the Group × Task interaction. First, we compared groups within each task. As demonstrated in Figure 3, SZ performed worse than HCs in both the social, $F(1, 60) = 15.90$, $p < .001$, $\eta_p^2 = .21$, 90% CI [.07, .35], and the monetary, $F(1, 60) = 4.94$, $p = .030$, $\eta_p^2 = .08$, 90% CI [.00, .19], tasks, indicating worse RL in SZ across the board. In comparing tasks for each group, we found SZ had worse social than monetary RL, $F(1, 60) = 14.42$, $p < .001$, $\eta_p^2 = .19$, 90% CI [.06, .33], while HCs performed equally well on both tasks, $F(1, 60) = 0.111$, $p = .74$, $\eta_p^2 = .002$, 90% CI [0, .05]. For the Group × Block interaction, SZ and HCs did not differ significantly in Block 1 ($p = .074$), but SZ had worse RL after this initial Block (all $ps < .05$). The group difference was largest in the middle Blocks, and smaller at beginning and end (Figure 4).

Table 2
Repeated Measures ANOVA of Reward Learning Performance Between Groups

Effect	F	η_p^2 [90% CI]	p
Within-subjects effects			
Task	8.53	0.13 [.02, .26]	.005*
Task × Group	5.99	0.09 [.01, .22]	.017
Valence	3.86	0.06 [0, .18]	.054
Valence × Group	0.20	0.003 [0, .06]	.656
Block	75.50	0.56 [.48, .61]	.000*
Block × Group	2.82	0.05 [.002, .08]	.017*
Task × Valence	3.91	0.06 [0, .17]	.053
Task × Valence × Group	1.90	0.03 [0, 0.13]	.174
Task × Block	2.94	0.05 [.003, .09]	.013
Task × Block × Group	0.27	0.004 [0, .01]	.929
Valence × Block	1.57	0.04 [0, .06]	.169
Valence × Block × Group	0.82	0.01 [0, .04]	.530
Task × Valence × Block	0.74	0.01 [0, .03]	.594
Task × Valence × Block × Group	1.44	0.02 [0, .05]	.209
Between-subjects effects			
Group	13.00	0.18 [.05, .31]	.001*

Note. ANOVA = analysis of variance; CI = confidence interval.
* $p < 0.05$.

Social Pleasure and RL

Grubbs test indicated a significant outlier in the SZ group for EmoHappy; as such these analyses exclude that outlier. SZ and HCs did not differ in their pleasantness ratings of happy, $t(1, 59) = 1.11$, $p = .27$, $d = 0.29$, 95% CI [−.23, .80] nor angry, $t(1, 60) = 0.54$, $p = .59$, $d = 0.14$, 95% CI [−.37, .65] faces. When we added EmoHappy as a covariate in our repeated measures ANOVA, we saw a significant interaction with Task, $F(1, 58) = 10.66$, $p = .002$, $\eta_p^2 = .16$, 90% CI [.03, .29], such that EmoHappy was more strongly related to social, $F(1,58) = 3.0$, $p = .089$, $\eta_p^2 = .05$, 90% CI [0, .16], than monetary task performance, $F(1, 58) = 1.36$, $p = .246$, $\eta_p^2 = .023$, 90% CI [0, .11]. Still, significant Group × Task, $F(1, 58) = 9.23$, $p = .004$, $\eta_p^2 = .14$, 90% CI [.02, .27] and Group × Block interactions, $F(3.60, 209.15) = 3.01$, $p = .012$, $\eta_p^2 = .05$, 90% CI [.003, .09] remained with EmoHappy in the model, indicating that controlling for happy face valuation did not account for the poorer Social RL in SZ.

Adding EmoAngry as a covariate to our repeated measures ANOVA showed largely similar patterns. Specifically, the Group × Task, $F(1, 59) = 5.99$, $p = .017$, $\eta_p^2 = .09$, 90% CI [.01, .22] and Group × Block, $F(3.62, 213.640) = 2.72$, $p = .020$, $\eta_p^2 = .04$, 90% CI [.003, .07] interactions remained. However, the EmoAngry × Task interaction was nonsignificant, $F(1, 59) = 0.320$, $p = .574$, $\eta_p^2 = .002$, 90% CI [0, .07] indicating that the angry face pleasantness ratings related similarly to social and monetary RL. Overall, the inclusion of these covariates demonstrated that poorer social than monetary RL in SZ was not accounted for by the reward value (i.e., pleasantness) of the facial feedback.

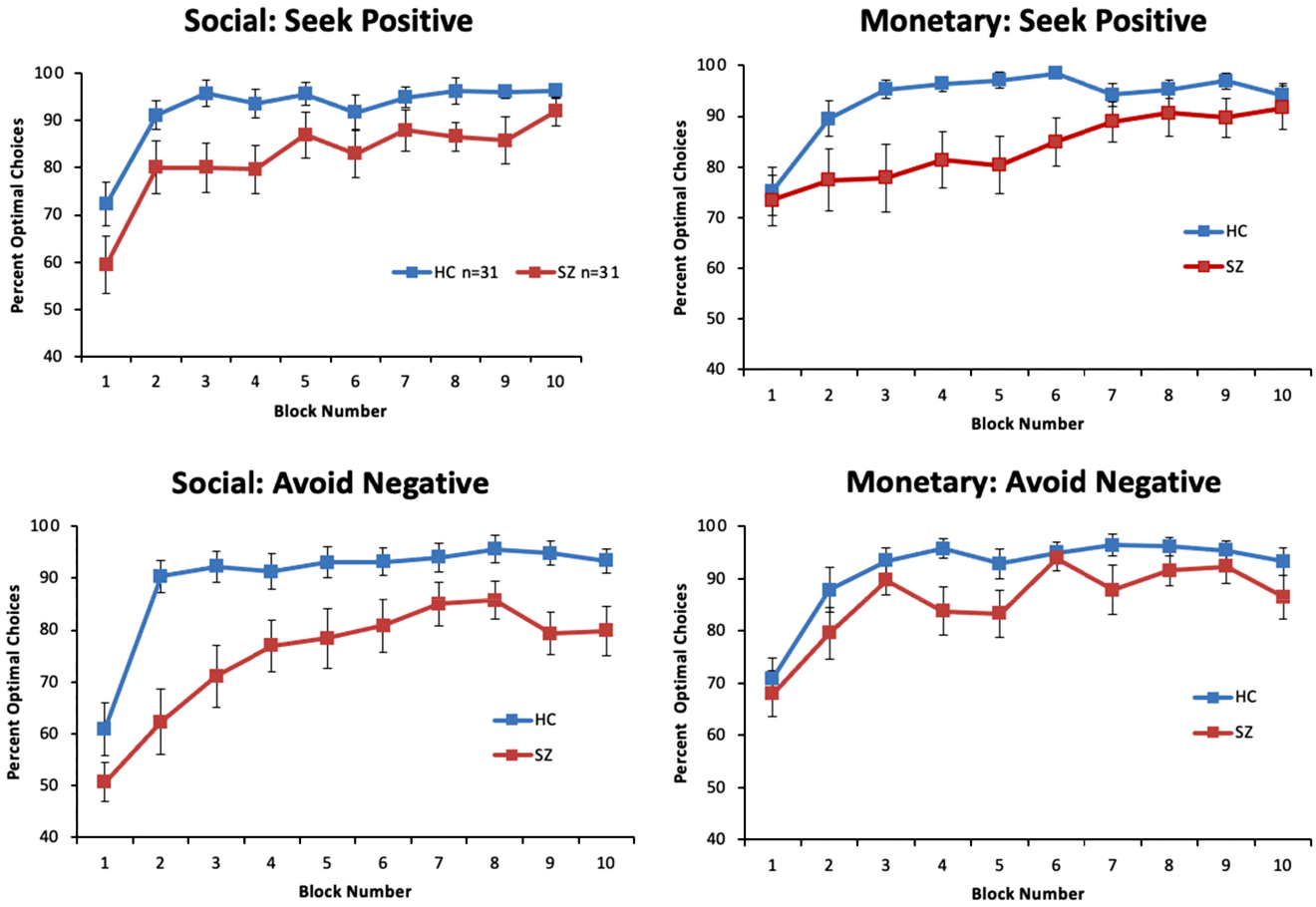
Emotion Recognition and RL

Although all participants completed the EmoDiscrim, one control and three patients did not complete the ER40 which yielded a final sample size of 30 HCs and 28 SZ for this task. Both groups had strong facial emotion recognition in the EmoDiscrim and ER40 but SZ performed worse than HCs in both tasks overall (see the online supplemental materials). More specifically, compared to HCs, SZ had significantly poorer recognition of angry and neutral (but not happy) faces on the EmoDiscrim and sad and fearful (but not happy, neutral, or angry) faces in the ER40. The online supplementary materials further detail these results.

When we added EmoDiscrim as a covariate in our model, we found a significant EmoDiscrim × Task interaction, $F(1, 59) = 5.23$, $p = .026$, $\eta_p^2 = .08$, 90% CI [.01, .20]. To determine the source of this interaction, we conducted separate repeated measures ANOVAs for the social and monetary tasks covarying for EmoDiscrim. These analyses found that EmoDiscrim related to

Figure 2

Line Graphs Demonstrating RL Accuracy in HCs and SZ for All 10 Blocks Split by Trial Valence and Task Type



Note. RL = reinforcement learning; HCs = healthy controls; SZ = schizophrenia. See the online article for the color version of this figure.

social, $F(1, 59) = 5.70$, $p = .020$, $\eta_p^2 = .08$, 90% CI [.01, .21], but not monetary RL, $F(1, 59) = 0.194$, $p = .661$, $\eta_p^2 = .04$, 90% CI [0, .06]. With EmoDiscrim as a covariate in our model, the main effect Group, $F(1, 59) = 4.98$, $p = .030$, $\eta_p^2 = .08$, 90% CI [.00, .20], remained indicating lower performance in SZ than HCs. However, there was no longer a significant Group × Task, $F(1, 59) = 0.903$, $p = .346$, $\eta_p^2 = .02$, 90% CI [0, .10], nor Group × Block, $F(3.59, 211.72) = 1.93$, $p = .090$, $\eta_p^2 = .03$, 90% CI [0, .07] interaction.

As a follow-up, we conducted additional ANOVAs that covaried for accuracy on each of the EmoDiscrim emotion types (i.e., happy, neutral, angry) separately (see Table S2 in the online supplemental materials for more information). Unlike with the EmoDiscrim total score, controlling for the recognition of happy or neutral expressions did not account for the Group × Task interaction. However, controlling for the recognition of angry faces did eliminate this Group × Task interaction.

When we added ER40 as a covariate in our repeated measures ANOVA, we found that it was significantly related to RL, $F(1, 55) = 6.32$, $p = .015$, $\eta_p^2 = .10$, 90% CI [.01, .24] but that similarly to EmoDiscrim there was an ER40 × Task interaction, $F(1, 55) = 5.78$, $p = .020$, $\eta_p^2 = .10$, 90% CI [.01, .23] indicating that ER40 related to performance on the social, $F(1, 55) = 9.70$, $p = .003$, $\eta_p^2 = .15$, 90% CI [.03, .28], but not the monetary RL task, $F(1, 55) = 1.21$, $p = .277$, $\eta_p^2 = .02$, 90% CI [0, .12]. As with EmoDiscrim as a covariate, when we controlled for ER40, the main effect of Group, $F(1, 55) = 4.56$, $p = .037$, $\eta_p^2 = .08$, 90% CI [.002, .20] remained but there was no longer a significant Group × Task, $F(1, 55) = 1.69$, $p = .200$, $\eta_p^2 = .03$, 90% CI [0, .13] nor Group × Block, $F(3.41, 187.51) = 1.79$, $p = .115$, $\eta_p^2 = .03$, 90% CI [0, .07] interaction. We also conducted follow-up analyses covarying for recognition each of the specific emotions in the ER40 task separately (Table S3 in the online supplemental materials). Controlling for the recognition of fear accounted for the Group × Task interaction (though this remained marginally significant).

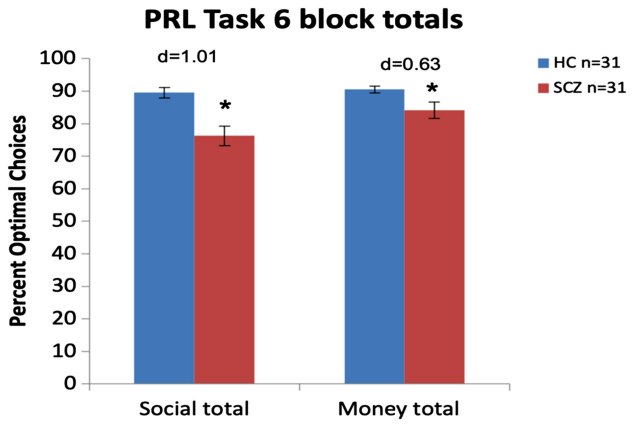
As controlling for emotion recognition but not social pleasure eliminated the Group × Task interaction, these analyses suggest that the differentially worse social RL performance in SZ is related to difficulties with facial emotion recognition, and maybe especially to the recognition of negative facial expressions.

Correlations With Social and Monetary RL

Table 3 details exploratory correlations in SZ between clinical (CAINS MAP, CAINS EXP, PANSS Positive) or face (EmoHappy,

Figure 3

Social Versus Monetary RL Accuracy in SZ Versus HCs Collapsed Across the Six Blocks Included in the PRL Analyses



Note. RL = reinforcement learning; SZ = schizophrenia; HCs = healthy controls; PRL = probabilistic RL. See the online article for the color version of this figure.

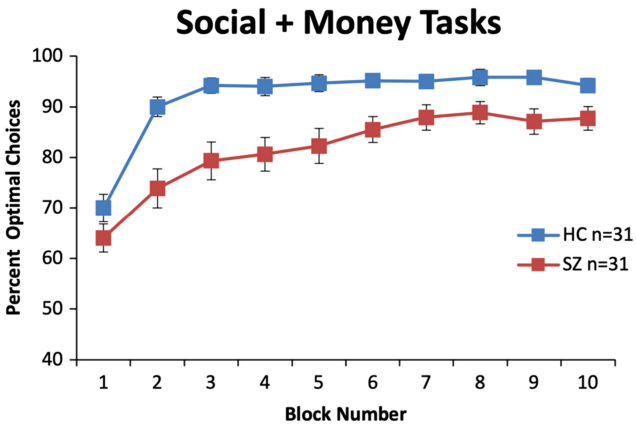
EmoAngry, EmoDiscrim, ER40) measures and Social or Monetary RL. Interestingly, Monetary RL did not relate significantly to any clinical or face measures. In contrast, Social RL related negatively to CAINS EXP (i.e., increased expressivity symptoms related to decreased social RL) and positively to both measures of facial emotion recognition (EmoDiscrim and ER40) prior to FDR corrections. After these corrections, the relationship with CAINS EXP and ER40 remained, but that with EmoDiscrim was reduced to trend-level significance. Social pleasure, CAINS MAP, and PANSS Positive scores were not associated with either Social or Monetary RL (Table 3).

Discussion

The present study aimed to examine patterns of impairment in social versus monetary RL in SZ. While SZ had deficits in both social and monetary RL compared to HCs, they were more impaired in their ability to update their behavior based on the receipt of social than monetary feedback. This differential deficit to social RL was not accounted for by differences in reported pleasure from the social feedback. Instead, the ability to recognize the facial expressions (and particularly the negative facial expressions) presented as social feedback, accounted for this increased impairment to social RL. These results elucidate factors that may relate to difficulty learning from and updating behavior based on social feedback in SZ. Our findings and their implications are discussed in more detail below.

Figure 4

Social + Monetary RL Accuracy in SZ Versus HCs for Each of the 10 Blocks



Note. RL = reinforcement learning; SZ = schizophrenia; HCs = healthy controls. See the online article for the color version of this figure.

The present results demonstrated impaired RL in SZ across both social and monetary tasks. This idea that SZ has a general RL deficit compared to HCs aligns with a body of prior evidence (largely using monetary tasks) that documents impaired RL in these patients (see Barch et al., 2017 for a review). The current findings add to this prior literature by suggesting that impaired social RL in SZ may not solely be an extension of these general (i.e., monetary) RL deficits, but that additional factors may further impair the ability to learn from social relative to monetary feedback in SZ. Two of the three prior studies that have examined social RL in SZ also found that patients had differential social versus monetary RL deficits in their behavioral task performance (Catalano et al., 2018) or reward-related neural activation (J. Lee et al., 2019) to social versus monetary feedback. Of note, although both J. Lee et al. (2019) and Le et al. (2022) used a similar paradigm to that in the current study, they did not find behavioral differences between groups based on the social versus monetary nature of the feedback. However, their results also differed from one another: Le et al. (2022) found that across groups, participants had better social than monetary RL while J. Lee et al. (2019) found the opposite pattern of better monetary than social RL across groups (J. Lee et al., 2019). Part of this divergence of results could be because, as outlined in Butler et al. (2020), the current study optimized the PRL paradigm from the original version so that: (a) participants could perform behaviorally at above-chance levels and (b) HCs would perform equally well on the social and monetary task conditions. Thus, it is possible that participants using the original version of the paradigm as in the aforementioned studies may have been unable to perform much above chance levels on the PRL which may have mitigated the ability to find behavioral differences between groups. This difficulty with PRL across groups can be observed in the data by Le et al. (2022) (PRL percent correct: HCs: 64%–67%; SZ: 56%–60%). However, behavioral data were not presented in the paper by Lee and colleagues. Despite these task differences, the overall pattern of results indicates that factors beyond the general RL deficits in SZ may inhibit their ability to learn from social feedback.

Thus, we investigated factors that could contribute to the differentially worse social than monetary RL in SZ. Consistent with previous evidence that SZ rate happy faces as equally pleasant and scowling faces as equally unpleasant as HCs (Campellone, Truong, et al., 2018), we found that groups did not differ in how pleasant they found the socially rewarding or punishing facial feedback. Further, this affective valuation of faces was not associated with either social or monetary RL in SZ and did not account for their differentially worse social RL. This suggests that SZ may value social feedback to the same extent as HCs, and that other factors may instead drive their difficulty using this valued information to inform future behavioral decisions.

A large body of work has documented deficits in facial emotion recognition in SZ (see Gao et al., 2021 for a review). J. Lee et al. (2019)

Table 3
RL Correlations With Symptom and Face Measures

Measure		Social RL	Monetary RL
CAINS MAP	*R* [95% CI]	−.26 [−.56, .11]	−.20 [−.52, .17]
	p	.165	.293
	N	31	31
CAINS EXP	*R* [95% CI]	−.46 [−.70, −.12]	−.16 [−.48, .21]
	p	.010*	.404
	N	31	31
PANSS Positive	*R* [95% CI]	−.13 [−.46, .24]	−.38 [−.65, −.03]
	p	.495	.034
	N	31	31
EmoDiscrim	*R* [95% CI]	.38 [.03, .65]	.08 [−.28, .42]
	p	.034	.664
	N	31	31
ER40	*R* [95% CI]	.54 [.20, .76]	.13 [−.26, .48]
	p	.003*	.519
	N	28	28
EmoHappy	*R* [95% CI]	−.19 [−.51, .18]	.19 [−.19, .51]
	p	.321	.327
	N	30	30
EmoAngry	*R* [95% CI]	−.08 [−.42, .28]	−.14 [−.47, .23]
	p	.656	.462
	N	31	31

Note. The relationship between EmoDiscrim and Social RL became marginally significant (adjusted $p = .079$) and that between PANSS Positive and monetary RL became nonsignificant (adjusted $p = .238$) after FDR corrections. RL = reinforcement learning; CAINS MAP = clinical assessment interview of negative symptoms motivation and pleasure subscale; CAINS EXP = CAINS experience subscale; PANSS Positive = positive and negative syndrome scale positive subscale; ER40 = Penn Emotion Recognition Task; CI = confidence interval; FDR = false discovery rate; CI = confidence interval.
* Indicate *p* values that remain significant ($p > .05$) after FDR corrections.

who did not find that social RL was associated with impaired neurocognition or social cognition in SZ, suggested that examining its relationship with facial emotion recognition was a critical future direction. The present study, which assessed this relationship, found that impaired facial emotion recognition accounted for the differential social RL deficit in SZ: patients had reduced emotion recognition accuracy compared to HCs on both emotion recognition tasks and controlling for overall performance in either task eliminated the finding that SZ had worse social than monetary RL, though it did not eliminate their general RL impairment. This indicates that the differential impairment in learning from social feedback in SZ could be related to difficulty recognizing the affective cues provided by others rather than to reduced pleasure from them. Interestingly, this pattern of results was replicated with the ER40 task, which, unlike the EmoDiscrim, does not contain any faces used in the Social RL task. This suggests that it is not just impaired perception of the faces from the PRL, but a generalized facial emotion recognition deficit that relates to poorer social RL in SZ. Further, this work extends the prior literature that documents impaired emotion recognition in SZ by providing a possible method by which these deficits may relate to real-world functioning.

Importantly, the present analyses suggest that this may specifically be the case for the recognition of negative emotional expressions. In line with research that has found that SZ may have impaired recognition of negative (and neutral) but not happy faces (see Lee et al., 2010 for a review), we found that SZ were largely impaired compared to HCs in their recognition of negative or neutral facial expressions (e.g., anger), but not positive (i.e., smiling) faces on both emotion recognition tasks. Further, when we controlled for the recognition of specific emotion types, we found that recognition of negative faces (i.e., angry in EmoDiscrim and fearful in ER40) but not neutral or happy faces accounted for the differentially worse social RL in SZ. Similarly, although Catalano et al. (2018) did not include negative facial expressions in their social RL task, they found that the ability to accurately distinguish between genuine and polite smiles in SZ did not account for their differential social versus monetary RL impairment. Taken together, it is possible that the ability to recognize positive feedback does not contribute to social RL in SZ. Instead, an impaired ability to recognize negative facial expressions may more specifically be associated with the decreased ability to learn from social feedback. Difficulty recognizing others' negative reactions could inhibit the ability to make behavioral adjustments and avoid future negative outcomes in SZ. Of course, as we do not know the directionality of this relationship; it is alternatively possible that over time an impaired ability to learn from others' (negative) feedback has led individuals with SZ to be more impaired in their ability to recognize these facial expressions.

Our results also demonstrated a trend whereby participants had more difficulty learning from negative than positive feedback in the social, but not monetary task. Although this idea could align with the above conceptualization, the three-way interaction including group was nonsignificant, so we cannot assert that this trend for more difficulty learning to avoid social punishment was specifically the case in SZ. Still, we may have lacked power to find this three-way interaction and our findings that SZ primarily had difficulty recognizing negative faces (social negative feedback) which accounted for their differentially worse social RL suggests that further assessment of social positive versus social negative RL in SZ is important. The lack of group difference as a function of valence also contrasted with our hypothesis that SZ would be worse at learning from positive than negative monetary feedback. Previous work has found more evidence for impaired monetary positive than monetary negative RL in SZ (e.g., Gold et al., 2012) but

there is also work that has found similar impairments in learning from monetary reward and loss in SZ (e.g., Barch et al., 2017), consistent with the current pattern of findings.

We also explored how social versus monetary RL related to individual differences in SZ. In contrast to our hypothesis and prior literature that has found that deficits in monetary RL are related to MAP-negative symptoms of SZ (e.g., Barch et al., 2017; Moran et al., 2017), none of the assessed individual difference factors (including CAINS MAP) was associated with monetary RL after adjusting for corrections. On the other hand, poorer social RL in SZ was significantly related to increased expressive negative symptoms and reduced facial emotion recognition. Interestingly, these observed correlates of social RL all involve either a reduced ability to recognize expressions or a reduced expressive presentation. The link between social RL and facial emotion recognition was discussed above, but the additional relationship with expressive negative symptoms provides the interesting possibility that SZ who are less likely to modulate their own expressions may also be less likely to use others' emotional expressions to motivate their behavioral decisions.

A number of limitations should be considered when interpreting the present results. First, it is possible that our sample size of 62 limited the power to detect significance for some of our analyses. As noted above, we may have been inhibited in the ability to find three-way interactions such as indications that SZ may have been more impaired when learning from social negative than social positive feedback. Additionally, some previous work has found gender-related effects such that men, but not women, have increased difficulty learning from social compared to monetary reinforcement (Spreckelmeyer et al., 2009). However, due to our limited sample size, we did not have the power to test for this effect. As evidence indicates that pleasure and displeasure are distinct constructs (Diener & Emmons, 1984) and thus best measured separately, our scale of social pleasure, which ranged from "extremely pleasant" to "extremely unpleasant" could have inhibited our ability to find differing positive versus negative emotional reactions to the social feedback (i.e., participants who rated certain faces both as more highly positive and more highly negative vs. those that had more neutral ratings for both). Another possible limitation of the current work is that the social feedback came in the form of static pictures of happy, angry, or neutral faces. Although these faces and expressions had been piloted prior to running the task (Butler et al., 2020), it is possible that they may not reflect the more dynamic and complex social cues in the real world which may be associated with additional behavioral consequences in participants' daily lives.

This study points to several possible future directions. First, research could further explore the possible valence-based discrepancies in social versus monetary RL in SZ such as whether SZ are more specifically impaired in learning from social, but not monetary, RL due to difficulties with recognition of negative social cues. In doing so, examining the directionality of the relationship between emotion recognition and social RL would provide important information about possible treatment directions for these functionally impairing social RL deficits in SZ. It would also be interesting to assess gender-related differences in social versus monetary RL and whether gender may moderate a relationship between feedback valence and social RL. Additionally, as we found that SZ did not have reduced social pleasure compared to HCs (nor did this social pleasure relate to social RL), future work could extend these methods to assess whether these results would also hold for ratings of social displeasure or for the anticipation of social feedback. The use of more naturalistic forms of social reward or punishment (e.g., social role-play tasks, interactions with avatars) to assess social RL could also help assess the generalizability of the present findings.

Overall, the current work provides evidence that SZ are impaired in both social and monetary RL, but that this impairment is greater when attempting to learn from social than monetary feedback. It also suggests that this differential deficit to social RL relates to difficulty recognizing the cues presented as social feedback, especially in the case of negative faces, rather than from reduced pleasure from this feedback. As this decreased ability to modify behavior based on others' feedback could inhibit the formation of social relationships in SZ, these findings provide a functional link to the well-documented emotion recognition deficit in this population. Thus, it is critical to examine whether and how working to improve emotion recognition in SZ could serve as a beneficial treatment target to enhance social functioning in this population.

References

American Psychiatric Association. (Ed.). (2000). *Diagnostic and statistical manual of mental disorders: DSM-IV-TR* (4th ed., text revision).

Badcock, J. C., Di Prinzio, P., Waterreus, A., Neil, A. L., & Morgan, V. A. (2020). Loneliness and its association with health service utilization in people with a psychotic disorder. *Schizophrenia Research*, *223*, 105–111. https://doi.org/10.1016/j.schres.2020.05.059

Barch, D. M., Carter, C. S., Gold, J. M., Johnson, S. L., Kring, A. M., MacDonald, A. W., Pizzagalli, D. A., Ragland, J. D., Silverstein, S. M., & Strauss, M. E. (2017). Explicit and implicit reinforcement learning across the psychosis spectrum. *Journal of Abnormal Psychology*, *126*(5), 694–711. https://doi.org/10.1037/abn0000259

Benjamini, Y., & Hochberg, Y. (2000). On the adaptive control of the false discovery rate in multiple testing with independent statistics. *Journal of Educational and Behavioral Statistics*, *25*(1), 60–83. https://doi.org/10.3102/10769986025001060

Blanchard, J. J., Park, S. G., Catalano, L. T., & Bennett, M. E. (2015). Social affiliation and negative symptoms in schizophrenia: Examining the role of behavioral skills and subjective responding. *Schizophrenia Research*, *168*(1–2), 491–497. https://doi.org/10.1016/j.schres.2015.07.019

Butler, P. D., Hoptman, M. J., Smith, D. V., Ermel, J. A., Calderone, D. J., Lee, S. H., & Barch, D. M. (2020). Grant report on social reward learning in schizophrenia †. *Journal of Psychiatry and Brain Science*, *5*, Article e200004. https://doi.org/10.20900/jpbs.20200004

Campellone, T. R., & Kring, A. M. (2018). Anticipated pleasure for positive and negative social interaction outcomes in schizophrenia. *Psychiatry Research*, *259*, 203–209. https://doi.org/10.1016/j.psychres.2017.09.084

Campellone, T. R., Truong, B., Gard, D., & Schlosser, D. A. (2018). Social motivation in people with recent-onset schizophrenia spectrum disorders. *Journal of Psychiatric Research*, *99*, 96–103. https://doi.org/10.1016/j.jpsychires.2018.01.006

Catalano, L. T., Heerey, E. A., & Gold, J. M. (2018). The valuation of social rewards in schizophrenia. *Journal of Abnormal Psychology*, *127*(6), 602–611. https://doi.org/10.1037/abn0000366

Csukly, G., Polgár, P., Tombor, L., Réthelyi, J., & Kéri, S. (2011). Are patients with schizophrenia rational maximizers? Evidence from an ultimatum game study. *Psychiatry Research*, *187*(1–2), 11–17. https://doi.org/10.1016/j.psychres.2010.10.005

Culbreth, A. J., Barch, D. M., & Moran, E. K. (2021). An ecological examination of loneliness and social functioning in people with schizophrenia. *Journal of Abnormal Psychology*, *130*(8), 899–908. https://doi.org/10.1037/abn0000706

Diener, E., & Emmons, R. A. (1984). The independence of positive and negative affect. *Journal of Personality and Social Psychology*, *47*(5), 1105–1117. https://doi.org/10.1037/0022-3514.47.5.1105

Edwards, J., Jackson, H. J., & Pattison, P. E. (2002). Emotion recognition via facial expression and affective prosody in schizophrenia: A methodological review. *Clinical Psychology Review*, *22*(6), 789–832. https://doi.org/10.1016/s0272-7358(02)00130-7

Gao, Z., Zhao, W., Liu, S., Liu, Z., Yang, C., & Xu, Y. (2021). Facial emotion recognition in schizophrenia. *Frontiers in Psychiatry*, *12*, Article 633717. https://doi.org/10.3389/fpsyt.2021.633717

Gold, J. M., Waltz, J. A., Matveeva, T. M., Kasanova, Z., Strauss, G. P., Herbener, E. S., Collins, A. G. E., & Frank, M. J. (2012). Negative symptoms in schizophrenia result from a failure to represent the expected value of rewards: Behavioral and computational modeling evidence. *Archives of General Psychiatry*, *69*(2), 129–138. https://doi.org/10.1001/archgenpsychiatry.2011.1269

Harvey, P. D., Friedman, J. I., Bowie, C., Reichenberg, A., McGurk, S. R., Parrella, M., White, L., & Davis, K. L. (2006). Validity and stability of performance-based estimates of premorbid educational functioning in older patients with schizophrenia. *Journal of Clinical and Experimental Neuropsychology*, *28*(2), 178–192. https://doi.org/10.1080/13803390500360349

Herbener, E. S., Song, W., Khine, T. T., & Sweeney, J. A. (2008). What aspects of emotional functioning are impaired in schizophrenia? *Schizophrenia Research*, *98*(1–3), 239–246. https://doi.org/10.1016/j.schres.2007.06.025

Hollingshead, A. A. (1975). *Four-factor index of social status* [Unpublished manuscript]. Yale University.

Horan, W. P., Kring, A. M., Gur, R. E., Reise, S. P., & Blanchard, J. J. (2011). Development and psychometric validation of the clinical assessment interview for negative symptoms (CAINS). *Schizophrenia Research*, *132*(2–3), 140–145. https://doi.org/10.1016/j.schres.2011.06.030

Jetha, M. K., Goldberg, J. O., & Schmidt, L. A. (2013). Temperament and its relation to social functioning in schizophrenia. *International Journal of Social Psychiatry*, *59*(3), 254–263. https://doi.org/10.1177/0020764011433639

Johnstone, B., Callahan, C. D., Kapila, C. J., & Bouman, D. E. (1996). The comparability of the WRAT-R reading test and NAART as estimates of premorbid intelligence in neurologically impaired patients. *Archives of Clinical Neuropsychology*, *11*(6), 513–519. https://doi.org/10.1016/0887-6177(96)82330-4

Kay, S. R., Fiszbein, A., & Opler, L. A. (1987). The positive and negative syndrome scale (PANSS) for schizophrenia. *Schizophrenia Bulletin*, *13*(2), 261–276. https://doi.org/10.1093/schbul/13.2.261

Kohler, C. G., Turner, T. H., Bilker, W. B., Brensinger, C. M., Siegel, S. J., Kanes, S. J., Gur, R. E., & Gur, R. C. (2003). Facial emotion recognition in schizophrenia: Intensity effects and error pattern. *American Journal of Psychiatry*, *160*(10), 1768–1774. https://doi.org/10.1176/appi.ajp.160.10.1768

Kring, A. M., & Moran, E. K. (2008). Emotional response deficits in schizophrenia: Insights from affective science. *Schizophrenia Bulletin*, *34*(5), 819–834. https://doi.org/10.1093/schbul/sbn071

Le, T. P., Green, M. F., Lee, J., Clayson, P. E., Jimenez, A. M., Reavis, E. A., Wynn, J. K., & Horan, W. P. (2022). Aberrant reward processing to positive versus negative outcomes across psychotic disorders. *Journal of Psychiatric Research*, *156*, 1–7. https://doi.org/10.1016/j.jpsychires.2022.09.045

Lee, E., Kim, J.-J., Namkoong, K., An, S. K., Seok, J.-H., Lee, Y. J., Kang, J. I., Choi, J. H., Hong, T., Jeon, J. H., & Lee, H. S. (2006). Aberrantly flattened responsivity to emotional pictures in paranoid schizophrenia. *Psychiatry Research*, *143*(2–3), 135–145. https://doi.org/10.1016/j.psychres.2005.09.011

Lee, J., Jimenez, A. M., Reavis, E. A., Horan, W. P., Wynn, J. K., & Green, M. F. (2019). Reduced neural sensitivity to social versus nonsocial reward in schizophrenia. *Schizophrenia Bulletin*, *45*(3), 620–628. https://doi.org/10.1093/schbul/sby109

Lee, S. J., Lee, H.-K., Kweon, Y.-S., Lee, C. T., & Lee, K.-U. (2010). Deficits in facial emotion recognition in schizophrenia: A replication study with Korean subjects. *Psychiatry Investigation*, *7*(4), 291–297. https://doi.org/10.4306/pi.2010.7.4.291

Lin, A., Adolphs, R., & Rangel, A. (2012). Social and monetary reward learning engage overlapping neural substrates. *Social Cognitive and Affective Neuroscience*, *7*(3), 274–281. https://doi.org/10.1093/scan/nsr006

McCarthy, J. M., Bradshaw, K. R., Catalano, L. T., Garcia, C. P., Malik, A., Bennett, M. E., & Blanchard, J. J. (2018). Negative symptoms and the formation of social affiliative bonds in schizophrenia. *Schizophrenia Research*, *193*, 225–231. https://doi.org/10.1016/j.schres.2017.07.034

Merchant, J. T., Moran, E. K., & Barch, D. M. (2022). Negative and depressive symptoms differentially relate to real-world anticipatory and consummatory pleasure in schizophrenia. *Schizophrenia Research*, *241*, 72–77. https://doi.org/10.1016/j.schres.2022.01.012

Moran, E. K., Culbreth, A. J., & Barch, D. M. (2017). Ecological momentary assessment of negative symptoms in schizophrenia: Relationships to effort-based decision making and reinforcement learning. *Journal of Abnormal Psychology*, *126*(1), 96–105. https://doi.org/10.1037/abn0000240

Moran, E. K., & Kring, A. M. (2018). Anticipatory emotion in schizophrenia. *Clinical Psychological Science*, *6*(1), 63–75. https://doi.org/10.1177/2167702617730877

Radke, S., Pfersmann, V., & Derntl, B. (2015). The impact of emotional faces on social motivation in schizophrenia. *European Archives of Psychiatry and Clinical Neuroscience*, *265*(7), 613–622. https://doi.org/10.1007/s00406-015-0589-x

Sobeih, T., & Robinson, J. (n.d.). *Innovative Clinical Research Solutions/Information Sciences Division*. ICRS. icrs.rfmh.org

Spinzy, Y., Nitzan, U., Becker, G., Bloch, Y., & Fennig, S. (2012). Does the internet offer social opportunities for individuals with schizophrenia? A cross-sectional pilot study. *Psychiatry Research*, *198*(2), 319–320. https://doi.org/10.1016/j.psychres.2012.02.022

Spreckelmeyer, K. N., Krach, S., Kohls, G., Rademacher, L., Irmak, A., Konrad, K., Kircher, T., & Gründer, G. (2009). Anticipation of monetary and social reward differently activates mesolimbic brain structures in men and women. *Social Cognitive and Affective Neuroscience*, *4*(2), 158–165. https://doi.org/10.1093/scan/nsn051

Tottenham, N., Tanaka, J. W., Leon, A. C., McCarry, T., Nurse, M., Hare, T. A., Marcus, D. J., Westerlund, A., Casey, B., & Nelson, C. (2009). The NimStim set of facial expressions: Judgments from untrained research participants. *Psychiatry Research*, *168*(3), 242–249. https://doi.org/10.1016/j.psychres.2008.05.006

Received December 10, 2022
Revision received July 7, 2023
Accepted July 11, 2023 ■