Journal of Psychopathology and Clinical Science


ISSN: 2769-7541

2023, Vol. 132, No. 4, 490–498
https://doi.org/10.1037/abn0000822

# Effort-Cost Decision-Making in Psychotic and Mood Disorders

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Avolition and anhedonia are core symptoms across psychosis and mood disorders. One important mechanism thought to relate to these symptoms is effort-cost decision-making (ECDM), the valuation and estimation of work required to obtain a given reward. While recent work suggests impairments in ECDM in both mood disorders and psychosis relative to controls, limited work has taken a transdiagnostic approach to examine how these deficits relate to different symptom profiles across disorders. The present study investigated ECDM across schizophrenia/schizoaffective disorder ($N = 33$), bipolar disorder ($N = 47$), unipolar depression ($N = 61$), and healthy controls ($N = 58$) to examine willingness to expend physical effort. Moreover, we examined the relationship between ECDM and motivation and pleasure symptoms across participants. We found that people with schizophrenia and bipolar disorder showed a reduced willingness to expend physical effort at high reward values relative to controls, while as a group, those with depression showed no differences relative to controls. However, individual differences in self-reported motivation and pleasure predicted reduced ECDM, particularly at high reward values, suggesting that both severity of symptoms and diagnostic categories are important for understanding altered ECDM in psychopathology.

***General Scientific Summary***

Decreased motivation and pleasure are common symptoms across mood and psychotic disorders however it is unclear whether these symptoms are related to similar mechanisms transdiagnostically. Findings from this study suggest that willingness to expend effort for high rewards may be a transdiagnostic marker of motivation and pleasure deficits across mood and psychotic disorders.

*Keywords:* effort-cost decision-making, motivation, schizophrenia, depression, bipolar disorder

*Supplemental materials:* https://doi.org/10.1037/abn0000822.supp



Impairments in pleasure and motivation are key symptoms of several disorders including schizophrenia, major depressive disorder (MDD), and bipolar disorder that are linked to poor functioning and are often unresponsive to currently available treatments (Bowie et al., 2010; Fervaha et al., 2015). While these symptoms represent a critical target for novel treatments, treatment development may be improved by understanding mechanisms that drive these symptoms. Further, while these symptoms are common across disorders, they may be driven by different mechanisms. For example, while anhedonia in depression is associated with blunting in both the experience and anticipation of pleasure (Dichter, 2010), anhedonia in schizophrenia is thought to be more related to a deficit in one's ability to anticipate pleasure and use this information to guide motivated behavior (Kring & Barch, 2014). Thus, while both demonstrate deficits in pleasure and motivation, they show differential patterns which may relate to how individuals with these conditions make decisions and motivate themselves toward rewards.

One framework useful for understanding motivation and pleasure impairments is effort-cost decision-cumaking (ECDM). ECDM refers to the calculations one makes to estimate the value of a

This article was published Online First April 20, 2023.

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We thank the participants in this study who generously gave their time. We also thank those that helped with all aspects of data collection. This study was supported by NIMH R34 MH066031-11.

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.

Erin K. Moran served as lead for data curation, formal analysis, visualization, writing–original draft, and contributed equally to conceptualization, investigation, and methodology. Caroline Prevost contributed to conceptualization, data analysis, writing-review and editing, and visualization. Adam J. Culbreth contributed equally to conceptualization, data analysis, writing-review and editing, and visualization. Deanna M. Barch served as lead for funding acquisition, and contributed equally to conceptualization, investigation, methodology, data analysis, and writing–review and editing.

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potential reward, the probability of receiving the reward, and the amount of work needed to obtain that reward. One important outcome of ECDM is a person's willingness to expend effort to obtain said reward. Research in schizophrenia suggests a fairly consistent pattern demonstrating that people with schizophrenia show a deficit in willingness to expend physical effort relative to controls, especially as reward value and probability of receipt increase (see Culbreth et al., 2018a for review). That is, findings suggest that reduced effort expenditure in schizophrenia is specific to those circumstances that are the most beneficial—trials that result in higher reward and have a higher likelihood of paying off. For example, Barch et al. (2014) found that people with schizophrenia were less likely to expend effort on a physical effort task at the two highest reward levels relative to controls. Similar findings of reduced effort expenditure at high reward and high probability levels have also been seen in those with first-episode psychosis (Chang et al., 2019) and in those across the psychosis spectrum (Whitton et al., 2020). Further, a number of studies have found that effort expenditure in schizophrenia is related to negative symptoms such that those with higher deficits in motivation and pleasure were the least willing to expend effort (e.g., Barch et al., 2014; Cooper et al., 2019; Culbreth et al., 2020; Gold et al., 2013; Moran et al., 2017). However, other studies have not seen this relationship with negative symptoms (Docx et al., 2015; Fervaha et al., 2013; Huang et al., 2016; Zou et al., 2020). In their review, Hartmann-Riemer et al. (2018) posit that some of these inconsistencies may be due to the symptom measure used, suggesting that motivation and pleasure deficits (also known as experiential negative symptoms) may be more closely linked to effort deficits compared to overall negative symptoms. Similarly, Zou et al. (2020) posited that while they did not see relationships between Positive and Negative Syndrome Scale-negative symptoms or self-reported measures of anhedonia, it may be important to use measures that capture both pleasure and motivational impairments.

Studies investigating ECDM in depression have shown a reduced willingness to expend physical effort in those with clinical depression and those with depressive symptoms (Hershenberg et al., 2016; Treadway et al., 2009, 2012; Yang et al., 2014; Zou et al., 2020). However, this deficit may be state-specific, as in one study those with remitted depression showed no deficit, suggesting that experience of current depressive symptoms is important (Yang et al., 2014). In contrast, some studies have not seen a difference in effort expenditure between people with current depression relative to controls (e.g., Tran et al., 2020; Yang et al., 2021). There are also mixed findings regarding what symptoms relate to ECDM in depression. In a study by Tran et al. (2020), while people with depression did not show a significant group difference relative to controls in willingness to expend physical or cognitive effort, they did find that anhedonia ratings within the depressed group predicted an overall reduced willingness to expend physical effort (Tran et al., 2020). However, others have not seen this relationship between anhedonia and ECDM in depression, and instead have found a relationship with anticipatory pleasure ratings (Sherdell et al., 2012; Yang et al., 2021). Thus, while several studies have shown deficits in ECDM in depression, this may be specific to people who have current depressive symptoms and relationships to symptoms remain mixed.

While a growing body of research has highlighted impairments in ECDM in schizophrenia and unipolar depression, relatively little is known about ECDM in bipolar disorder. People with bipolar disorder, like those with depression and schizophrenia, experience disruptions in both pleasure and motivation with similar blunted responses to reward and reduced motivation during depressive episodes. In contrast, manic phases of bipolar disorder are associated with increases in pleasure seeking and goal setting. In the handful of studies examining ECDM in bipolar disorder, the findings suggest potential differences by phase of illness. For example, one study administered a progressive ratio task in individuals with bipolar depression, unipolar depression, and healthy controls (Hershenberg et al., 2016). They found reduced effort in both clinical groups compared to controls, but no significant difference between unipolar and bipolar depressed groups. Similar to the pattern seen in schizophrenia, Yang et al. (2021) found that those with bipolar disorder who were currently manic showed reduced willingness to expend effort in the high reward and high probability conditions relative to controls. However, those that were currently manic also showed greater hard choice selection at the low-value choices relative to controls thus suggesting an inefficient effort allocation pattern. Further, they found that those with unipolar and bipolar depression did not differ in hard task choice relative to controls. In a study examining physical effort in those with schizophrenia, bipolar disorder, and unipolar depression relative to controls, Zou et al. (2020) found that all patient groups including those with bipolar disorder showed a decreased willingness to expend effort for high rewards relative to controls. One study examining relationships between goal setting and ECDM found that in those with remitted bipolar disorder, lofty goal setting was related to greater effort expenditure (Johnson et al., 2017). Thus, while findings point to potential deficits in ECDM that vary by phase of illness in bipolar disorder, more work is needed to replicate previous findings and clarify what symptoms ECDM relates to in bipolar disorder.

## Current Study

The current study sought to fill several gaps in the literature by taking a transdiagnostic approach examining ECDM across psychotic and mood disorders to identify similar or disparate deficits in ECDM. It may be the case that while each group shows differences in ECDM, these differences may be specific to group and thus group status is important. However, it may also be the case that given the overlap in motivation and pleasure deficits across groups, relationship between symptoms and ECDM will be important across all participants. To address this we examined willingness to expend effort in two ways. First, we examined group differences in ECDM to identify differences in willingness to expend effort between controls, those with schizophrenia (SZ)/schizoaffective disorder, bipolar disorder, and unipolar depression. Second, we took a transdiagnostic approach to examine whether motivation and pleasure negative symptoms relate to ECDM across disorders. We hypothesized that all patient groups (schizophrenia, bipolar disorder, and unipolar depression) would be less willing to expend physical effort for high reward values relative to control participants. Further, while previous studies have assessed self-reported anhedonia or single-item measures of avolition transdiagnostically (Yang et al., 2021; Zou et al., 2020), the current study sought to examine the relationship between the motivation and pleasure factor of negative symptoms and ECDM across mood and psychotic disorders. Based on research in schizophrenia suggesting the strong relationship between these symptoms and ECDM at high reward levels, we hypothesized that motivation and pleasure would be related to ECDM at high reward levels regardless of group status.

# Method

## Participants

Study participants included 33 people with SZ or schizoaffective disorder, 61 people with MDD, and 47 people with bipolar I disorder (BD) in any phase of illness at the time of testing (25 euthymic, 13 depressed, 3 manic, and 6 hypomanic) as defined by the DSM-5 (American Psychiatric Association, 2013). In addition, there were 58 control participants (CON). Exclusion criteria included: (a) DSM-5 diagnosis of substance abuse or dependence in the past 6 months; (b) IQ less than 70 as measured by the Wechsler Test of Adult Reading (WTAR; Wechsler, 2001); and (c) history of severe head trauma and/or loss of consciousness. Additional exclusion criteria for patient groups included (a) medication changes in the month prior to study participation and (b) inpatient or partial hospital status. Additional criteria for controls included (a) no personal or immediate relative with a history of schizophrenia, schizoaffective disorder, or bipolar disorder; (b) no current or past major depression; and (c) no current psychotropic medication. All participants provided written informed consent to the protocol approved by the Washington University Institutional Review Board.

## Diagnostic and Symptom Assessment

Diagnostic status was confirmed using the Structured Clinical Interview for DSM-5 conducted by masters or PhD-level clinicians. Clinician-rated negative symptoms were assessed in all those with mood or psychotic disorders using the Clinical Assessment Interview for Negative Symptoms (CAINS; Kring et al., 2013), which includes a Motivation and Pleasure (MAP) and Expression (EXP) subscale, with higher scores indicating greater impairment. Participants also completed self-report assessments of symptoms relevant across disorders. To assess motivation and pleasure negative symptoms, participants completed the Motivation and Pleasure Scale-Self-Report (MAP-SR; Llerena et al., 2013) which assesses motivation and pleasure across a variety of domains including social, occupational, and recreational activities over the prior week. The measure includes a total score with higher scores equaling more motivation and pleasure across the week (i.e., lower motivation and pleasure negative symptoms). Depression symptoms were assessed using the Center for Epidemiological Studies Depression Scale (CES-D; Radloff, 1977) assessing the full range of depression symptoms with higher scores meaning more depression symptoms across the prior week. Mania symptoms were assessed using the Altman Self-Rating Mania Scale (ASRM; Altman et al., 1997) a short 5-item measure assessing mania symptoms over the prior week with higher scores indicating more potential mania symptoms.

### *Balloon Task*

We used a modified version of the Balloon task (Gold et al., 2013) to shorten the task. This task assesses participants' willingness to expend physical effort and complete easy or hard button-pressing tasks for varying levels of reward. On each trial, participants were instructed to choose between completing either an easy task or a hard task. The hard task involves pressing alternating buttons 100 times for the chance to win a reward ($3, $4, $5, $6, and $7). The easy task requires participants to press alternating buttons 20 times to have the chance to win $1.00. Once participants selected either the easy or hard task, they completed the button press task for that trial. There was no time limit for completing the trial, however, participants were encouraged to complete the task as quickly as possible. Participants completed 25 total trials. Outcome measures include the percentage of hard tasks chosen overall and the percentage within the five different reward amounts ($3/4/5/6/7). Participants received the sum of three randomly selected trials for task payment.

## Procedure

Approximately half of all data collection was completed prior to the COVID-19 pandemic. At this time, participants completed clinical interviews, task data, and self-report measures in person during a single session. Following the COVID-19 pandemic shutdown procedures for the study were changed due to concerns regarding the spread of COVID-19. Following the COVID-19 shutdown, given that facial expressions are an important aspect of CAINS negative symptom ratings, clinician-rated symptom interviews were conducted via zoom in a session prior to completion of tasks and self-report measures (Mean = 7.15 days, $SD = 5.40$). Specifically, 46% of SZ, 48% of BD, and 52% of our MDD sample were collected post-COVID-19 and thus have clinician symptom ratings that were not collected on the same day as task and self-report data were collected. Because of differences in how CAINS data was collected, we used MAP-SR as our primary outcome measure, however, analyses examining CAINS MAP are included in the online supplemental materials.

## Data Analysis

Consistent with Gold et al. (2013), balloon task data were analyzed using a series of mixed model repeated measures analyses of covariance (ANCOVAs). The first ANCOVA included Diagnostic Group (CON, SZ, BD, and MDD) as a between-subject factor and a within-subject factor for Reward Level (five levels: $3, $4, $5, $6, and $7). Significant Diagnostic Group × Reward level interactions were followed up by a series of planned comparisons at each reward level among the diagnostic groups. To examine both group and symptom effects a subsequent model added MAP-SR as a predictor to examine potential main effects and interactions with reward. Lastly, to determine whether symptom relations differed by group, a final model included interactions between group, reward, and MAP-SR score. Gender and race were also added as covariates to account for group differences between groups. Importantly, all patterns of findings were similar with and without covariates.

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 and Symptom Characteristics

Demographics for all four groups are shown in Table 1. There was a significant difference in gender with more women in the MDD and BD groups relative to the CON and SZ groups, $X^2(3, N = 199) = 8.81$, $p = .03$. Additionally, there was a significant difference in

**Table 1**
*Participant Demographic and Clinical Measures*

| Demographics | CON ($n = 58$) | SZ ($n = 33$) | BD ($n = 47$) | MDD ($n = 61$) | Group diffs ($p$) |
|---|---|---|---|---|---|
| Sex (M:F) | 29:29[a] | 14:19[a] | 16:31[b] | 15:46[b] | .03 |
| Ethnicity, ($n$) | | | | | <.001 |
| African American | 19 | 20 | 7 | 12 | |
| Asian | 4 | 0 | 5 | 2 | |
| Caucasian | 35[a] | 13[b] | 35[a] | 47[a] | |
| Age | 35.17 (8.76) | 33.55 (8.16) | 37.55 (8.28) | 34.28 (8.88) | .15 |
| Education (years) | 14.60 (2.54) | 13.52 (2.32) | 14.89 (2.49) | 15.01 (2.40) | .11 |
| Parental education (years) | 13.33 (2.60) | 13.20 (2.52) | 13.47 (2.89) | 14.31 (2.14) | .12 |
| WTAR | 38.05 (9.09)[a] | 29.22 (11.93)[b] | 38.62 (9.31)[a] | 39.57 (8.71)[a] | <.001 |
| Unmedicated ($n$) | 58 | 5 | 9 | 24 | |
| Antidepressant ($n$) | 0 | 15 | 33 | 38 | |
| Mood stabilizer ($n$) | 0 | 5 | 37 | 2 | |
| Antipsychotic ($n$) | | | | | |
| Typical | 0 | 2 | 0 | 0 | |
| Atypical | 0 | 25 | 16 | 3 | |
| Combination | 0 | 1 | 0 | 0 | |
| CPZ | — | 338.06 (303.33) | 137.45 (226.13) | 7.79 (36.95) | |
| CES-D | 4.78 (3.42)[a] | 12.31 (6.44)[b] | 11.55 (6.49)[b] | 13.65 (6.62)[b] | <.001 |
| MAP-SR | 44.28 (8.57)[a] | 32.42 (12.77)[b] | 36.47 (9.79)[b] | 32.15 (8.97)[b] | <.001 |
| ASRM | 4.93 (4.04)[a] | 4.84 (3.27)[a] | 4.89 (4.11)[a] | 2.72 (2.83)[b] | .002 |
| CAINS MAP | — | 14.77 (7.65) | 11.15 (6.51) | 12.36 (5.87) | .06 |
| CAINS EXP | — | 3.03 (3.02)[a] | 1.13 (2.32)[b] | 1.41 (1.59)[b] | .001 |

*Note.* CON = control; SZ = schizophrenia; BD = bipolar disorder; MDD = major depressive disorder; WTAR = Wechsler Test of Adult Reading; CPZ = chlorpromazine equivalent dose; CES-D = Center for Epidemiological Studies Depression Scale; MAP-SR = Motivation and Pleasure Scale-Self-Report; ASRM = Altman Self-Rating Mania Scale; CAINS MAP = Clinical Assessment Interview for Negative Symptoms Motivation and Pleasure Subscale; CAINS EXP = CAINS Experience Subscale.
Superscripts denote significant differences between groups, $p < .05$.



race by group, $X^2(6, N = 199) = 26.92$, $p = .0002$. All patient groups reported significantly higher rates of motivation and pleasure-negative symptoms, $F(3,198) = 18.13$, $p < .001$ and depression symptoms, $F(3,198) = 26.43$, $p < .001$ than controls. There were no significant differences between patient groups on motivation and pleasure ($ps > .10$) or depression ($ps > .25$). There was also a significant difference in self-reported mania $F(3, 198) = 5.13$, $p = .002$), however, this was driven primarily by the MDD group reporting significantly fewer mania symptoms relative to CON, SZ, and MDD groups.

## Group Differences in Effort-Based Decision-Making

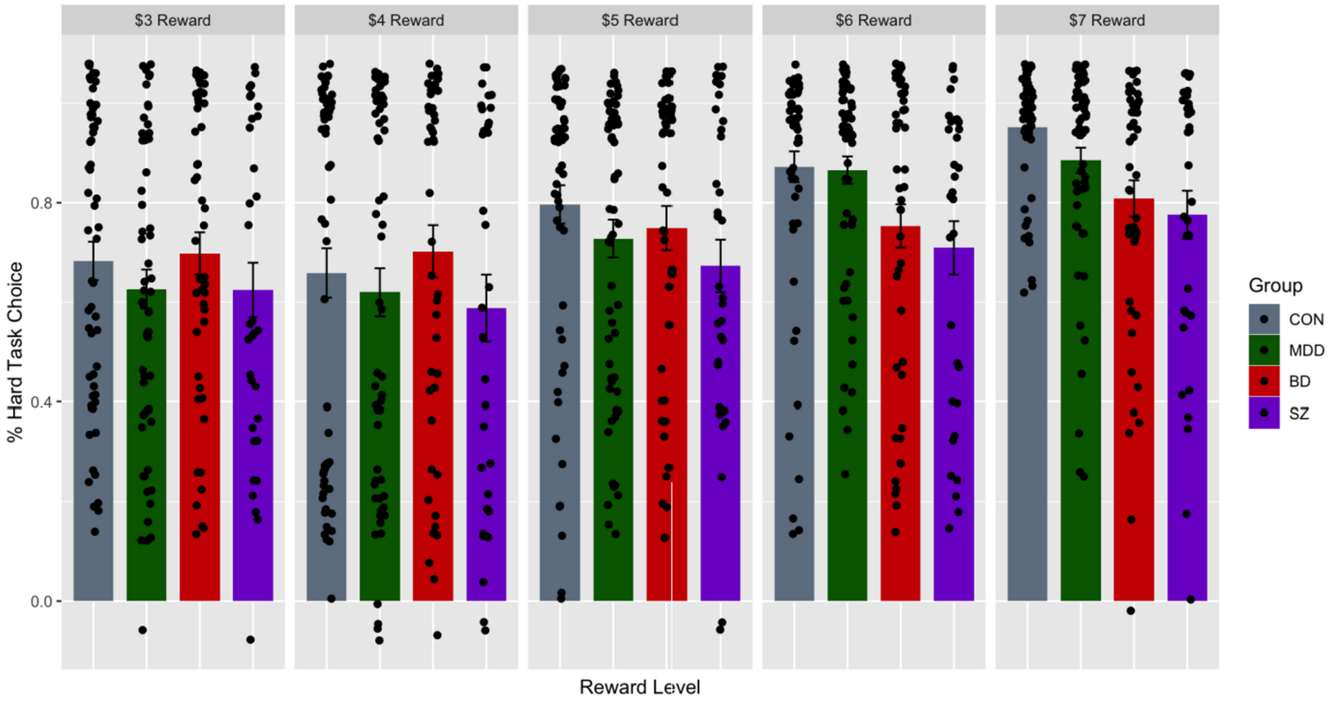
We started with the ANCOVA including Diagnostic Group and Reward factors. As shown in Figure 1, we observed a significant main effect of Reward Magnitude, $F(4,188) = 44.96$, $p < .001$, $\eta_p^2 = .19$ suggesting that people were more willing to expend effort as reward value increased. As hypothesized, there was not a main effect of Group, $F(3,188) = 1.29$, $p = .28$, but there was a Group × Reward interaction, $F(3, 188) = 2.87$, $p = .03$, $\eta_p^2 = .05$. Follow-up analyses revealed significant between-group differences in hard task choice in the \$6, $F(3, 188) = 2.83$, $p = .03$, $\eta_p^2 = .04$ and \$7 reward conditions, $F(3,188) = 3.88$, $p = .01$, $\eta_p^2 = .05$, indicating significantly lower effort expenditure in the SZ and BD group relative to controls ($ps < .05$). Unexpectedly there were no significant between-group differences between MDD and CON at any reward level ($ps > .18$). There were also no group differences between the three patient groups at any reward level.

## Relationship Between Hard-Task Choices and Self-Reported Symptoms

In the second ANCOVA, we added MAP-SR and examined main effects and interactions with Reward. We no longer saw a main effect of Reward, $F(4,186) = 1.44$, $p = .22$, but we still saw a Diagnostic Group × Reward interaction, $F(3,186) = 3.30$, $p = .01$, $\eta_p^2 = .05$, with the same pattern as in the first analysis of variance (ANOVA; see Figure S1 in the online supplemental materials). There was not a main effect of MAP-SR, $F(1,186) = .49$, $p = .48$, but there was a significant interaction between Reward and MAP-SR, $F(1,186) = 7.65$, $p = .006$, $\eta_p^2 = .04$. To understand the source of this interaction, we conducted a regression predicting hard task choice at the highest reward level (\$7) with MAP-SR, group, gender, and race added as predictors. As shown in Figure 2, we found that the overall model was significant, $r = .31$, $r^2 = .10$, $p = .003$, while MAP-SR was the significant predictor, standardized $\beta = .28$, $t = 3.65$, $p = .0002$. To further examine the strength of predictors, we conducted exploratory post hoc analyses to predict hard task choice at the highest reward level (\$7) we entered Group, gender, and race as predictors in a single step. The overall model was significant ($r = .16$, $r^2 = .03$, $p = .04$) with Group being the only significant predictor (standardized $\beta = -.16$, $t = -2.30$, $p = .02$). Next, we took a stepwise approach entering Group in Step 1 and then MAP-SR as Step 2. In this analysis, we found that while the Step 1 model was significant, there was a significant $F$ Change between models ($r = .29$, $r^2 = .08$, Sig $F$ Change = .001), where Group was no longer significant in the model (standardized $\beta = .08$, $t = .98$, $p = .24$) while MAP-SR is a significant predictor (standardized $\beta = .30$, $t = 3.37$, $p = .001$).

**Figure 1**

*Frequency of Hard Task Choice*

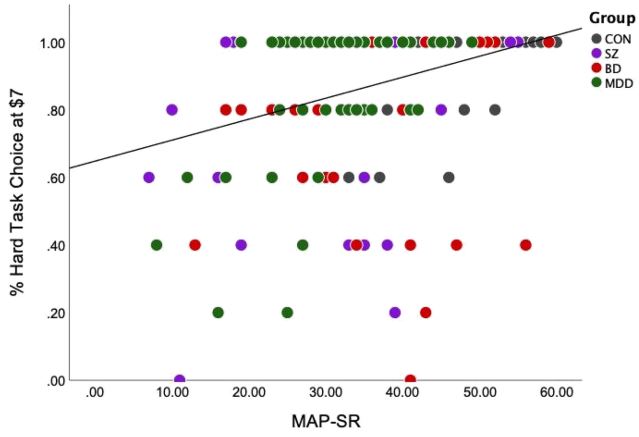



*Note.* Hard task choice data plotted for each reward level by group. Individual data points have been jittered vertically to improve visual clarity of individual data points. CON = control; MDD = major depressive disorder; BD = bipolar disorder; SZ = schizophrenia. See the online article for the color version of this figure.

Thus, our findings suggest that while Group is a significant predictor of ECDM at the highest reward value, when MAP-SR is added as a predictor, MAP-SR appears to be the stronger predictor in this stepwise regression approach.

**Figure 2**

*Correlation Between MAP-SR and Hard Choice at the Highest Reward Level*




*Note.* CON = control; SZ = schizophrenia; BD = bipolar disorder; MDD = major depressive disorder; MAP-SR = Motivation and Pleasure Scale-Self-Report. See the online article for the color version of this figure.

While the Group × Reward interaction was most apparent in the highest reward condition ($7) we conducted post hoc exploratory analyses within each reward level to examine potential relationship between MAP-SR and hard task choice. We used simple regressions to predict hard task choice at each reward level with MAP-SR as a predictor. We found that MAP-SR was a marginally significant predictor of % of hard task choice at the $6 reward level (standardized $\beta = .15$, $t = 1.98$, $p = .05$) and trending in the $5 reward condition (standardized $\beta = .13$, $t = 1.88$, $p = .06$). There were no significant relationships between MAP-SR and hard task choice in either the $4 (standardized $\beta = .01$, $t = .12$, $p = .91$) or $3 reward condition (standardized $\beta = .06$, $t = .81$, $p = .42$). Thus, consistent with our hypotheses and previous research, group differences and motivation and pleasure symptoms appear to be focused on high reward regions.

## Diagnostic Group Differences in the Relationship Between Hard-Task Choices and Self-Reported Symptoms

In the third ANCOVA, we allowed MAP-SR to interact with the Diagnostic Group as well as Reward. This ANCOVA no longer showed a significant main effect of Reward, $F(4,182) = .95$, $p = .43$, nor a Reward × Diagnostic Group interaction, $F(12,182) = 1.21$, $p = .27$. However, there was still a significant Reward × MAP-SR interactions, $F(4,182) = 6.42$, $p = .02$, again suggesting that more motivation and pleasure was related to effort at higher reward values. There was no

three-way interaction between Reward × MAP-SR × Diagnostic Group, $F(3,182) = 1,94$, $p = .12$.

## Relationship Between Hard Task Choice and Completion Time

Post hoc exploratory analyses were conducted to examine whether mean completion time of hard task choice (a proxy for difficulty) significantly differed by group and whether it was related to tendency to choose the hard task options. First, we conducted an ANOVA to examine group differences in mean hard task completion times and found that while the SZ group took the longest to complete the hard task trials, there was not a significant difference between group, $F(3,196) = 1.76$, $p = .16$. However, despite a lack of group difference in completion time, there may still be an important relationship between completion time and decision to complete the hard task. Across all participants, we saw no significant correlations between % of hard task choice and mean completion time ($r = .13$, $p = .10$). Still, it may be that this relationship is specific to certain groups, thus we examined whether this might differ by group and found no significant correlations between completion time and hard task choice in CONs ($r = .04$, $p = .79$), people with SZ ($r = -.10$, $p = .61$) or BD ($r = -.13$, $p = .49$). However, we did see a significant relationship between hard trial completion time and total hard choice in the MDD group ($r = -.32$, $p = .01$). To further examine this relationship between completion time and hard task choice within the MDD group, we conducted further exploratory correlations within each reward level and found that relationship between hard task choice in the \$6 ($r = -.35$, $p = .006$) and \$7 ($r = -.54$, $p < .001$) was significantly related to completion time in MDD. Relationships between mean hard task completion time and other reward levels were not significant (\$3 Reward, $r = -.15$, $p = .24$; \$4 Reward: $r = .01$, $p = .94$; \$5 Reward: $r = .24$, $p = .07$). Thus, shorter completion time for the hard task choice was significantly related to decision to complete the hard task in the highest reward values in those with MDD.

## Relationship Between Hard Task Choice and Estimated IQ

Post hoc exploratory analyses were conducted to examine whether estimated IQ, as measured by the WTAR, was related to ECDM. In correlations across all participants, we found no significant relationships between WTAR and ECDM (\$3 Reward: $r = .04$, $p = .54$; \$4 Reward: $r = .03$, $p = .70$, \$5 Reward: $r = .09$, $p = .19$; \$6 Reward: $r = .10$, $p = .18$; \$7 Reward: $r = .14$, $p = .05$). Given the trend in the highest reward level (\$7) and the focus of the group differences on this reward level, we conducted further post hoc exploratory analyses within each group to examine whether this relationship was Group specific. Indeed, and surprisingly, we found a strong significant relationship between WTAR and hard task choice in the \$7 Reward level in the MDD group ($r = .422$, $p = .001$). In contrast, there were no significant relationships between WTAR and choice in the other groups (CON: $r = -.02$, $p = .87$; SZ: $r = .01$, $p = .97$; BD: $r = -.03$, $p = .86$). Thus, there was no relationship between WTAR and task choice in CON, BD, or SZ, however, there was a strong relationship between greater estimated IQ and greater hard task choice in the \$7 reward level in those with MDD.

## Relationship Between Hard Task Choice and Medication

We calculated chlorpromazine (CPZ) equivalency doses in all patients taking an antipsychotic and examined correlations between CPZ and ECDM across all patient groups and within the SZ group in particular given that the majority of SZ patients were taking an antipsychotic. As shown in Table 2, we saw no significant relationships between CPZ and % of total hard choices or % of hard task choices at each reward level. Further, we confirmed this finding in the SZ group alone, with no significant relationships between ECDM and CPZ.

# Discussion

The goal of the current study was to examine willingness to expend effort for reward across psychosis and mood disorders to examine both potential differences between groups and transdiagnostic symptoms that relate to ECDM across disorders. Consistent with our hypotheses, we found that people with schizophrenia and bipolar disorder showed reduced effort expenditure at the highest reward levels, suggesting a deficit in willingness to expend effort on trials that are the greatest benefit. In contrast to our hypothesis, we did not see a group difference in those with unipolar depression relative to controls. Further, we found that motivation and pleasure negative symptoms significantly related to ECDM across disorders suggesting important symptom relationships regardless of group status. We discuss these findings in further detail below.

In regards to groups differences, our findings replicate and extend previous work demonstrating that people with schizophrenia show a decreased willingness to expend effort at high reward levels relative to controls, again suggesting that deficits in ECDM in schizophrenia are seen in those trials that have the greatest potential for reward (see Culbreth et al., 2018b for review). The present findings add to the accumulating evidence suggesting ECDM is an important target of study in schizophrenia and highlights a need for novel interventions that aim to increase willingness to work toward high rewards and goals. Further, we found that people with bipolar disorder showed a similar deficit suggesting decreased effort expenditure at high reward levels relative to controls. While work examining ECDM in bipolar disorder is limited, work has shown a similar finding in those currently manic suggesting a particular deficit in ECDM at high reward levels relative to controls. Similarly, Hershenberg et al. (2016) found that people with bipolar disorder who were currently depressed showed a reduced willingness to expend effort for reward. While the majority of our sample with bipolar disorder were euthymic at testing (53%), our sample also includes those who were currently depressed (28%) and hypomanic/manic

**Table 2**
*Correlations Between CPZ and Percentage of Hard Task Choice Across all Reward Conditions*

| | CPZ (all patient groups) | CPZ (in SZ group) |
|---|---|---|
| % Total hard choice | −.03 | −.03 |
| % Hard reward 3 | .01 | −.05 |
| % Hard reward 4 | −.08 | .07 |
| % Hard reward 5 | −.01 | .07 |
| % Hard reward 6 | −.12 | −.21 |
| % Hard reward 7 | .03 | .18 |

*Note*. CPZ = chlorpromazine equivalent dose; SZ = schizophrenia.

(19%), our findings combined with previous findings showing decreased ECDM in both euthymic and depressed BD participants may suggest that effort deficits are apparent across at least euthymic and depressed phases of illness. Given that mania is characterized by increased positive affect and reward seeking (Gruber, 2011) it may be the case that ECDM in mania is heightened relative to controls and other patient groups for specific reward values. Taken together the current work suggests that ECDM deficits in bipolar disorder may not be state dependent and may be most relevant to high reward values. It will be important for future work to replicate these findings and to further examine ECDM across all phases of illness, to examine whether ECDM varies by reward during different phases of illness.

Inconsistent with our hypothesis, we did not see a group difference in willingness to expend effort in those with unipolar depression relative to controls. As reviewed in the introduction, while some studies have shown a decreased willingness to expend effort in those with unipolar depression (Hershenberg et al., 2016; Treadway et al., 2012; Zou et al., 2020), others have failed to find a significant group difference relative to controls (Tran et al., 2020; Yang et al., 2021). The inconsistent findings may be due to a number of variables including differences in task design and symptom characteristics. For example, to our knowledge, the Balloon task has not been used in previous studies in depression and does offer higher reward values (e.g., $3/4/5/6/7) than more frequently used tasks such as the Effort Expenditure for Reward task (EEfRT; Treadway et al., 2009) which typically ranges from $1 to $4. It may be that level of reward is important and perhaps the higher reward value in the present study was particularly incentivizing in unipolar depression. Moreover, in the present study, we did not vary probability of reward as is done in the EEfRT task. Given that probability has been shown to be important in schizophrenia and in relationship to depression symptoms, deficits in unipolar depression may be particularly sensitive to probability of receipt of reward. Indeed, probability of receiving rewards in daily life varies and is likely important in deciding when to expend effort to reach goals. However, despite these differences in task, previous work has seen mixed findings using the EEfRt task (Tran et al., 2020; Yang et al., 2021) thus other characteristics may also be important to understand mixed findings. For example, those with remitted depression did not show a deficit in ECDM, thus suggesting a state-like association (Yang et al., 2014)—however, the current study contained only those who were currently depressed. It may also be that mixed findings are driven by other group characteristics. In the current sample, women made up 75% of the unipolar depression group, while in other studies such as Zou et al. (2020) women made up 44% of the unipolar group. While gender was not related to ECDM variables in the current analyses, Zou and others have seen gender related to effort expenditure (Huang et al., 2016; Zou et al., 2020). Further, in the present study, only a current depressive episode was required and perhaps ECDM deficits would be more apparent in those with more persistent depression or in those that have experienced multiple episodes of depression throughout their lives. In addition, while exploratory and post hoc, the relationship between higher estimated IQ and hard task choice in the MDD group warrants further examination. It will be important for studies to clarify these distinctions by carefully examining the boundaries of ECDM deficits in unipolar depression, characterizing when these deficits occur, if more focal aspects of cognition (e.g., cognitive control) may be relevant, and what additional factors predict deficits in depression. This will be important both for understanding these deficits and in helping identify who might best benefit from treatments targeting ECDM in this population. Lastly, while the analyses were exploratory and post hoc, given the relationship between completion time (a potential proxy for difficulty) and tendency to choose the high reward values in MDD, it will be important for future studies to examine whether difficulty or time to complete the task is especially relevant in MDD. For example, future studies could use a task that requires all participants to exert effort for a set time. Assessing subjective difficulty will also be important as how difficult one feels the task is, despite the ability to complete the task, may play an important role in whether one chooses to take on hard tasks. It may be that subjective difficulty in addition to reward level is critical in MDD when deciding whether to exert effort.

While our findings suggest ECDM deficits in individuals with serious mental illness at the group level, our findings also suggest that individual differences in severity of symptoms are important to consider even when group status is accounted for. More specifically, we found that individual differences in motivation and pleasure negative symptoms interacted with reward beyond group effects, such that across participants regardless of group status, those who report lower motivation and pleasure are less likely to expend effort at high reward levels. Further, in regression analyses, it was motivation and pleasure and not group that was a significant predictor of willingness to expend effort at the highest reward values when both Group and symptoms were entered into the model. While previous transdiagnostic studies examining physical effort expenditure have failed to find a significant relationship between self-reported anhedonia (Yang et al., 2021; Zou et al., 2020) or in single-item measures of avolition (Zou et al., 2020), our findings suggest that it is the combination of self-reported motivation and pleasure (or experiential negative symptoms) that may be a transdiagnostic marker related to willingness to expend effort for high reward values. This finding is important as it points to the need to consider motivation and pleasure deficits regardless of group membership and highlights a transdiagnostic marker for treatment. It may be the case that a lack of group differences in the depressed group is related to different levels of motivation and pleasure negative symptoms within the depression group, though on average their MAP-SR symptom severity was quite similar to the schizophrenia group. Moreover, while motivation and pleasure are frequently discussed in schizophrenia as one important factor in understanding negative symptoms, to our knowledge it is less frequently examined in other disorders despite the overlap in symptoms across disorders and despite the high levels of motivation and pleasure deficits reported across the patient groups. It will be important to extend our understanding of motivation and pleasure deficits across disorders and identify common or disparate relationships with these symptoms in psychopathology.

The present study had several limitations. First, differences in gender and race between groups were significant, and while all of our findings held when accounting for these variables, demographic differences are still important to understand. While conducting transdiagnostic research is an important avenue for the field, it presents additional challenges when recruiting samples and comparing populations that have different demographic profiles. For example,

women are approximately 2 times more likely to be diagnosed with unipolar depression relative to men (Salk et al., 2017) while in schizophrenia estimates suggest either similar incidence rates between men and women or higher rates of illness in men (McGrath et al., 2008). Thus, consideration should be given to recruiting comparable groups while also ensuring that samples are reflective of the disorder being studied. Future studies will need to carefully weigh the need to have samples with similar demographics while also appreciating that group demographics are not always similar.

Second, the majority of patients were on a variety of psychotropic medications including antipsychotics, antidepressants, and mood stabilizers. This is especially important when considering the number of participants on antipsychotic drugs given the evidence suggesting that rodents given D2 agonists such as haloperidol show reduced effort expenditure (Randall et al., 2012). While the present study along with several studies examining the relationship between ECDM and antipsychotic dose effects have failed to see a relationship (e.g., Barch et al., 2014; Fervaha et al., 2013; Gold et al., 2013) an important next step will be examining antipsychotic-free or antipsychotic naïve participants. Similarly, studies examining the relationship between selective serotonin reuptake inhibitor (SSRI) use and ECDM have not seen significant relationships (Hershenberg et al., 2016; Yang et al., 2021), and indeed SSRIs are not particularly effective in treating motivational impairments (e.g., Salamone et al., 2018), however, this is an important consideration for future research.

Third, the current sample size did not allow us to examine ECDM as it varies by mood state in bipolar disorder. While the majority of our participants were euthymic during their study participation, we did have people with bipolar disorder that were depressed and manic/hypomanic. It will be important for future work to further clarify how ECDM changes across mood state as ECDM may be more related to mood state or a symptom profile rather than a general diagnostic category.

Finally, the current study includes data collected both before the COVID-19 pandemic and post the COVID-19 pandemic shutdown. Due to issues with conducting clinical interviews that involve the need to rate facial expressions, all clinical interviews post-COVID-19 were conducted over zoom an average of 7 days before they completed task and self-reported symptom ratings. Because of this, we focused our analyses on relationships with self-reported motivation and pleasure which was completed in the behavioral data testing session. It will be important for future work to examine these relationships in both clinician-rated and self-reported symptoms to identify potential similarities or differences in relationships between symptoms and effort expenditure.

Taken together, the current findings provide further evidence for impairments in ECDM in schizophrenia and bipolar disorder as reward level increases. Further, we found that self-reported motivation and pleasure symptoms were significantly related to effort expenditure at the high reward levels regardless of group status, suggesting that ECDM may be a transdiagnostic marker of motivation and pleasure deficits. These findings represent an important step toward identifying mechanisms related to motivational and emotional functioning in people with psychotic and mood disorders. Moreover, they suggest that the assessment of motivation and pleasure negative symptoms are relevant outside of schizophrenia and should be considered in other patient populations given the overlap in symptom profiles.



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Received March 17, 2022
Revision received January 13, 2023
Accepted January 19, 2023 ■