Effort-based decision-making in ultra-high-risk for psychosis and bipolar disorder

E. Bora[1,2,3] (iD), E. Cesim[2], M. S. Eyuboglu[2], M. Demir[2], B. Yalincetin[2], C. Ermis[4], S. Özbek Uzman[1], E. Sut[5], C. Demirlek[2,6], B. Verim[2], B. Baykara[5], N. İnal[5] and B. B. Akdede[1,2]

[1]Department of Psychiatry, Faculty of Medicine, Dokuz Eylul University, Izmir, Turkey; [2]Department of Neurosciences, Health Sciences Institute, Dokuz Eylul University, Izmir, Turkey; [3]Department of Psychiatry, Melbourne Neuropsychiatry Centre, University of Melbourne and Melbourne Health, Carlton South, Victoria 3053, Australia; [4]Department Child and Adolescent Psychiatry, Queen Silvia Children's Hospital, Gothenburg, Sweden; [5]Department of Child and Adolescent Psychiatry, Faculty of Medicine, Dokuz Eylul University, Izmir, Turkey and [6]Department of Psychiatry, McLean Hospital, Harvard Medical School, Belmont, MA, USA

Abstract

Background. Effort-based decision-making has been proposed as a potential mechanism contributing to transdiagnostic motivational deficits in psychotic disorder and bipolar disorder. However, very limited information is available about deficits in effort-cost-decision-making in the early stages of psychotic disorder and no study has investigated effort allocation deficits before the onset of bipolar disorder. Our aim was to investigate effort-based-decision-making in ultra-high-risk for psychosis (UHR-P) and bipolar disorder (UHR-BD).

Methods. Effort-cost decision-making performance was evaluated in UHR-P ($n = 72$) and UHR-BD ($n = 68$) and healthy controls ($n = 38$). Effort-Expenditure for Reward Task (EEfRT) was used.

Results. Compared to controls, both UHR-P and UHR-BD groups were associated with a reduced possibility to choose the harder task when the reward magnitudes and/or the likelihood of receiving the reward were high. In both groups, effort allocation abnormalities were associated with poor social functioning.

Conclusions. The current findings suggest that difficulties in effort-cost computation are transdiagnostic markers of illness liability in psychotic and bipolar disorders. In early intervention services, effort-based decision-making abnormalities should be considered as a target for interventions to manage motivational deficits in individuals at high risk for psychosis and BD.

![CAMBRIDGE UNIVERSITY PRESS]

Introduction

Motivational deficits and anhedonia are observed in many psychiatric disorders and might be reflections of transdiagnostic mechanisms (Trøstheim et al., 2020). The framework, which might be labeled as effort-cost-decision-making (ECDM), or willingness to exert effort, is one of the promising transdiagnostic mechanisms leading to motivational deficits in mental disorders. The concept of ECDM refers to decisions of people about how much effort to increase as a function of factors such as the amount or type of reward that one would receive, the likelihood of receiving that reward or the amount of time it would take to obtain the reward (Barch et al., 2023; Strauss, Waltz, & Gold, 2014). Previous research has used several behavioral paradigms to investigate ECDM. These tasks include Effort Expenditure for Reward Task (EEfRT), Progressive Ratio Task and Effort Discounting Task (Blouzard, Pouchon, Polosan, Bastin, & Dondé, 2023). In these computerized tests, in each trial, participants must choose between a 'low effort' and a 'high effort' option and their willingness to exert physical or cognitive effort for a given level of reward is measured (Treadway, Buckholtz, Schwartzman, Lambert, & Zald, 2009).

The main focus of the available research on ECDM has been schizophrenia and negative symptoms. Most of the available studies on schizophrenia showed that patients display a reduced willingness to expend effort to obtain rewards under certain conditions. Most commonly, participants with schizophrenia spectrum disorders, unlike typical individuals, were shown to not increase their effort in high-reward and high-probability of obtaining the reward conditions (Barch, Treadway, & Schoen, 2014; Fervaha et al., 2013; Ince Guliyev, Guloksuz, & Ucok, 2022; McCarthy, Treadway, Bennett, & Blanchard, 2016; Treadway, Peterman, Zald, & Park, 2015). A recent meta-analysis of 19 studies in schizophrenia supported a deficit in willingness to expend effort to obtain higher rewards (Blouzard et al., 2023). In this meta-analysis, subjects with high negative symptoms had a significantly stronger impairment in effort-cost-decision-making compared to people with low negative symptoms.

However, unlike categorical analyses, correlational analyses between ECDM abnormality and negative symptoms gave inconsistent findings across studies (Barch et al., 2014; Fervaha et al., 2013; McCarthy et al., 2016).

Traditionally, BD has not been related to amotivation beyond depressive episodes. However, in fact, amotivation, apathy, and mild negative symptoms are present in a subgroup of patients with BD in the euthymic phase of the illness (Ihler et al., 2023; Kirschner et al., 2020; Strauss, Vertinski, Vogel, Ringdahl, & Allen, 2016). Several studies provided evidence for ECDM impairment in bipolar disorder (BD) (Barch et al., 2023; Hershenberg et al., 2016; Yang et al., 2021; Zou et al., 2020). A reduced willingness to exert effort at the higher reward values might be a trans-diagnostic feature related to motivational abnormalities seen in schizophrenia and BD.

Most of the available reports that investigated ECDM were based on studies conducted in chronic patients. However, motivational deficits are prevalent in the early stages of psychotic disorder and are important factors in explaining psychosocial impairment (Fervaha, Foussias, Agid, & Remington, 2015). Furthermore, chronic patients with schizophrenia and BD have a long history of antipsychotic use which can have a negative impact on patients' motivation via dopamine-receptor blockade (Juckel, 2016; Kirschner, Aleman, & Kaiser, 2017). For example, one might argue that motivational deficits might be a primary feature of schizophrenia but are secondary characteristics of BD in the context of antipsychotic use in BD (Ueda et al., 2016). Vascular changes in the context of meta-bolic syndrome and obesity in BD and psychosis might also lead to effort allocation problems over the years (Bora, McIntyre, & Ozerdem, 2019; Saleh et al., 2021). Therefore, it is important to investigate ECDM after the first-episode or before the onset of the illness. To date, very few studies have investigated ECDM in the early stages of psychotic disorder. Two reports from a single group investigated effort allocation in an overlapping sample of first-episode psychosis using two different paradigms (EEfRT and Cognitive Effort-Discounting) (Chang et al., 2019, 2020). The outcome of these studies suggests that first-episode psychosis patients display a reduced willingness to expend effort for high-value/high-probability reward as compared to controls.

Both schizophrenia and BD are often preceded by a prodromal period that is characterized by attenuated positive or hypomanic symptoms and gradually worsening functional outcomes (Van Meter, Burke, Youngstrom, Faedda, & Correll, 2016; Yung et al., 1996). In recent years, ultra-high-risk (UHR) paradigms have been increasingly used to identify youth with probable prodromal syndromes of psychosis and BD. Amotivation is a common feature of individuals with ultra-high-risk for psychosis (UHR-P) (Piskulic et al., 2012). To date, we are aware of a only single study that investigated ECDM in UHR-P (Strauss, Bartolomeo, & Luther, 2023). This study found that participants with UHR-P, similar to chronic patients, display a reduced willingness to exert high effort for high probability and magnitude rewards. Studies using the UHR paradigm might be important to investigate whether the willingness to expend effort for high-value/high-probability reward is also decreased in BD before the first-episode. Studies comparing UHR-P and UHR-BD might also potentially reveal the specificity of ECDM deficits to psychosis in the early stages of severe mental disorders. To the best of our knowledge, no prior study investigated ECDM in early stages of BD.

The goal of the current study was to examine whether there are cross-diagnostic ECDM deficits using EEfRT in UHR-P and UHR-BD. Our hypothesis was that ECDM defcits would be evident in both UHR-P and UHR-BD. In addition, we aimed to examine whether the social functioning and clinical symptoms correlate with ECDM across UHR-P and UHR-BD.

Method

Participants

The study was conducted at the Department of Psychiatry and Department of Neurosciences, Dokuz Eylul University. The study included 72 UHR-P, 68 UHR-BD, and 38 healthy controls. The participants were aged between 13 and 30. People with UHR-P and UHR-BD were recruited from the Early Intervention in Psychiatric Disorders Unit (ETAP) of the Department of Psychiatry at Dokuz Eylul University Hospital. Exclusion criteria for UHR groups were: (a) personal history of medical and neurological disorders that have a negative impact on cognitive abilities; (b) current alcohol/substance abuse; (c) problems in vision, motor function or hearing that will have a negative effect on participants' ability to use computerized EEfrT; (d) diagnosis of intellectual disability.

Healthy controls (HCs) were recruited through advertisements on the Dokuz Eylul University campus and at the university hospital. In addition to the exclusion criteria above, HC had no history of psychiatric treatment and had no relatives with psychosis or BD. The study protocol was approved by the Dokuz Eylul Hospital Ethics Committee. Written informed consent was signed by the participants and parents (only for the participants under age 18).

Procedure

UHR-P: Help-seeking participants were rated by the Turkish version of Structured Interview for Prodromal Syndromes (SIPS; Miller et al., 2003; Tonyali et al., 2022). SIPS include three UHR-P syndromes including Attenuated Psychosis Symptoms (APS), Brief Limited Intermittent Psychotic Symptoms (BLIPS), and Genetic Risk and Deterioration Syndrome (GRDS). p score was used as a measure of the severity of subclinical psychotic symptoms.

UHR-BD: Help-seeking participants were assessed through the Turkish version of the semistructured Bipolar Prodrome Symptom Interview and Scale-Full Prospective (BPSS-P) (Correll et al., 2014; Yalın Sapmaz et al., 2022). The items of the BPSS-P target signs of prodromal BD including subthreshold hypomanic symptoms, and affective and general symptoms. M score was used as a measure of the severity of subtreshold hypomanic symptoms.

Negative symptoms of both at-risk groups were assessed with the Brief Negative Symptom Scale (BNSS) (Kirkpatrick et al., 2011; Polat Nazlı et al., 2016). In addition to total BNSS score, motivation and pleasure (MAP: anhedonia, avolition, and asociality) and diminished expression (EXP: alogia and blunted affect) scores and five domain scores were calculated (Chang et al., 2021). All participants were interviewed through the Structured Clinical Interview for the DSM-IV Axis I Disorders (SCID-I) (First, Spitzer, Gibbon, & Williams, 2002). Additionally, UHR-P and UHR-BD groups were assessed using the Hamilton Depression Rating Scale (HAM-D-17) (Hamilton, 1960), the Young Mania Rating Scale (YMRS) (Young, Biggs, Ziegler, &

Meyer, 1978), and formal thought disorder subscale of the Scale for the Assessment of Positive Symptoms (SAPS FTD) (Andreasen, 1984).

The Personal and Social Performance (PSP) scale was used to assess the level of current functioning of the participants. The PSP variables include the total score and four subscores for main areas including socially useful activities, personal and social relationships, self-care and disturbing, and aggressive behavior (Morosini, Magliano, Brambilla, Ugolini, & Pioli, 2000; Aydemir et al., 2009).

The clinical interviews were administered by a psychiatrist (E.B) or one of the three psychiatry or child/adolescent psychiatry residents (C.E, S.U, or E.S) who were trained before the onset of the study and regularly use these tools in the early treatment and Diagnosis Program at Dokuz Eylul University Hospital/ Department of Psychiatry in Turkey.

Effort-Expenditure for Rewards Task (EEfRT)

Effort-Expenditure for Rewards Task (EEfRT) was used to assess ECDM (Treadway et al., 2009). During this task, which lasts 20 min, the participant is expected to choose either a hard or an easy task according to the cues on the screen. The task requires participants to choose between performing a low physical effort task (30 button presses within 7 s with the dominant hand index finger) for a lower reward value ($1) or a high effort option (100 button presses within 21 s with the non-dominant hand little finger) for higher reward values ($1.24–$4.30) (McCarthy et al., 2016). The probability of reward receipt is different across trials with cues at the start of each trial indicating a high (88%), medium (50%), or low (12%) probability of receiving money on that trial. The rate of selecting the high effort choice across probability and magnitude levels is the key variable in EEfRT. We also calculated 'change from 12 to 88' and 'change from low to high reward' scores by subtracting the percentage of selection of hard-task in the second condition (88% or high-reward) from the first condition (12% or low-reward).

Statistical analyses

Demographic and clinical characteristics of the groups were compared using a chi-square test and an analysis of variance test (ANOVA). The analysis of the EEFRT data included three separate ANOVAs for main effects (group, reward magnitude, or probability) and three different separarate mixed model repeated measures ANOVA for group interactions with reward magnitude and/ or probability. Two of these latter mixed ANOVAs included group (UHR-P, UHR-BD, and HC) as a between-subject factor and either probability (12, 50, and 88%) or reward magnitude (low, medium, and high) as within-subjects factors. The third mixed ANOVA included both probability and reward magnitude instead of selecting one. The dependent measure for each condition was the percentage of 'hard' task choices. The analyses were corrected for sex. In post-hoc tests, Tukey's HSD test was used for correction of multiple pairwise comparisons. Correlations of EEfRT with clinical and other measures were investigated by conducting Pearson's correlation analyses. As amotivation subdomain of negative symptoms may be potentailly more specifically linked to impaired effort allocation, we also used a categorical approach by classifying UHR-P patients into high (HIgh-MAP) and low (low-MAP) amotivation subgroups, based on a median split (split score = 15) of BNNS MAP score (Chang et al., 2019). As BNSS MAP scores were lower in UHR-BD, participants were

divided from upper quartile instead of median (split score = 7) in this group. Statistical analyses were performed using JAMOVI (Version 2.3.26) (The Jamovi project, 2022) and R (R Core Team, 2021).

Results

Demographic and clinical variables

The UHR-P group had a significantly higher percentage of males compared to UHR-BD and healthy controls ($p = 0.044$) (Table 1). There was no significant difference in age among groups (Table 1). The duration of education was significantly different among the groups (UHR-P < UHR-BD<healthy controls). In contrast, the durations of education of fathers and mothers of the participants were not significantly different among the groups. There were no significant differences in BMI between groups. UHR-P had a significantly reduced functioning level as measured by the total PSP score compared to UHR-BD.

The clinical characteristics of the groups are summarized in Table 1. A higher percentage of UHR-BD participants were using mood stabilizers compared to UHR-P (23.5% v. 4.2%). There were no significant differences in the use of antipsychotics (all atypical antipsychotics, mean chlorpromazine equivalent doses: 89.9 v. 61.1 mg) and antidepressants (Table 1). History of co-morbid alcohol abuse was significantly more common in UHR-BD compared to UHR-P and healthy controls. All of the seven participants who had been prescribed stimulants for ADHD were in the UHR-BD group (Table 1). As expected negative symptoms and formal thought disorder were more pronounced in UHR-P compared to UHR-BD (Table 1). There were no significant differences between UHR-P and UHR-BD for current depressive symptoms.

Main effects

There were significant main effects of probability ($F = 6.3$, $p = 0.002$) and reward ($F = 12.0$, $p < 0.001$). The participants overall chose the hard task more often in the context of increasing probability of reward (12%, 50%, and 88%) and greater reward amount (low, medium, and high). The main effect of group was not significant ($F = 1.20$, $p = 0.30$).

Group effects and interactions

There was a significant interaction between group and probability ($F = 5.75$, $p < 0.001$) (Fig. 1). As seen in Fig. 1, both UHR-P and UHR-BD had significantly reduced increases than controls as a function of increasing the probability. Planned comparisons showed that, in 88% probability condition, both UHR-P ($t = -4.18$, $p < 0.001$) and UHR-BD ($t = -2.32$, $p = 0.02$) participants selected significantly fewer hard task choices than healthy controls. In this condition, the difference between UHR-P and UHR-BD was also significant ($t = -2.25$, $p = 0.02$).

There was a significant interaction between group and reward ($F = 6.18$, $p < 0.001$). As seen in Fig. 2, both UHR-P and UHR-BD had significantly reduced increases in the selection of hard effort conditions than controls as a function of the increasing value of the reward. Planned comparisons revealed that, in high-reward condition, both UHR-P ($t = -3.25$, $p = 0.001$) and UHR-BD ($t = -2.08$, $p = 0.04$) participants selected significantly fewer hard task choices than healthy controls. In this condition,

Table 1. Clinical and demographic features of ultra-high-risk for psychosis (UHR-P) and bipolar disorder (UHR-BD) and healthy controls

	UHR-P ($n = 72$)	UHR-BP ($n = 68$)	HC ($n = 38$)			
	Mean (s.d.)	Mean (s.d.)	Mean (s.d.)	F	p	Post-hoc
Age	20.0 (4.1)	20.9 (4.0)	21.9 (4.4)	327	0.07	
Education (years)	11.5 (2.3)	13.0 (2.3)	14.1 (2.6)	15.7	<0.001	I < II<III
Education (mother)	9.1 (4.8)	10.3 (4.3)	10.0 (5.0)	1.3	0.48	
Education (father)	10.9 (4.4)	10.8 (4.4)	11.6 (4.5)	0.4	0.67	
Body mass index	24.1 (5.1)	24.7 (5.0)	23.4 (5.2)	0.7	0.48	
PSP	50.7 (12.6)	64.0 (12.9)		36.9	<0.001	
BNSS total score	21.8 (13.9)	7.5 (10.9)		45.3	<0.001	
-BNSS MAP	15.4 (9.2)	5.0 (7.1)		54.5	<0.001	
-BNSS EXP	6.4 (6.0)	2.2 (4.6)		21.2	<0.001	
-BNSS anhedonia	5.4 (4.1)	2.1 (3.3)		26.9	<0.001	
-BNSS asociality	4.9 (3.1)	1.5 (2.4)		51.9	<0.001	
-BNSS avolition	4.2 (2.9)	1.6 (2.4)		33.2	<0.001	
-BNSS blunted affect	4.3 (3.8)	1.6 (3.2)		20.8	<0.001	
-BNSS alogia	2.0 (2.6)	0.6 (1.6)		14.8	<0.001	
SAPS FTD	2.4 (3.7)	0.9 (2.5)		7.3	0.008	
YMRS	0.2 (1.3)	1.0 (2.3)		6.8	0.01	
HDRS	6.6 (5.1)	5.5 (4.5)		1.8	0.18	
CPZ equivalent (mg)	89.9 (134.0)	61.1 (120.0)		1.8	0.19	
				χ^2	p	
Sex (m/f)	38/34	23/45	13/25	6.3	0.044	I > II = III
Antipsychotics (%)	45.1	32.4		2.4	0.12	
Antidepressants (%)	40.9	35.3		0.5	0.50	
Mood stabilizers (%)	4.2	23.5		10.9	0.001	
Smoking (%)	32.9	45.6	17.2	7.6	0.02	II > III
History of alcohol Use disorder (%)	5.7	17.7	3.5	7.1	0.03	II > I = III
History of cannabis Use disorder (%)	12.7	14.7	3.5	2.5	0.28	
History of other substance Use disorders (%)	2.8	2.9	0	0.9	0.65	
Stimulant use for ADHD (%)	0	10.3	0	10.7	0.005	II>I = III

CPZ, Chlorpromazine equivalent; MAP, Motivation and Pleasure; EXP, Diminished expression.
PSP, Personal and Social Performance scale; BNSS, Brief Negative Symptom Scale; SAPS FTD; Formal thought disorder subscale of the Scale for the Assessment of Positive Symptoms, HDRS; Hamilton Depression Rating Scale; YMRS; Young Mania Rating Scale.

the difference between UHR-P and UHR-BD was not significant ($t = -1.42$, $p = 0.16$).

There was also a significant interaction between group × reward × probability interaction (F = 4.45 <0.001). As seen (online Supplement Figure s1), there was a significant interaction between probability and reward as a function of group. Post-hoc analyses revealed significant between-group differences in three conditions. In 88% probability-high reward condition, both UHR-P ($t = -5.92$, $p < 0.001$) and UHR-BD ($t = 3.63$, <0.001) participants selected fewer number of hard choices. In this condition, the difference between UHR-P and UHR-BD was also significant ($t = -2.76$, $p = 0.006$). In, 50% probability-high reward condition, UHR-P ($t = -2.51$ $p = 0.01$) but not UHR-BD group ($t = -1.67$

$p = 0.1$) had selected fewer hard choices. In this condition, the difference between UHR-P and UHR-BD was not significant ($t = -1.02$, $p = 0.31$). Finally, in 88% probability-medium reward condition, both UHR-P ($t = -3.36$, $p < 0.001$) and UHR-BD ($t = -1.97$, $p = 0.05$) had a significantly reduced number of hard task choices. In this condition, there was no significant difference between UHR-P and UHR-BD ($t = -1.68$, $p = 0.09$).

There was a significant difference on whether participants could complete the tapping task successfully after chosing the hard option. Healthy controls (98%) were significantly more successful in completing effort task than UHR-P (90%) and UHR-BD (92%) (F = 5.53, $p = 0.005$). The findings were similar in antipsychotic naive individuals (F = 3.1, $p = 0.04$). However,
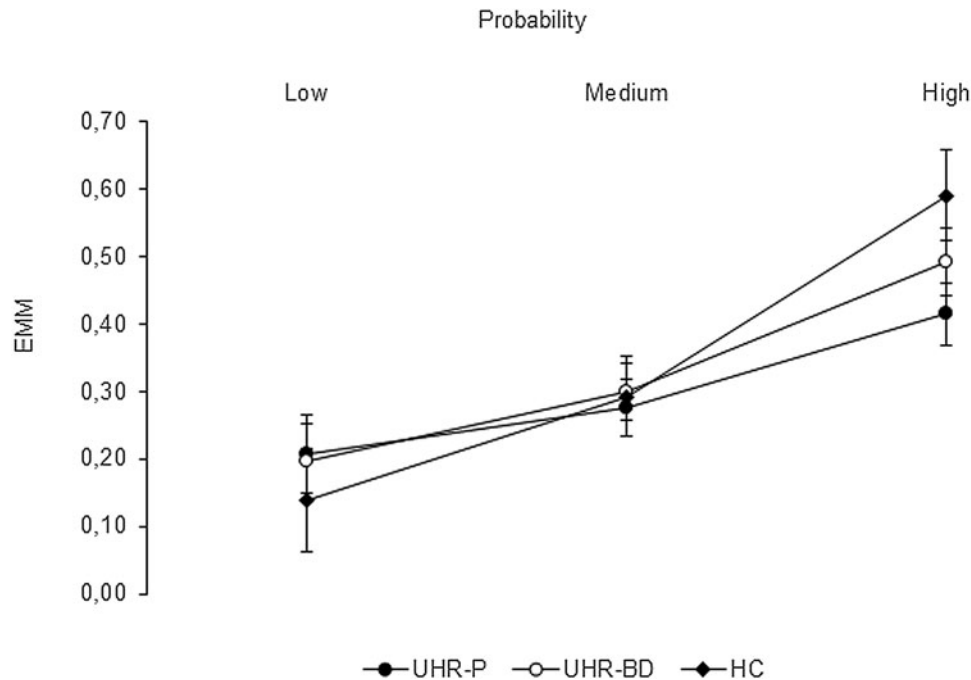
Figure 1. Effort expenditure by group and reward probability in UHR-P, UHR-BD, and healthy control participants.

the proportion of completed trials did not significantly correlate with the percentage of high-effort trials selected in UHR-P ($r = 0.13$, $p = 0.27$), UHR-BD ($r = 0.01$, $p = 0.96$) and healthy controls ($r = 0.22$, $p = 0.19$).

Correlations with personal and social functioning and clinical ratings

In UHR-P, better social functioning, as measured by PSP-total score, was significantly associated with the selection of a higher number of hard choices in 88% probability-high reward condition ($r = 0.30$, $p = 0.01$) and change from low to high reward score ($r = 0.31$, $p < 0.01$). PSP-activities subscore was significantly correlated with 88% probability-high reward condition ($r = -0.31$, $p = 0.01$), change from 12 to 88% probability score ($r = -0.24$, $p < 0.05$) and the change from low to high reward score ($r = -0.29$, $p < 0.05$).

In UHR-BD, PSP-activities subscore was significantly correlated with the selection of a higher number of hard choices in 88% probability-high reward condition ($r = -0.26$, $p < 0.05$) and change from low to high reward score ($r = 0.25$, $p < 0.05$). PSP-relationships subscore was significantly related to 88% probability-high reward ($r = -0.33$, $p < 0.01$), 88% probability ($r = -0.30$, $p < 0.01$), and change from 12 to 88% ($r = -0.36$, $p < 0.001$) scores. PSP-self-care was also associated with better 88% probability-high reward ($r = -0.25$, $p < 0.05$), 88% probability ($r = -0.25$, $p < 0.05$), and change from 12 to 88% ($r = -0.28$, $p < 0.05$) scores.

None of the EEfRT measures were significantly correlated with negative symptoms or depression ratings. p score, which reflects the severity of the history of subthreshold positive symptoms, was significantly related to the change from 12 to 88% probability score in UHR-BD ($r = -0.27$, $p < 0.05$).

Effort task performance in high and low amotivation groups

In UHR-P, there was no significant difference in number of hard choices selected between low-MAP and high-MAP subjects in high-reward ($F = 0.35$, $p = 0.56$), high-probability ($F = 0.38$, $p = 0.54$), 88% probability-high reward condition ($F = 0.52$, $p = 0.47$), 50% probability-high reward condition ($F = 1.08$, $p = 0.30$), and 88% probability-medium reward ($F = 0.28$, $p = 0.60$) conditions. There were also no significant differences in change from low to high reward ($F = 0.18$, $p = 0.67$) and change from 12 to 88% ($F = 0.29$, $p = 0.59$) scores.

In UHR-BD, there was no significant difference in number of hard choices selected between low-MAP and high-MAP subjects in high-reward ($F = 0.01$, $p = 0.96$), high-probability ($F = 3.19$, $p = 0.08$), 88% probability-high reward condition ($F = 2.87$, $p = 0.1$), 50% probability-high reward condition ($F = 0.01$, $p = 0.93$), and 88% probability-medium reward ($F = 0.96$, $p = 0.33$) conditions. However, UHR-BD participants with low-MAP scores had significantly higher scores + than UHR-BD participants with High-MAP in change from 12 to 88% proability ($F = 6.31$, $p = 0.014$) measure.

Correlations with antipsychotic chlorpromazine equivalents

In the UHR-P group, there were significant correlations between chlorpromazine equivalents and the percentage of hard task choices in the 88% probability condition ($r = -0.39$, $p < 0.001$), 88% probability-high-reward condition ($r = -0.35$, $p < 0.05$), and in the change in hard task choice from the 12% to 88% condition ($r = -0.42$, $p < 0.001$). In the UHR-BD group, there was no significant relationship between chlorpromazine equivalents and EEfRT variables (Table 2).

Effort allocation in antipsychotic naive participants

The EEfRT analyses were repeated in antipsychotic naive UHR-P ($n = 39$) and UHR-BD ($n = 46$) participants. Group-probability ($F = 4.3$, $p = 0.002$), group-reward ($F = 6.9$, $p < 0.001$), group × reward × probability ($F = 3.4$, $p < 0.001$) interactions were again
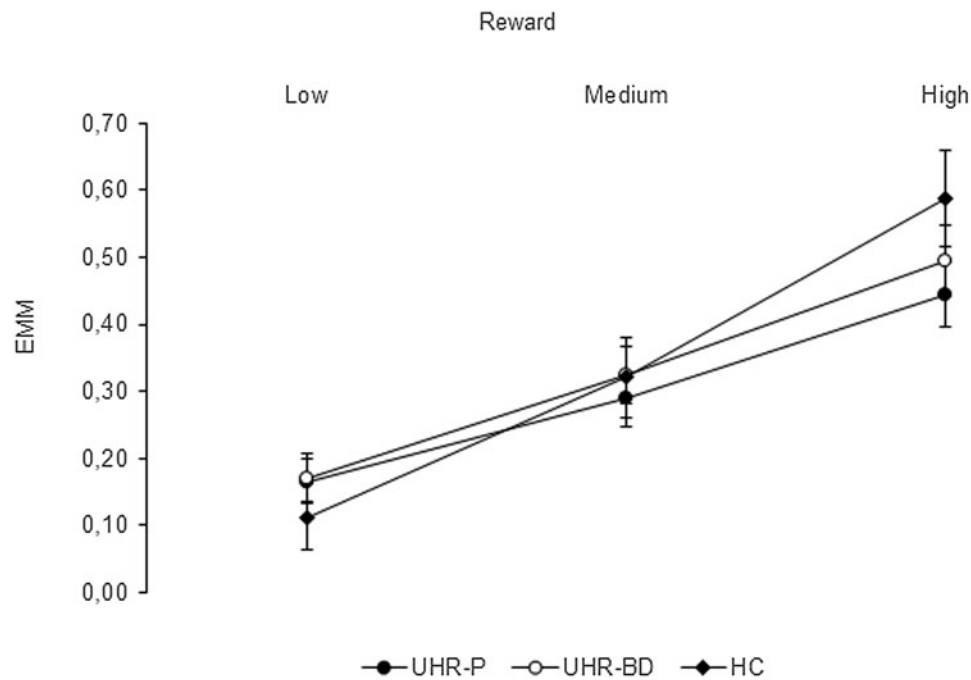
Figure 2. Effort expenditure by group and reward magnitude in UHR-P, UHR-BD, and healthy control participants.

significant. The findings of analyses in drug-naive UHR samples and healthy controls were very similar to the findings in the whole sample (See Figure 2s in the Supplement). Similar to results of the analyses in the whole sample, in 88% probability-high reward condition, both UHR-P ($t = -5.11$, $p < 0.001$) and UHR-BD ($t = 3.05$, <0.001) participants selected fewer number of hard choices.

Discussion

The goal of the current study was to investigate effort allocation in response to different reward magnitudes and reward probabilities using the Effort-Expenditure for Rewards Task (EEfRT) in UHR-P and UHR-BD. In general, participants with both UHR-P and UHR-BD were less likely than healthy controls to choose the harder task when the reward magnitudes and/or the likelihood of receiving the reward were high.

Reduced effort expenditure for high probability and high reward magnitude conditions in UHR-P is consistent with prior studies in schizophrenia both in chronic and first-episode samples (Barch et al., 2014; Chang et al., 2019; Chang et al., 2020; Culbreth, Moran, & Barch, 2018; McCarthy et al., 2016). The current findings are also compatible with the outcome of a single previous UHR-P study (Strauss et al., 2023). Importantly, ECDM impairment in UHR-P was significantly related to poorer social functioning, particularly in the subdomain of socially useful activities (school, work, other). Our findings extend the previously observed relationship between real-life functioning and laboratory effort tasks in chronic and first-episode stages of psychotic disorders (Barch et al., 2014; Chang et al., 2019; Horan et al., 2015) to the UHR stage of psychotic disorders.

More originally, the current study showed that effort expenditure for high probability and high reward magnitude conditions was also reduced in UHR-BD. To the best of our knowledge, this is the first study investigating ECDM impairment in people at clinical risk for BD. However, the current findings are consistent

with the outcome of a few studies in chronic BD samples (Barch et al., 2023; Hershenberg et al., 2016; Yang et al., 2021; Zou et al., 2020). Our findings suggest that reduced willingness to exert effort at the higher reward values might be a transdiagnostic feature of psychotic and bipolar disorders in both early and chronic stages of these disorders. Another important point is the potential relationship between effort allocation and social functioning in BD. A recent study reported a significant relationship between goal-directed activities and effort allocation performance in chronic BD (Barch et al., 2023). In this study, we found significant relationships between ECDM deficits and impaired functioning in interpersonal relationships, socially useful activities and self-care. Originally, the current findings suggest that effort allocation abilities are related to social functioning not only in chronic BD but also in UHR-BD.

In the current study, in dimensional analyses, clinical ratings for negative symptoms were not significantly correlated with any measure of EEfRT in UHR-P and UHR-BD. This finding is inconsistent with the findings of Strauss et al. (2023) who found a modest but significant correlation between BNSS and lower effort expenditure on the very high reward magnitude condition in UHR-P. The studies in schizophrenia did not consistently provide evidence for a robust relationship between negative symptoms and ECDM (Barch et al., 2014; Fervaha et al., 2013; McCarthy et al., 2016). In general, categorical approaches that divide schizophrenia into subsamples with or without amotivation reported more significant differences in ECDM (Chang et al., 2019; Gold et al., 2013). For example, Chang et al. (2019) investigated the relationship between effort allocation deficits and negative symptoms with both categorical and dimensional approaches and found a significant relationship only with the categorical approach. In our study, there was no significant difference in ECDM between UHR-P with and without high-MAP scores. However, our findings indicated that ECDM deficits were more pronounced in UHR-BD with high-MAP

Table 2. Correlations between EEfRT measures, clinical characteristics and social functioning in ultra-high-risk for psychosis (UHR-P) and bipolar disorder (UHR-BD)

	BNSS total	BNSS MAP	p score	M Score	HDRS	PSP Activities	PSP Relationships	PSP Self-care	PSP Disturbing	PSP Total	CPZ Eq
UHR-P											
88% Probability	0.03	−0.01	−0.14	0.13	0.12	−0.17	−0.14	−0.23	−0.05	0.16	−0.39**
high Reward	−0.04	−0.04	−0.05	0.10	−0.03	−0.16	−0.16	−0.22	−0.02	0.18	−0.28*
88%-Prob-high reward condition	−0.10	−0.09	−0.07	0.22	0.08	−0.31*	−0.21	−0.20	−0.12	0.30*	−0.35*
Change from 12 to 88% Probability	−0.10	−0.05	−0.16	0.20	0.18	−0.24*	−0.17	−0.12	−0.08	0.23	−0.42**
change from low to high Reward	−0.08	−0.07	−0.05	0.16	−0.08	−0.29*	−0.21	−0.12	−0.10	0.31**	−0.15
UHR-BD											
88% Probability	−0.08	−0.12	−0.16	0.03	0.01	−0.17	−0.30*	−0.25*	−0.01	0.15	−0.07
high reward	0.03	0.02	0.05	0.19	−0.04	−0.17	−0.12	−0.10	0.02	0.06	−0.22
88%- prob-high reward condition	−0.10	−0.12	−0.11	0.04	−0.09	−0.26*	−0.33**	−0.25*	−0.11	0.21	−0.17
Change from 12 to 88% Probability	−0.17	−0.20	−0.27*	−0.03	−0.13	−0.15	−0.36**	−0.28*	−0.07	0.18	0.04
change from low to high reward	−0.04	−0.02	0.08	0.18	−0.14	−0.25*	−0.19	−0.11	−0.07	0.15	−0.23

* = <0.05, ** = <0.01.

CPZ Eq, chlorpromazine equivalent; MAP, motivation and pleasure; PSP, personal and social performance scale; BNSS, Brief Negative Symptom Scale; HDRS, Hamilton Depression Rating Scale; p score, psychosis score; M, mania score; EEfRT, Effort-Expenditure for Rewards Task.

compared to UHR-BD with low-MAP scores. These findings suggest that ECDM deficits as measured by the EEfRT task might not be a proxy of MAP aspect of negative symptoms which might be related to striatal dysfunction and might be more sensitive to amotivation caused by extra-striatal mechanisms (Kirschner et al., 2020).

One can also argue that alternative approaches such as using multiple momentary symptom assessments in daily life using EMA methodology might represent a more sensitive measurement of amotivation and can more effectively reveal the relationship between amotivation and ECDM (Gard et al., 2014). The potential effects of antipsychotics on effort allocation is another important subject. In our study, there was some evidence of a relationship between antipsychotic dose and effort allocation deficits in UHR-P but not in UHR-BD. However, our analyses in antipsychotic naive participants revealed that reduced willingness to extend effort for rewards magnitudes and probabilities in UHR-P and UHR-BD was not secondary to the effects of treatment.

The current study has several limitations. The cross-sectional nature of the study was the main limitation. The longitudinal follow-up and data collection of the current sample to investigate the potential of baseline ECDM abnormalities in predicting long-term prognosis and functioning in UHR-P and UHR-BD is in progress. Second, the current study included a task that only assess willingness to extend physical effort but not cognitive effort. It would be more informative to use multiple types of ECDM tasks but this was not feasible in the current study due to practical concerns about duration of administration of cognitive tasks. Third, the rate of antipsychotic use was relatively high as UHR subjects were expected to be in the later stages of prodrome and had a high-risk of transition to full-blown illness which is typical for the newly established early intervention programs who have a high-influx of clinician-referred help-seeking individuals. Fourth, the co-morbidity of psychiatric diagnoses were assessed but no assessment was conducted for personality disorders. Five, Turkish version of SIPS was validated in adolescents (age range 12–18) (Tonyali et al., 2022) but we recently validated the same instrument in adults. Finally, our study was purely behavioral. Future studies investigating brain imaging or neurobiological correlates of ECDM deficits in at-risk subjects for psychosis and BD would be important.

To the best of our knowledge, this is the first study that investigated effort allocation in response to different reward magnitudes and reward probabilities in UHR-BD compared with controls and UHR-P. The current findings might have important clinical implications. Effort-based decision-making paradigms and related laboratory effort tasks might potentially have a role as measures of real-world motivation. The reduced willingness to exert effort at the higher reward values is a transdiagnostic feature of psychotic and bipolar disorders that can be a target for interventions from the early stages of these disorders.

References

Andreasen, N. C. (1984). *Scale for the assessment of positive symptoms* (*SAPS*). Iowa City: University of Iowa.

Aydemir, Ö., Üçok, A., Esen-Danaci, A., Canpolat, T., Karadayi, G., Emiroğlu, B., & Sariöz, F. (2009). Bireysel ve sosyal performans ölçeği'nin Türkçe sürümünün geçerlilik ve güvenilirlik çalışması [The validation of Turkish version of Personal and Social Performance Scale (PSP)]. *Klinik Psikofarmakoloji Bülteni/Bulletin of Clinical Psychopharmacology, 19*(2), 93–100.

Barch, D. M., Culbreth, A. J., Ben Zeev, D., Campbell, A., Nepal, S., & Moran, E. K. (2023). Dissociation of cognitive effort-based decision making and its associations with symptoms, cognition, and everyday life function across schizophrenia, bipolar disorder, and depression. *Biological Psychiatry, 94* (6), 501–510. doi:10.1016/j.biopsych.2023.04.007

Barch, D. M., Treadway, M. T., & Schoen, N. (2014). Effort, anhedonia, and function in schizophrenia: Reduced effort allocation predicts amotivation and functional impairment. *Journal of Abnormal Psychology, 123*(2), 387–397.

Blouzard, E., Pouchon, A., Polosan, M., Bastin, J., & Dondé, C. (2023). Effort-cost decision-making among individuals with schizophrenia: A systematic review and meta-analysis. *JAMA Psychiatry, 80*(6), 548–557. doi:10.1001/jamapsychiatry.2023.0553

Bora, E., McIntyre, R. S., & Ozerdem, A. (2019). Neurocognitive and neuroimaging correlates of obesity and components of metabolic syndrome in bipolar disorder: A systematic review. *Psychological Medicine, 49*(5), 738–749. doi:10.1017/S0033291718003008

Chang, W. C., Chu, A. O. K., Treadway, M. T., Strauss, G. P., Chan, S. K. W., Lee, E. H. M., … Chen, E. Y. H. (2019). Effort-based decision-making impairment in patients with clinically-stabilized first-episode psychosis and its relationship with amotivation and psychosocial functioning. *European Neuropsychopharmacology, 29*(5), 629–642. doi:10.1016/j.euroneuro.2019.03.006

Chang, W. C., Strauss, G. P., Ahmed, A. O., Wong, S. C. Y., Chan, J. K. N., Lee, E. H. M., … Chen, E. Y. H. (2021). The latent structure of negative symptoms in individuals with attenuated psychosis syndrome and early psychosis: Support for the 5 consensus domains. *Schizophrenia Bulletin, 1647* (2), 386–394. doi:10.1093/schbul/sbaa129

Chang, W. C., Westbrook, A., Strauss, G. P., Chu, A. O. K., Chong, C. S. Y., Siu, C. M. W., … … Chen, E. Y. H. (2020). Abnormal cognitive effort allocation and its association with amotivation in first-episode psychosis. *Psychological Medicine, 50*(15), 2599–2609. doi:10.1017/S0033291719002769

Correll, C. U., Olvet, D. M., Auther, A. M., Hauser, M., Kishimoto, T., Carrión, R. E., … Cornblatt, B. A. (2014). The Bipolar Prodrome Symptom Interview and Scale-Prospective (BPSS-P): Description and validation in a psychiatric sample and healthy controls. *Bipolar Disorders, 16*(5), 505–522. doi:10.1111/bdi.12209

Culbreth, A. J., Moran, E. K., & Barch, D. M. (2018). Effort-based decision-making in schizophrenia. *Current Opinion in Behavioral Sciences, 22*, 1–6. doi:10.1016/j.cobeha.2017.12.003

Fervaha, G., Foussias, G., Agid, O., & Remington, G. (2015). Motivational deficits in early schizophrenia: Prevalent, persistent, and key determinants of functional outcome. *Schizophrenia Research, 166*(1–3), 9–16. doi:10.1016/j.schres.2015.04.040

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

First, M. B., Spitzer, R. L., Gibbon, M., & Williams, J. B. W. (2002). *Structured clinical interview for DSM-IV axis I disorders, clinician version (SCID-CV)*. New York: Biometrics Research, New York State Psychiatric Institute.

Gard, D. E., Sanchez, A. H., Cooper, K., Fisher, M., Garrett, C., & Vinogradov, S. (2014). Do people with schizophrenia have difficulty anticipating pleasure, engaging in effortful behavior, or both? *Journal of Abnormal Psychology*, 123(4), 771–782. doi:10.1037/abn0000005

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

Hamilton, M. (1960). A rating scale for depression. *Journal of Neurology Neurosurgery Psychiatry*, 23(1), 56–62. doi:10.1136/jnnp.23.1.56

Hershenberg, R., Satterthwaite, T. D., Daldal, A., Katchmar, N., Moore, T. M., Kable, J. W., & Wolf, D. H. (2016). Diminished effort on a progressive ratio task in both unipolar and bipolar depression. *Journal of Affective Disorders*, 196, 97–100. doi:10.1016/j.jad.2016.02.003

Horan, W. P., Reddy, L. F., Barch, D. M., Buchanan, R. W., Dunayevich, E., Gold, J. M., … Green, M. F. (2015). Effort-based decision-making paradigms for clinical trials in schizophrenia: Part 2 – external validity and correlates. *Schizophrenia Bulletin*, 41(5), 1055–1065. doi:10.1093/schbul/sbv090

Ihler, H. M., Lyngstad, S. H., Mørch-Johnsen, L. E., Lagerberg, T. V., Melle, I., & Romm, K. L. (2023). A transdiagnostic approach to negative symptoms: Exploring factor structure and negative symptoms in bipolar disorders. *Frontiers in Psychiatry*, 14, 1136097. doi:10.3389/fpsyt.2023.1136097

Ince Guliyev, E., Guloksuz, S., & Ucok, A. (2022). Impaired effort allocation in patients with recent-onset schizophrenia and Its relevance to negative symptoms assessments and persistent negative symptoms. *Journal of Clinical Medicine*, 11(17), 5060. doi:10.3390/jcm11175060

Juckel, G. (2016). Inhibition of the reward system by antipsychotic treatment. *Dialogues in Clinical Neuroscience*, 18(1), 109–114. doi:10.31887/DCNS.2016.18.1/gjuckel

Kirkpatrick, B., Strauss, G. P., Nguyen, L., Fischer, B. A., Daniel, D. G., Cienfuegos, A., & Marder, S. R. (2011). The brief negative symptom scale: psychometric properties. *Schizophrenia Bulletin*, 37(2), 300–305. doi:10.1093/schbul/sbq059

Kirschner, M., Aleman, A., & Kaiser, S. (2017). Secondary negative symptoms – A review of mechanisms, assessment and treatment. *Schizophrenia Research*, 186, 29–38. doi:10.1016/j.schres.2016.05.003

Kirschner, M., Cathomas, F., Manoliu, A., Habermeyer, B., Simon, J. J., Seifritz, E., Tobler, P. N., … Kaiser, S. (2020). Shared and dissociable features of apathy and reward system dysfunction in bipolar I disorder and schizophrenia. *Psychological Medicine*, 50(6), 936–947. doi:10.1017/S0033291719000801

McCarthy, J. M., Treadway, M. T., Bennett, M. E., & Blanchard, J. J. (2016). Inefficient effort allocation and negative symptoms in individuals with schizophrenia. *Schizophrenia Research*, 170(2–3), 278–284. doi:10.1016/j.schres.2015.12.017

Miller, T. J., McGlashan, T. H., Rosen, J. L., Cadenhead, K., Cannon, T., Ventura, J., … Woods, S. W. (2003). Prodromal assessment with the structured interview for prodromal syndromes and the scale of prodromal symptoms: Predictive validity, interrater reliability, and training to reliability. *Schizophrenia Bulletin*, 29(4), 703–715. doi:10.1093/oxfordjournals.schbul.a007040

Morosini, P. L., Magliano, L., Brambilla, L., Ugolini, S., & Pioli, R. (2000). Development, reliability and acceptability of a new version of the DSM-IV Social and Occupational Functioning Assessment Scale (SOFAS) to assess routine social functioning. *Acta Psychiatrica Scandinavica*, 101, 323–329.

Piskulic, D., Addington, J., Cadenhead, K. S., Cannon, T. D., Cornblatt, B. A., Heinssen, R., … Walker, E. F. (2012). Negative symptoms in individuals at clinical high risk of psychosis. *Psychiatry Research*, 196(2–3), 220–224. doi:10.1016/j.psychres.2012.02.018

Polat Nazlı, I., Ergül, C., Aydemir, Ö., Chandhoke, S., Üçok, A., & Gönül, A. S. (2016). Validation of Turkish version of brief negative symptom scale. *International Journal of Psychiatry and Clinical Practice*, 20(4), 265–271. doi:10.1080/13651501.2016.1207086

R Core Team. (2021). R: A Language and environment for statistical computing. (Version 4.1) (Computer software). Retrieved from https://cran.r-project.org (R packages retrieved from MRAN snapshot 2022-01-01).

Saleh, Y., Le Heron, C., Petitet, P., Veldsman, M., Drew, D., Plant, O., … Husain, M. (2021). Apathy in small vessel cerebrovascular disease is associated with deficits in effort-based decision making. *Brain*, 144(4), 1247–1262. doi:10.1093/brain/awab013

Strauss, G. P., Bartolomeo, L. A., & Luther, L. (2023). Reduced willingness to expend effort for rewards is associated with risk for conversion and negative symptom severity in youth at clinical high-risk for psychosis. *Psychological Medicine*, 53(3), 714–721. doi:10.1017/S003329172100204X

Strauss, G. P., Vertinski, M., Vogel, S. J., Ringdahl, E. N., & Allen, D. N. (2016). Negative symptoms in bipolar disorder and schizophrenia: A psychometric evaluation of the brief negative symptom scale across diagnostic categories. *Schizophrenia Research*, 170(2–3), 285–289. doi:10.1016/j.schres.2015.12.014

Strauss, G. P., Waltz, J. A., & Gold, J. M. (2014). A review of reward processing and motivational impairment in schizophrenia. *Schizophrenia Bulletin*, 40 (Suppl 2), S107–S116. doi:10.1093/schbul/sbt197

The Jamovi Project. (2022). Jamovi (Version 2.3) (Computer Software). Retrieved from https://www.jamovi.org

Tonyali, A., Karaçetin, G., Kanik, A., Ertaş, E., Karabağ, U., Umut, Ö, … Ermiş, Ç (2022). Turkish version of structured interview of psychosis-risk syndromes (SIPS) and proposal of a brief version of SIPS as a pretest risk enrichment. *Noro Psikiyatr Ars* (*Archives of Neuropsychiatry*), 59(2), 139–146. doi:10.29399/npa.27793

Treadway, M. T., Buckholtz, J. W., Schwartzman, A. N., Lambert, W. E., & Zald, D. H. (2009). Worth the "EEfRT"? The effort expenditure for rewards task as an objective measure of motivation and anhedonia. *PLoS One*, 4(8), e6598. doi:10.1371/journal.pone.0006598

Treadway, M. T., Peterman, J. S., Zald, D. H., & Park, S. (2015). Impaired effort allocation in patients with schizophrenia. *Schizophrenia Research*, 161(2–3), 382–385. doi:10.1016/j.schres.2014.11.024

Trøstheim, M., Eikemo, M., Meir, R., Hansen, I., Paul, E., Kroll, S. L., … Leknes, S. (2020). : Assessment of anhedonia in adults with and without mental illness: A systematic review and meta-analysis. *JAMA Network Open*, 3(8), e2013233. doi:10.1001/jamanetworkopen.2020.13233

Ueda, S., Sakayori, T., Omori, A., Fukuta, H., Kobayashi, T., Ishizaka, K., … Okubo, Y. (2016). Neuroleptic-induced deficit syndrome in bipolar disorder with psychosis. *Neuropsychiatric Disease and Treatment*, 12, 265–268. doi:10.2147/NDT.S99577

Van Meter, A. R., Burke, C., Youngstrom, E. A., Faedda, G. L., & Correll, C. U. (2016). The bipolar prodrome: Meta-analysis of symptom prevalence prior to initial or recurrent mood episodes. *Journal of American Academy of Child and Adolescent Psychiatry*, 55(7), 543–555. doi:10.1016/j.jaac.2016.04.017

Yalın Sapmaz, Ş, Ermiş, Ç, Çakır, B., Öztekin, S., Guinart, D., Alşen Güney, S., … Aydemir, Ö (2022). Reliability and validity of the bipolar prodrome symptom interview and scale-full prospective in Its turkish translation. *Journal of Child and Adolescent Psychopharmacology*, 32(3), 178–186. doi:10.1089/cap.2021.0071

Yang, X., Huang, J., Harrision, P., Roser, M. E., Tian, K., Wang, D., & Liu, G. (2021). Motivational differences in unipolar and bipolar depression, manic bipolar, acute and stable phase schizophrenia. *Journal of Affective Disorders*, 283, 254–261. doi:10.1016/j.jad.2021.01.075

Young, R. C., Biggs, J. T., Ziegler, V. E., & Meyer, D. A. (1978). A rating scale for mania: reliability, validity and sensitivity. *British Journal of Psychiatry*, 133, 429–435. doi:10.1192/bjp.133.5.429

Yung, A. R., McGorry, P. D., McFarlane, C. A., Jackson, H. J., Patton, G. C., & Rakkar, A. (1996). Monitoring and care of young people at incipient risk of psychosis. *Schizophrenia Bulletin*, 22(2), 283–303. doi:10.1093/schbul/22.2.283

Zou, Y. M., Ni, K., Wang, Y. Y., Yu, E. Q., Lui, S. S. Y., Zhou, F. C., … Chan, R. C. K. (2020). Effort-cost computation in a transdiagnostic psychiatric sample: Differences among patients with schizophrenia, bipolar disorder, and major depressive disorder. *PsyCh Journal*, 9(2), 210–222. doi:10.1002/pchj.316