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A Transdiagnostic Study of Effort-Cost Decision-Making in Psychotic and Mood Disorders

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***Background*: Research suggests that effort-cost decision-making (ECDM), the estimation of work required to obtain reward, may be a relevant framework for understanding motivational impairment in psychotic and mood pathology. Specifically, research has suggested that people with psychotic and mood pathology experience effort as more costly than controls, and thus pursue effortful goals less frequently. This study examined ECDM across psychotic and mood pathology. *Hypothesis*: We hypothesized that patient groups would show reduced willingness to expend effort compared to controls. *Study Design*: People with schizophrenia ($N = 33$), schizoaffective disorder ($N = 28$), bipolar disorder ($N = 39$), major depressive disorder ($N = 40$), and controls ($N = 70$) completed a physical ECDM task. Participants decided between completing a low-effort or high-effort option for small or larger rewards, respectively. Reward magnitude, reward probability, and effort magnitude varied trial-by-trial. Data were analyzed using standard and hierarchical logistic regression analyses to assess the subject-specific contribution of various factors to choice. Negative symptoms were measured with a clinician-rated interview. *Study Results*: There was a significant effect of group, driven by reduced choice of high-effort options in schizophrenia. Hierarchical logistic regression revealed that reduced choice of high-effort options in schizophrenia was driven by weaker contributions of probability information. Use of reward information was inversely associated with motivational impairment in schizophrenia. Surprisingly, individuals with major depressive disorder and bipolar disorder did not differ from controls. *Conclusions*: Our results provide support for ECDM deficits in schizophrenia. Additionally, differences between groups in ECDM suggest a seemingly similar behavioral phenotype, reduced motivation, could arise from disparate mechanisms.**

Key words: transdiagnostic/schizophrenia/motivation/effort-cost decision-making/reward processing/experimental psychopathology

Introduction

Reduced motivation, a core negative symptom, is a feature of multiple psychiatric disorders including schizophrenia (SZ), schizoaffective affective disorder (SZA), bipolar disorder (BD), and major depressive disorder (MDD).[1] Although not explicitly termed negative symptoms across diagnoses, several psychiatric disorders outside of the schizophrenia-spectrum include reduced motivation within their diagnostic criteria or associated features (eg, BD, MDD).[2,3] Reduced motivation is both debilitating and not completely responsive to available treatments, highlighting a need to further understand this symptom from a mechanistic standpoint.[4,5] Further, while reduced motivation is a common symptom across psychotic and mood disorders, it is not currently known whether this symptom reflects similar contributory mechanisms across diagnoses.[6] Thus, transdiagnostic studies are needed to determine whether motivational impairment in psychotic and mood disorders reflects similar contributors.

Recently, an approach for understanding the etiology of motivational impairment has been to consider it within the framework of effort-cost decision-making (ECDM).[6–9] In this conceptualization, individuals vary in their subjective evaluation of whether an outcome is worth the effort required to obtain it.[10] Factors in ECDM include the magnitude of a potential reward, the probability of receiving the reward, and the amount of work needed to obtain the reward. Intuitively, most studies show that, on average, participants' willingness to exert effort increases with the magnitude of the potential reward and the probability of receiving reward, but decreases with the amount of work required to obtain the reward.[11,12] However, there are substantial individual differences in the relative contribution of these factors to ECDM. An aim of the current report was to quantify these relative contributions for each individual subject.

Willingness to expend effort has been shown to be reduced in SZ.[6,7] For example, a recent meta-analysis found a consistent pattern demonstrating that people with SZ show reduced willingness to expend effort relative to controls, with the greatest group differences emerging when reward magnitude and probability of reward receipt were highest.[13] Further, many studies have shown associations between negative symptoms and willingness to expend effort, such those with the greatest negative symptom severity demonstrate the least willingness to expend effort for reward.[14–21] However, other studies have not found significant relationships with negative symptoms.[22–24] Finally, Cooper and colleagues recently applied a computational model to a large sample of participants with SZ. They found that nearly half of the participants with SZ failed to use probability and reward information to guide ECDM. Further, they showed a negative association between negative symptoms and choice of the hard task in those with SZ.[25] Thus, ECDM deficits are characteristic of individuals with SZ, with mixed evidence for negative symptoms associations.

Several ECDM studies have shown reduced willingness to expend effort in individuals with MDD or those with depressive symptoms.[12,24,26,27] In contrast, multiple recent studies have not observed reduced willingness to expend effort in individuals with MDD.[18,28–32] There is some suggestion that ECDM deficits in MDD may be state-specific (ie, only present for those in a current major depressive episode).[27] However, such hypotheses are inconsistent with recent work involving both patients in a current episode and those in remission which did not find reductions in ECDM in either group relative to controls.[18,28] Thus, while several studies have shown deficits in ECDM in MDD, the results and their associations with depressive symptoms remain mixed.

Studies of ECDM in BD have been limited. Several studies found that individuals with BD in a depressive phase showed reduced willingness to expend effort compared to controls.[18,26,28] Yang and colleagues[32] found that individuals with BD in a manic phase demonstrated reduced ECDM compared to controls overall, but enhanced ECDM for low-value choices, suggesting potential inefficiency in choice. Thus, there is some initial evidence for state-based effects. Finally, Johnson and colleagues[33] described findings linking lofty goal setting to greater willingness to expend effort in BD.

Samples Including Multiple Diagnostic Groups

There have been several studies of ECDM including both individuals with psychotic and mood disorders. Recently, Barch and colleagues[28] recruited individuals with MDD, BD, or SZ/SZA and showed that individuals with BD and SZ demonstrated reduced willingness to expend cognitive effort compared to controls, but individuals with MDD did not. Moran and colleagues[18] found that people with SZ and BD showed reduced willingness to expend physical effort at high reward values relative to controls, while as a group, those with MDD showed no differences relative to controls. Additionally, both reports found individual difference relationships across diagnostic groups, such that individuals with greater experiential negative symptoms demonstrated less willingness to exert effort. In a similar vein, Zou and colleagues[24] found that participants with SZ, BD, and MDD were less willing to expend effort in high expected value conditions; however, they did not observe relationships with symptoms. Saperia and colleagues[34] applied a clustering algorithm to ECDM task data in a sample of individuals with MDD and SZ, finding that participants could be characterized based on the extent that they used decision factors to make choices. Finally, Whitton and colleagues found reduced willingness to expend effort in a combined sample of individuals with BD and SZ compared to controls. In this sample, effects of reward probability on choice were weaker in those with lower working memory capacity.[35] Thus, previous reports have provided initial evidence for an ECDM impairment across psychotic and mood pathology.

Present Study

We examined ECDM across a sample of individuals with MDD, BD, SZ, SZA, and HCs. We hypothesized that all patient groups would show reduced willingness to expend effort compared to HCs. Further, we hypothesized that patients with the greatest experiential negative symptoms would demonstrate the greatest reduction in willingness to expend effort. Importantly, we analyzed ECDM task behavior using two methods: (1) traditional analyses using summary statistics (frequency of choice of high-effort option), (2) analyses using a hierarchical logistic regression to estimate the contribution of various factors (reward magnitude, effort magnitude, and reward probability) to choice behavior. We conducted these regression analyses because traditional analyses do not provide

resolution as to which specific decision-making factors might be the strongest contributors to reduced willingness to expend effort, and whether these factors are similar or different across psychiatric disorders.

Methods

Participants

Participants in the current study were recruited as part of the Cognitive Neuroscience Test Reliability and Clinical applications for Serious mental illness (CNTRACS) Consortium, which included five different recruitment sites: University of California–Davis, University of Maryland–Baltimore, University of Chicago, University of Minnesota–Twin Cities, and Washington University in St. Louis. All participants provided written informed consent to the protocol approved by a central Institutional Review Board at Washington University in St. Louis.

237 Participants completed the study. However, 27 participants (SZ = 6, SZA = 2, BD = 4, MDD = 7, HC = 8) were excluded from the analyses due to inflexible responding on the ECDM task (eg, selecting one option >85% of the time, consistent with previous research[36]), leaving 210 participants (SZ = 33, SZA = 28, BD = 39, MDD = 40, HC = 70).[36] There was not a group effect in terms of the proportion of inflexible responders excluded from the analysis ($\chi^2 = 2.14$, $P = .7$). Exclusion criteria included: (1) history of significant head trauma or neurological disease, (2) diagnosis of substance use disorder in the last 6 months, and (3) failing a drug or alcohol screen administered the day of testing. Additional criteria for the participants with psychiatric diagnoses who were prescribed medications included no medication changes in the month prior to study participation. Individuals with BD all met criteria for Bipolar I Disorder and were required to have a previous history of psychosis. Of the 39 participants with BD: 3 met DSM-5 criteria for a current manic episode, 10 for a current depressive episode, and 26 were euthymic. To be included in the study, participants with MDD were required to meet DSM-5 criteria for at least two depressive episodes, with at least one episode occurring within the last 3 years. Further, individuals with MDD were excluded if they had a previous history of psychosis. Additional criteria for HC included: (1) no personal or 1st degree relative with SZ, SZA, or BD; (2) no current MDD or dysthymia; and (3) no current psychotropic medication.

Diagnostic and Symptom Assessment

Diagnosis was confirmed using the Structured Clinical Interview for DSM-5 (SCID-5). Individuals with a psychiatric diagnosis were also assessed for general psychiatric symptoms using the Brief Psychiatric Rating Scale.[37] Negative symptoms were assessed using the Clinical Assessment Interview for Negative Symptoms (CAINS[38]) which includes a Motivation and Pleasure (MAP) and Expression (EXP) subscale, with higher scores indicating greater impairment. Depressive symptoms were assessed with the Patient Health Questionnaire (PHQ-9[39]), a self-report questionnaire with higher scores indicating greater severity. The Young Mania Rating Scale (YMRS) was used to assess manic symptoms.

Balloon Effort Task

Participants completed a modified version of a Balloon Effort task[36] originally reported by Gold and colleagues.[16] This task was created with the Honeycomb task-template.[40] In this task, participants are told that they will play a game where they must press a computer keyboard button multiple times to pop balloons. On each trial, participants were instructed to choose between completing either a low-effort or high-effort option (figure 1). The low-effort option required pressing a button 20 times within a 25-s window to have the chance to win 1 point. The high-effort option involved pressing a button either 50, 100, or 200 times within a 25-s window for the chance to win 3, 5, or 7 points. On half of the trials, the probability of reward receipt was 50% and on the other half it was 100%. Participants were given 6.5 s to make a choice. If participants failed to make a response within this window, the trial was terminated and the next trial was presented. A brief quiz was taken following the task instructions to ensure participant understanding. Incorrect quiz answers were reviewed with participants.

Once participants selected an option, they completed a button-pressing task for that trial. In this variant of the task, participants were not required to precisely exert the amount of effort demanded. Rather, they could either press less than the required amount to earn a prorated portion of the allotted points or, if they pressed more than the required amount, they could earn bonus points based on their exertion. Specifically, the number of points when completing the high-effort option was determined by this formula:

$$\text{Trial Points} = \text{Hard Task Reward} \times \left(\frac{\text{Number of Presses}}{\text{Hard Task Effort}}\right)$$

For example, if the potential reward was 5 points and the number of required presses was 100, but the participant completed 50 presses, they would still earn 2.5 points. Alternatively, if the participant completed 200 presses, they would earn 10 points. For the low-effort option, participants could not earn partial or bonus points. The purpose of this proration was to measure motivated behavior following the commitment to the initial choice of the high-effort option. Indeed, the initial choice behavior was very sensitive to the required effort, but once participants committed to the high-effort option, they tended to press a similar amount (see Supplementary

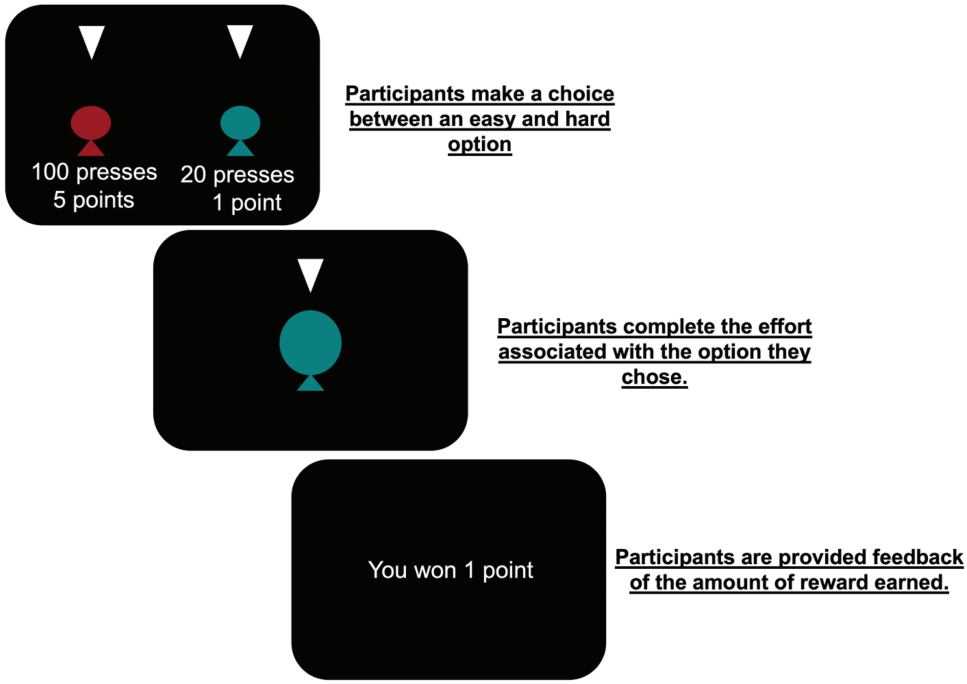

Fig. 1. Trial diagram.

Material S1 for a breakdown of the number of button presses per task condition); thus, the current report focused on frequency of high-effort option choice for various task conditions.

Participants completed a total of 72 trials (4 repetitions of 18 unique trials: 3 high-effort option reward levels, 3 high-effort option effort levels, 2 reward probability levels). Prior to beginning the task, participants were informed that for every 20 points they earned on the task, they would receive $1 in bonus payment at the end of the study.

Data Analysis

Summary Measures. Consistent with previous reports,[16,18] group differences were examined using a mixed-model repeated measures ANOVA. The dependent variable was frequency of choosing the high-effort option. Diagnostic Group (HC, SZ, SZA, BD, MDD) served as a between-subject factor and Reward Level (3 levels: 3, 5, 7), Effort Level (3 levels: 50, 100, 200), and Probability Level (50, 100) were treated as within-subject factors.

Previous reports examining ECDM in psychosis have frequently found the strongest group differences and symptom effects when reward certainty is highest.[13] Thus, we conducted Spearman correlations between the frequency of choosing the high-effort option for 100% reward probability trials and experiential negative symptoms (CAINS-MAP), in each clinical group. For these correlations, we used a Bonferroni correction to determine an appropriate significance threshold (0.05/4 = 0.0125).

Hierarchical Logistic Regression Analyses

We supplemented the analyses described above with analyses using a hierarchical logistic regression. This approach was taken to determine, on the subject level, contributions of each decision-making variable (reward level, effort level, and reward probability level) to choice of the high-effort option. Specifically, we fit the following model:

$$\begin{aligned}\text{Choice} \sim\ & 1 + \text{Reward Level} + \text{Effort Level} + \text{Reward Probability Level} \\ & + (1 + \text{Reward Level} + \text{Effort Level} + \text{Reward Probability Level} | \text{Subject})\end{aligned}$$

Choice was dummy coded (1 = high-effort option, 0 = low-effort option) and predictor variables were grand mean centered to aid model convergence. The model was fit using the lme4 mixed-effects package in R.[41]

Beta estimates were extracted for each individual subject. Group differences in beta estimates were analyzed through a series of one-way ANOVAs with beta estimates as the dependent variable and a between-subject factor of diagnostic group (HC, SZ, SZA, BD, MDD). We conducted Spearman correlations between beta estimates and CAINS-MAP, for the clinical groups. For these correlations, we used a Bonferroni correction to determine an appropriate significance threshold (0.05/4 = 0.0125)

Results

Demographics

Groups did not significantly differ on age, parental education, or gender identity (table 1). For personal education, both the SZ and SZA groups completed significantly

Table 1. Demographic Information

	Diagnostic Group					Test Statistic	
	HC	MDD	BD	SZA	SZ	*P*-value	Post Hoc Test
Sample size (*N*)	70	40	39	28	33		
Age	34.9 (10.2)	33.8 (9.4)	37.7 (10.8)	36.1 (11.9)	39.2 (11.2)	.18	
Gender identity (*N*)						.06	
Female	35	19	24	9	10		
Male	34	20	15	17	23		
Non-binary	1	1	0	2	0		
Race, (*N*)						.002	
Black	17	6	5	9	17		
Mixed Race	5	2	4	1	0		
White	34	28	26	16	14		
Asian	14	1	1	2	1		
Other	0	1	1	0	0		
Unreported	0	2	2	0	1		
Education							
Personal (years)	16.4 (2.4)	16.5 (2.1)	15.2 (2.7)	13.8 (2.7)	14.5 (2.5)	<.001	HC > SZ and SZA MDD > SZ and SZA
Parental (years)	14.0 (3.8)	14.7 (3.2)	14.2 (3.4)	15.1 (2.5)	14.3 (2.4)	.57	
Symptom assessment							
PHQ-9	1.4 (2.1)	8.3 (5.0)	6.2 (6.2)	8.1 (5.7)	4.8 (3.7)	<.001	SZ, SZA, BD, and MDD > HC; MDD and SZA > SZ
CAINS-MAP		8.4 (4.3)	7.9 (5.5)	8.1 (4.1)	10.3 (7.5)	.27	
CAINS EXP		2.1 (2.1)	1.9 (2.5)	3.0 (2.8)	3.1 (2.6)	.12	
BPRS total		38.6 (7.1)	39.6 (9.1)	49.9 (11.7)	42.1 (10.4)	<.001	SZA > MDD, BD, and SZ
BPRS psychosis		4.5 (0.9)	5.4 (1.9)	10.9 (5.4)	9.0 (5.0)	<.001	SZ and SZA > MDD and BD
YMRS total		5.1 (0.9)	6.5 (0.9)	13.6 (1.1)	10.0 (1.0)	<.001	SZ and SZA > MDD and BD
WTAR	39.9 (7.3)	40.2 (7.5)	40.6 (8.3)	38.2 (10.02)	33.9 (10.3)	<.005	HC, MDD, and BD > SZ

fewer years of education than the HC and MDD group. Further, the SZ and SZA groups performed significantly lower on the WTAR than the HC, MDD, and BD groups. Finally, there were a greater percentage of white subjects in the MDD and BD groups.

The clinical groups did not significantly differ in terms of negative symptoms (table 1). The SZA and MDD groups reported significantly more depressive symptoms than the SZ group. The SZA and SZ groups reported significantly greater positive symptoms and manic symptoms than the MDD and BD groups. Finally, the SZA reported significantly more general psychopathology than the MDD, BD, and SZ groups.

Summary Task Measures—Group Differences

There was a significant effect of group on effort exertion across trials, such that individuals with BD and SZA made fewer button presses during the exertion period for the high-effort option compared to participants with MDD and HCs ($F(3,205) = 2.55$, $P = .04$, $\eta^2 = 0.047$). Individuals with SZ did not significantly differ from any other diagnostic group. Frequency of choice for the high-effort option by task condition is illustrated for each group in figure 2. We observed canonical task effects such that participants were more likely to choose the high-effort option when reward was high, effort was low, and the probability of reward receipt was 100% (table 2). We observed a significant Group × Probability interaction (table 2). Post hoc pairwise comparisons revealed that this interaction was driven by a smaller effect of reward probability on choice of the high-effort option in the SZ group compared to HC and MDD participants. Specifically, for 100% reward probability trials, individuals with SZ showed reduced choice of the high-effort option compared to HCs (Tukey's HSD: $t = 3.510$, $P = .018$) and participants with MDD (Tukey's HSD: $t = 3.263$, $P = .039$). There were no other significant interactions between group and task variables (table 2).

Summary Task Measures—Negative Symptom Associations

We observed a negative association between experiential negative symptoms and choice of the high-effort option in the 100% reward probability condition in the SZ group, such that the highest negative symptom patients were the least willing to exert effort (figure 2; *rho* = −0.4, $P = .02$). However, this effect did not survive Bonferroni correction. This effect was not significant in the other patient groups. When directly comparing the symptom associations, by *z*-transforming the *rho* coefficients, the

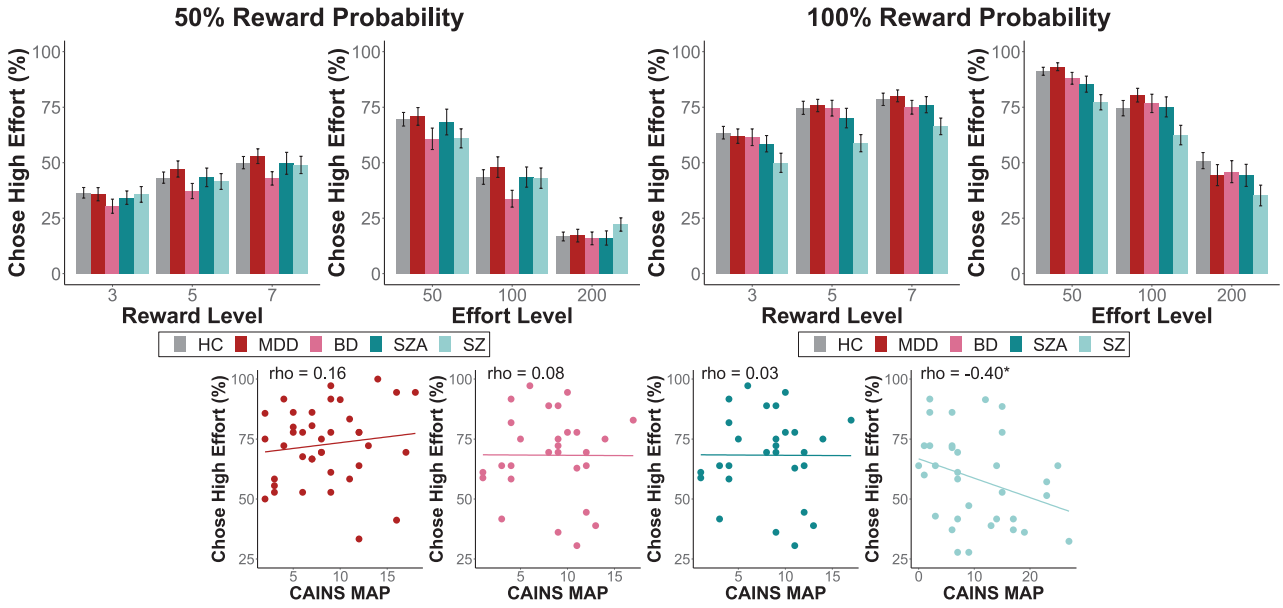

Fig. 2. Summary measures for the balloon task: (top row) choice of the high-effort option plotted for each group by trial type. (Bottom row) associations between experiential negative symptoms and summary measures for the balloon task: * Indicates $P < .05$. Shaded region indicates 95% confidence band. BD, bipolar disorder; HC, healthy control; MDD, major depressive disorder; SZ, schizophrenia; SZA, schizoaffective disorder. Error bars represent standard error of the mean.

Table 2. ANOVA Table for Summary Task Measures

Within Subjects Effects	*F*-value	*P*-value	η^2
Probability level	292.053	<.001	0.112
Probability level × Group	3.171	.015	0.005
Reward level	115.909	<.001	0.026
Reward Level × Group	0.673	.715	0.001
Effort Level	407.3	<.001	0.228
Effort Level × Group	0.925	.496	0.002
Probability Level × Reward Level	2.605	.075	0.001
Probability Level × Reward Level × Group	0.194	.992	0.001
Probability Level × Effort Level	12.961	<.001	0.003
Probability Level × Effort Level × Group	1.756	.084	0.002
Reward Level × Effort Level	13.664	<.001	0.004
Reward Level × Effort Level × Group	1.537	.08	0.002
Probability Level × Reward Level × Effort Level	9.947	<.001	0.003
Probability Level × Reward Level × Effort Level × Group	1.26	.217	0.001
Between subjects effects			
Group	2.01	.094	0.038

effect of experiential negative symptoms on ECDM was significantly stronger in the SZ group compared to the MDD (*z*-value = 2.38, $P = .02$) and BD (*z*-value = 2.04, $P = .04$) groups, but not the SZA group (*z*-value = 1.68, $P = .093$).

Decomposing Effects of Reward, Effort, and Probability—Group Differences

We supplemented the analyses described above with a hierarchical logistic regression approach to determine, for each subject, the independent contribution of each decision-making factor (reward magnitude, effort level, and reward probability level) to choice. Across the sample, participants demonstrated a positive reward magnitude beta (suggesting a higher frequency of choosing the high-effort option as reward increased), a positive reward probability beta (suggesting a higher frequency of choosing the high-effort option as the reward probability increased), and a negative effort beta (suggesting a lower frequency of choosing the high-effort option as effort increased) (figure 3). However, there were substantial individual differences. Regarding group differences, there was a significant main effect of diagnostic group on the magnitude of the reward probability beta

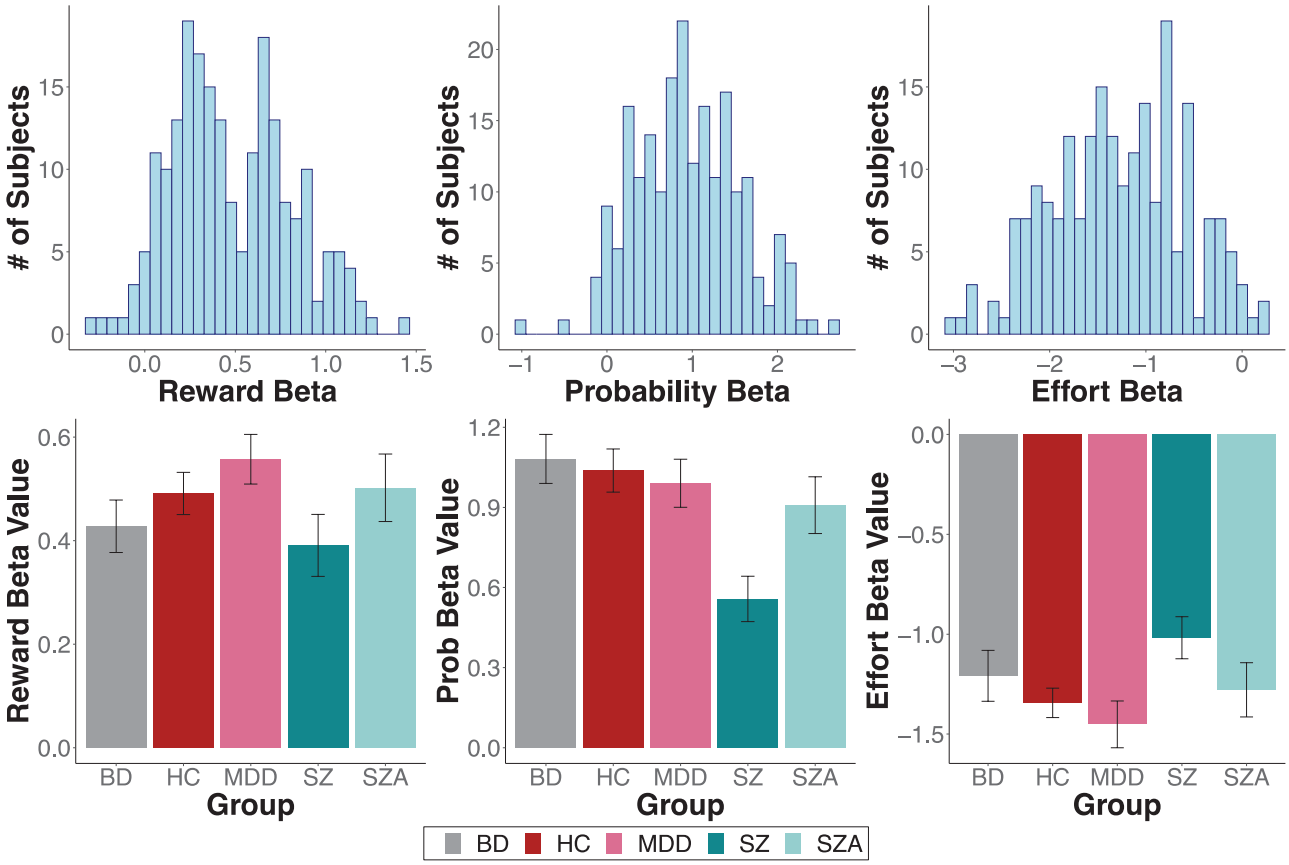

Fig. 3. Hierarchical logistic regression beta values for the balloon task: (top row) histograms of subject-specific beta values are provided for each decision-making factor across groups. (Bottom row) Beta values are plotted for each group for each decision-making factor. Error bars represent standard error of the mean. BD, bipolar disorder; HC, healthy control; MDD, major depressive disorder; SZ, schizophrenia; SZA, schizoaffective disorder.

($F(4,205) = 4.520$, $P = .002$, $\eta^2 = 0.081$). Post hoc pairwise comparisons revealed that this effect was driven by a smaller impact of reward probability on choice in the SZ group compared to the HC (Tukey's HSD: $t = 3.824$, $P = .002$), BD (Tukey's HSD: $t = 3.720$, $P = .002$), MDD (Tukey's HSD: $t = 3.093$, $P = .018$) participants. There were no significant effects of group on reward magnitude ($F(4,205) = 1.436$, $P = .223$, $\eta^2 = 0.027$) or effort magnitude ($F(4,205) = 2.064$, $P = .087$, $\eta^2 = 0.039$) beta estimates (figure 3).

Decomposing Effects of Reward, Effort, and Probability—Negative Symptom Associations

We observed significant negative associations between the reward magnitude and reward probability betas and CAINS-MAP, such that SZ patients with greater experiential negative symptoms demonstrated weaker impact of reward magnitude (*rho* = −0.456, $P = .008$) on ECDM (Supplementary Material S2). No other significant associations between parameter estimates and CAINS-MAP were observed. We directly compared the symptom associations by *z*-transforming the rho coefficients. The effect of experiential negative symptoms on the reward magnitude beta was significantly stronger in the SZ group compared to the SZA (*z*-value = 2.27, $P = .02$) but not the BD (*z*-value = 1.47, $P = .14$) and MDD group (*z*-value = 1.25, $P = .211$). The effect of experiential negative symptoms on the reward probability beta was significantly stronger in the SZ group compared to the BD (*z*-value = 2.06, $P = .039$) but not the SZA (*z*-value = 0.33, $P = .74$) and MDD group (*z*-value = 1.85, $P = .064$).

Associations Between Task Measures and Depressive and Positive Symptoms

In terms of positive symptoms, we did not find significant associations between ECDM and positive symptoms in any group. In terms of depressive symptoms, we did not find any significant associations in the expected direction between task measures and depressive symptoms (Supplementary Material S3). However, in the SZA group, we did find that the depressive symptoms were positively associated with the reward magnitude beta and negative associated with the effort beta. These findings were contrary to our hypotheses.

Discussion

The goal of the current study was to examine ECDM across individuals with psychotic and mood disorders. Consistent with our hypotheses, we observed reduced willingness to expend effort in SZ, particularly when the probability of reward receipt was high. This finding was evident in both standard analyses and our hierarchical logistic regression, which demonstrated reduced contributions of reward probability to ECDM in SZ. Additionally, we found that severity of experiential negative symptoms was associated with ECDM in SZ; however, this effect failed to remain significant following correction for multiple comparisons. Individuals experiencing severe negative symptoms exhibited a reduced willingness to expend effort, as well as diminished contributions of reward and probability information to ECDM. Surprisingly, we did not find aberrant ECDM or associations with negative symptoms in MDD or BD.

Our results regarding SZ are consistent with several previous reports.[7,13,42] Consistent with previous reports, we observed the most robust group differences at the highest reward probability levels.[14,16] Furthermore, our hierarchical logistic regression analyses revealed that reduced choice of the high-effort option in SZ is primarily driven by reduced impact of reward probability information on ECDM. Specifically, individuals with SZ choose the hard task less frequently in the 100% reward probability condition. Additionally, associations between negative symptoms and ECDM in SZ are driven by reduced reliance on reward and probability information. Therefore, the current manuscript demonstrates the benefit of applying advanced statistical approaches to behavioral data to draw conclusions regarding the contribution of decision-making factors in SZ.

Regarding BD and MDD, our results were inconsistent with some previous literature. Specifically, we did not find significant differences in ECDM between individuals with BD or MDD and HCs, nor did we find significant symptom associations in these groups. This finding contrasts with multiple reports demonstrating reduced ECDM in MDD and BD.[12,24,26,27] However, a number of recent reports have also failed to find reduced ECDM in individuals with MDD.[18,28,29,32] Future research is needed to understand these inconsistencies. For example, it may be the case that sampling of patients in differing clinical states (ie, current episode vs remission) could be driving inconsistent results. The majority of the MDD participants in our sample did not meet criteria for a current major depressive episode and reported relatively low levels of depressive symptoms. Regarding BD, our participants reported fewer negative and depressive symptoms than previous work which has found reduced ECDM in BD.[18,28] In summary, the low level of symptoms exhibited by the BD and MDD participants in the current study may have limited our ability to observe reduced ECDM.

The differences in ECDM between the SZA and the SZ groups in the current manuscript was surprising. Indeed, in most ECDM studies, researchers tend to analyze individuals with SZ and SZA together, as previous work has suggested that SZA may not be a distinct disease entity.[43] To our knowledge, the present ECDM study was the first to analyze individuals with SZA as a separate group. In the current study, individuals with SZA demonstrated more depressive symptoms and general psychiatric symptoms than individuals with SZ. Thus, it may be that differences in symptom profiles between these groups resulted in the absence of ECDM deficits. It will be important for future work to consider analyzing SZ and SZA separately to confirm whether effects of ECDM differ significantly between the two groups.

We used a hierarchical logistic regression to assess the contribution of factors (reward magnitude, reward probability, effort magnitude) to ECDM. However, this is not the only modeling approach that could be used. For example, Cooper and colleagues[25] recently used discount functions to model data in an ECDM task. Such modeling approaches are advantageous in that they allow for the estimation of non-linearities in the effect of reward magnitude and probability on choice; however, these models can be challenging to fit to participant data, particularly when trials are limited, and decision-making factors are not varied parametrically. Given that in our data factors of decision-making were not parametrically varied and we had a limited number of trials, assessment of non-linear effects using discount functions would have been a challenge. Future work will need to consider these design features when modeling ECDM data.

The current work had several limitations. First, conducting transdiagnostic research presents unique challenges when recruiting samples and comparing populations with different demographic profiles. Thus, there is an inherent tradeoff between matching groups on demographic variables and ensuring the recruitment of truly representative samples. Second, the diagnostic groups included in our study were prescribed a variety of different medications, which may influence ECDM. We did not have sufficient power to examine effects of participants ON/OFF medications or to look at the effect of classes of psychotropic medications within groups. Future research is needed to examine these results in a larger sample. Third, in the current sample we excluded individuals who primarily selected a single option. This approach was selected based on the analytical approach and aims of the paper; however, this approach may have excluded participants with specific types of motivational deficits (ie, individuals that solely selected the low-effort option). Fourth, in the current manuscript individuals with MDD were excluded if they experienced psychotic symptoms and individuals with BD were required to have psychotic symptoms. This led to a systematic difference between the groups

on the presence/absence of a history of psychosis and may complicate the interpretation of differences between the groups.

Summary

The current study aimed to examine ECDM in psychotic and mood pathology. We found evidence for reduced willingness to expend effort in the SZ group but not the other clinical groups. Our findings add to the accumulating evidence suggesting ECDM is an important target of study in SZ and highlights a need for novel interventions that aim to increase willingness to expend effort for rewards. However, in terms of mood pathology, the results provide another null result to an inconsistent literature. Future research is necessary to further explore ECDM in mood disorders to determine the sources of this inconsistency.

Supplementary Material

Supplementary material is available at https://academic.oup.com/schizophreniabulletin/.

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Conflict of Interest

The authors have declared that there are no conflicts of interest in relation to the subject of this study.

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