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Delay Discounting Abnormalities Are Seen in First-episode Schizophrenia but not in Bipolar Disorder

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Abstract

Delay discounting (DD) is the phenomenon of individuals discounting future rewards as a function of time. It has been studied extensively in chronic schizophrenia (SZ) and the results of these studies have been variable. Comorbidity in chronic samples could be one reason for the mixed findings and studies in first-episode (FE) samples are surprisingly lacking. Bipolar disorder (BP) which shares some genetic and symptom features with SZ could serve as an interesting comparison group for DD but has been underexplored. Here we present the first study that combines FE SZ, FE BP with psychotic features, as well as healthy controls and study DD with two versions of the task. We found that SZ showed steeper discounting than HC and BP on the well-validated Kirby DD task. SZ showed no difference than HC on a separate DD task with smaller rewards presented with decimal places and shorter delays. As a preliminary finding, DD was found to be positively related to positive symptoms in FE SZ, while no relationship was found between negative symptoms and DD. In addition, we found comparable DD in BP compared to HC. Ultimately, our data may help elucidate the psychopathology in SZ and BP during intertemporal decision making.

Keywords

First-episode Schizophrenia; First-episode Bipolar Disorder; Delay Discounting

1. Introduction

In a digital age where many things can be obtained instantly, it is becoming difficult to resist an immediate reward and wait for a larger payoff in the future. The propensity to discount future rewards as a function of time is called delay discounting (Kirby, 1997). DD is

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Contributors

TAL, CF and CSC designed the study and wrote the protocol. HW managed the literature review. HW undertook the statistical analysis under the supervision of TAL and RJM, and HW wrote the first draft of the manuscript. All authors contributed to and have approved the final manuscript.

Conflict of Interest

The authors declare no conflict of interest.

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considered one dimension of impulsivity and closely linked to other dimensions such as self-report impulsivity (MacKillop et al., 2016; de Wit, Flory, Acheson, McCloskey & Manuck, 2007). Individual differences in DD are argued to be a stable, trait-level feature (Horan, Johnson, & Green, 2017; Kirby, 2009) which is often associated with cognitive functions, such as working memory capacity and intelligence (Shamosh et al., 2008). These intertemporal choices are suggested to be modulated by a competition between two interacting systems, with the limbic system biased towards immediate payoffs while the lateral prefrontal cognitive control system favors more future-oriented goals achieved through self-control (Figner et al., 2010; McClure, Laibson, Loewenstein, & Cohen, 2004; Volkow & Baler, 2015).

Given the systems subserving intertemporal choices, schizophrenia patients (SZ) who show impaired cognitive functions, such as working memory maintenance (Cohen, Barch, Carter, & Servan-Schreiber, 1999) as well as diminished motivation towards receiving distant reward (Barch & Dowd, 2010; Gold, Waltz, Prentice, Morris, & Heerey, 2008), would be expected to also show abnormalities during delay discounting, presumably through a bias towards immediate choices. Indeed, a number of studies have found that chronic SZ patients showed steeper discounting in the form of higher discounting rate (k; Ahn et al., 2011; Brown, Hart, Snapper, Roffman, & Perlis, 2018; Heerey, Matveeva, & Gold, 2011; Heerey, Robinson, McMahon, & Gold, 2007; Weller et al., 2014; Yu et al., 2017). The discounting rate is derived from a hyperbolic model in which the present value of a future reward is inversely proportional to the delay as well as the k (Kirby, 1997; but see alternative models e.g. McClure et al., 2004). Therefore higher k indicates steeper discounting and more impulsive decision-making. Elevated discounting rates in SZ have been found to be correlated with lower working memory capacity (Ahn et al., 2011; Brown et al., 2018; Heerey et al., 2007), verbal reasoning (Yu et al., 2017) and the ability to forecast future events (Heerey et al., 2011), further linking cognitive impairments to DD. Nevertheless, a number of studies reported no DD difference between chronic SZ and healthy controls, making it difficult to make a definitive statement about DD in chronic SZ (Avsar et al., 2013; MacKillop & Tidey, 2011; Wing, Moss, Rabin, & George, 2012). Presumably, the susceptibility of DD to contextual influences such as incidental episodes of affective state (Lempert & Phelps, 2016) may help explain some of the inconsistencies.

On the other hand, there is substantial evidence showing that schizophrenia spectrum disorders share genetic and symptom overlap with bipolar disorder (Cardno & Owen, 2014; Craddock, O'Donovan, & Owen, 2009; Lee et al., 2013; Lichtenstein et al., 2009), which may offer an interesting comparison group that is particularly characterized by hypersensitivity for reward as well as a diminished ability for self-control (Reddy et al., 2014; Swann, Lijffijt, Lane, Steinberg, & Moeller, 2009; Whitton, Treadway, & Pizzagalli, 2015). These characteristics also tend to be associated with adverse consequences such as substance abuse (American Psychiatric Association, 2013; Swann, Pazzaglia, Nicholls, Dougherty, & Moeller, 2003) and are theoretically linked to more impulsive decision-making and steeper discounting. In particular, both SZ and BP show elevated trait impulsivity across multiple dimensions (Fortgang, Hultman, van Erp & Cannon, 2016), which are correlated with brain structural differences at orbitofrontal cortex (Nanda et al.,

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2016). Studying DD abnormalities across SZ and BP could help further our understanding of impulsive decision making across diagnostic boundaries.

Interestingly, a limited number of studies investigating DD in BP showed mixed results. Following the seminal work of Ahn et al. (2011) showing steeper discounting in chronic BP, a recent study failed to replicate the finding (Brown et al., 2018). It was argued that this null finding was predominantly driven by a depressed sample of BP patients. Despite the suggestion that manic and depressive mood states tap into different aspects of impulsivity (Swann, Steinberg, Lijffjt, & Moeller, 2008), it is not clear how they may differentially influence intertemporal decision-making (i.e., DD). Along this line, one study using individuals at risk for mania reported no DD differences relative to HC (Meyer, Newman, & Jordan, 2015). Interestingly, using an adolescent sample, Urosevic and colleagues found that BP patients did not show age-related DD improvements (older individuals are more able to wait for a larger reward) as observed in controls (Urosevic, Youngstrom, Collins, Jensen, & Luciana, 2016), highlighting potentially different developmental trajectories across the two groups.

The majority of the published literature focuses on DD in chronic SZ and BP. At earlier stages of illness, more proximal to the first episode, one hopes to minimize influences that are secondary to the illness (e.g., chronic medication effects, years of substance use, metabolic syndrome) which could serve as a first step addressing the inconsistencies among the previous DD findings. Furthermore, impulsivity is related to clinical symptoms in SZ and BP (Nanda et al., 2016), and DD specifically is associated with real-world impulsive behaviors (Reimers, Maylor, Stewart & Chater, 2009). A better understanding of DD process in SZ and BP would provide valuable information to clinical practice, especially for FE patients where early intervention is associated with better treatment outcomes (McFarlane et al., 2014). To our knowledge, no study has reported DD using a FE sample with both SZ and BP with psychotic features, as we do in the current study. Two versions of DD tasks were tested, the Kirby Monetary Choice Questionnaire following previous work (Heerey et al., 2011; Heerey et al., 2007; Kirby, Petry, & Bickel, 1999; Meyer et al., 2015) and a version evaluating the decimal effect of DD in which each monetary offer was shown either in rounded or decimal values (Fassbender et al., 2014). These two versions were selected in order to test comparability to the existing literature using the Kirby version and to evaluate whether changes in presentation style of monetary offers (e.g. decimal numbers) would reduce impulsive choices in individuals with SZ and BP, as has been previously shown in individuals with attention deficit/hyperactivity disorder (Fassbender et al., 2014). We further anticipated higher discounting rates for SZ relative to HC across both DD tasks, which were expected to be associated with negative symptoms (Heerey et al., 2007; Kring & Barch, 2014). Finally, based on the established literature on increased impulsivity in BP (Reddy et al., 2014; Fortgang et al., 2016) we hypothesized that BP would also show increased DD relative to HC.

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2. Methods

2.1. Participants

In total, there were 173 participants included in this study, including seventy-two SZ spectrum patients (49 schizophrenia, 20 schizoaffective disorder and 3 schizophreniform), twenty-eight euthymic BP patients with psychotic features, and seventy-three HC. All subjects provided written informed consent prior to their participation and the UC Davis Institutional Review Board approved all components of the current study.

All patients were recruited as outpatients through the Early Diagnosis and Preventive Treatment (EDAPT) clinic at UC Davis Medical Center. Diagnoses were assessed through the Structured Clinical Interview for DSM-IV (SCID; First, Spitzer, Gibbon, & Williams, 2002). Patients were within 2 years of their first psychotic episode. All but 12 (6 SZ, 6 BP) patients were taking antipsychotic medication at the time of the appointment. Exclusion criteria for patients were a history of substance abuse or dependence within the past six months, positive urine drug screen at the time of appointment, a diagnosis of major neurological or medical illness, head trauma resulting in a loss of consciousness for more than 10 mins and an IQ score lower than 70 assessed by the Wechsler Abbreviated Scale of Intelligence - second edition (WASI-II; Wechsler, 2011). Patients with a diagnosis of drug-induced psychosis or psychotic disorder not otherwise specified were also excluded. HC were excluded based on the same criteria in addition to a history of an Axis I mental illness or history of psychosis in a first-degree relative.

Clinical symptoms were assessed using the Scale for the Assessment of Negative Symptoms (SANS; Andreasen, 1989), Scale for the Assessment of Positive Symptoms(SAPS; Andreasen, 1984), Brief Psychiatric Rating Scale (BPRS; Overall & Gorham, 1962), Modified Global Assessment of Function (GAF-M) from DSM-IV, Young Mania Rating Scale (Young, Biggs, Ziegler, & Meyer; 1978) and Calgary Depression Scale for Schizophrenia (CDSS; Addington, Addington, & Schissel, 1990). In addition, based on previous work we calculated three core symptom dimensions using individual items from aforementioned scales: poverty (SANS anhedonia/asociality, avolition/apathy, alogia, and affective flattening; BPRS emotional withdrawal, motor retardation, and blunted affect), reality distortion (SAPS hallucinations and delusions; BPRS grandiosity, suspiciousness, hallucinations, and unusual thought content) and disorganization (SANS attention; SAPS positive formal thought disorder and bizarre behavior; and BPRS conceptual disorganization, mannerisms and posturing, and disorientation; see Barch, Carter, MacDonald III, Braver, & Cohen, 2003).

2.2. Procedures

Participants completed two DD tasks as well as the AX-Continuous Performance Task (AX-CPT; see Smucny et al., 2018) in a counterbalanced order on an IBM-compatible PC. We used the AX-CPT as a well-established way of measuring cognitive control (Carter, Minzenberg, West & Macdonald III, 2011; Smucny et al., 2018) and examined its contribution to DD (see Supplementary Material). The Kirby DD task consisted of three conditions of varying reward magnitude (small: 11-35$, medium: 20-60$, large: 31-85$).

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Each condition has 9 offers of a sooner-smaller reward (SSR) and a larger-later reward (LLR), which results in 27 questions in total. The average discrepancies in reward magnitude between SSR and LLR are $8.67, $16.11 and $23.56 for small, medium large conditions. The delay ranged from 7 to 186 days. The Decimal DD task had two conditions, round and decimal. The decimal condition shows monetary offers with decimal places (range $2.14-32.90; average discrepancy $7.77) whereas the round condition shows matched offers in rounded numbers (range $2.00-33.00; average discrepancy $7.39). There were 31 trials for each condition. The delay ranged from 7 to 56 days, presented as weeks (i.e. 1 to 8 weeks). Participants were asked to pick the offer they would prefer on the left or right by pressing “1” or “2” on a keyboard, respectively. SSR is always displayed on the left and LLR on the right. Participants were told that out of the two DD tasks, one trial would be randomly selected and be given to the participant based on the delay and amount that was chosen. Therefore, they were encouraged to treat every offer as the one to be compensated. The estimation procedure for k was described by previous studies (Heerey et al., 2007; Kirby, 2009). Briefly, an indifference point (i.e., k) was calculated for each trial using a hyperbolic model $V = A/(1+kD)$ in which V is the discounted value of a LLR, represented by A, and D is the delay in days. For example, the k for “$30 now or $35 in 20 days” would be 0.0583, suggesting that individuals with this k would be indifferent to the two offers. After trials were sorted based on their indifference points, participants’ k were calculated by taking the geometric means of indifference point from the trial in which they switch from SSR to LLR and the trial before, if that trial also has the highest consistency given all other choices. Consistency scores (i.e. model fit R^2) range from 0 to 1, with 1 being the most consistent choice pattern where participants switch only once from SSR to LLR and 0 being the opposite. K was calculated separately for each condition, resulting in three k values for Kirby (small, medium and large) and two for Decimal (decimal, round).

2.3. Data Analysis

For the Kirby DD task, we excluded 7 participants (2 HC, 4 SZ, 1 BP) for having choice consistency at the lowest five percent of the sample (less than or equal to 0.78), following previous work (Heerey et al., 2007; Kirby, 2009). For the Decimal DD task, the distribution of choice consistency differed across groups so participants were excluded separately for each group and condition based upon a cutoff at the lowest five percent (on average 0.74, 0.67, 0.73 for HC, SZ and BP respectively). As a result, 9 participants including 2 HC, 4 SZ and 3 BP were excluded. K values were approximately normalized using log transformation. For simplicity, we refer to $\log(k)$ as k throughout the manuscript.

Two-way mixed model analyses of variance (ANOVAs) were used to assess statistical differences in each DD task separately (condition and group). Significant group by condition interactions were explored by an examination of the simple effects. Main effects of group and condition were examined in the absence of an interaction. Pairwise t-tests were performed for significant main effects of group, collapsing across condition, and evaluated using the Fisher’s Least Significant Difference method. Significant main effects of condition, collapsing across group, were similarly evaluated. Alpha level was set to .05, two-tailed. The Greenhouse-Geisser correction was applied when the assumption of sphericity was violated. The relationships between DD and clinical symptoms were assessed with

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Pearson correlations. Follow-up multiple linear regressions examining whether DD tracked clinical symptoms transdiagnostically were also performed on significant Pearson correlations and presented in Supplementary Material. To minimize multiple comparisons in these correlation analyses, we constructed a composite measure of delay discounting by averaging the z-transformed *k* values across the three conditions in the Kirby and two conditions in the Decimal tasks (Heerey et al., 2011). We refer to this measure as Composite Delay Discounting (CDD) for the following sections.

3. Results

3.1. Demographical and Clinical

The three groups were not significantly different in age, gender and parental education (*p*s > .27; Table 1). As expected, HC had higher years of education than SZ ($p < .001$) and BP ($p = .004$). No difference was found between SZ and BP ($p = .91$).

3.2. Kirby DD

We first examined the two-way mixed model ANOVA with condition (small, medium, and large) and group (SZ, BP, HC) as factors. No group by condition interaction was found ($F(4, 326) = .44$, $p = .78$), although we did identify significant main effects of condition ($F(2, 326) = 21.93$, p <001) and group ($F(2, 163) = 3.79$, $p = .025$; Fig. 1a). To further explore the main effects, we examined pair-wise comparisons. We found that the main effect of condition was driven by significant differences among all levels, with small rewards showing higher *k* than medium ($F(1, 165) = 3.22$, p =.001) and large rewards ($F(1, 165) = 6.16$, p <.001), as well as medium showing higher *k* than large rewards ($F(1, 165) = 3,73$, p <,001), The main effect of group was driven by steeper discounting in SZ compared to HC ($F(1, 137) = 2.36$, p =.020) as well as BP ($F(1, 93) = 2.21$,p =.028). No difference was found between BP and HC ($F(1, 96) = -.46$, $p = .65$).

3.2. Decimal DD

For the Decimal task, no main effect of condition, group or condition by group interaction was found ($F(1, 161) = .16$, $F(2, 161) = ,16$, *p*s > .69, $F(2, 161) = 2.21$, p =.11, respectively; see Fig. 1b).

3.3. Relationships with DD and clinical variables

We examined the relationships between the DD composite measure and clinical variables, including Poverty, Reality Distortion, Disorganization, GAF, YMRS, CDSS and antipsychotic medication dosage (represented as chlorpromazine equivalents). For SZ, we found a positive relationship between reality distortion and DD, with higher positive symptoms relating to steeper discounting ($r = 32$, $p = .021$; Fig. 2). We did not find the expected relationship between negative symptoms and DD in SZ ($p = .37$). No other relationship was significant (*p*s > .21). For BP, DD was not related to any clinical variables (*p*s > .23). Additional follow-up analyses examining symptom relationships in more detail are presented in the supplement.

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4. Discussion

This study is the first to our knowledge that combined two versions of DD tasks to investigate intertemporal choice among FE SZ, BP and HC. We found that SZ patients at this stage of illness showed task-dependent abnormalities in discounting, which showed modest correlation with positive symptoms (uncorrected for multiple comparisons). Finally, BP did not differ from HC on any discounting measures, suggesting intact DD at early stage of the illness.

While we did find DD abnormalities in FE SZ in the Kirby task, previous studies examining DD in chronic SZ have reported mixed results. Similar to our current results, a total of six studies reported steeper discounting for SZ than HC (Ahn et al., 2011; Brown et al., 2018; Heerey et al., 2011; Heerey et al., 2007; Weller et al., 2014; Yu et al., 2017). Many studies found correlations between k and cognitive measures such as working memory or verbal reasoning (Ahn et al., 2011; Brown et al., 2018; Heerey et al., 2007; Yu et al., 2017), which is consistent with the notion that decision making deficits in SZ may be attributed to the diminished capacity to mentally maintain value or emotional experience to guide goal-directed behaviors (Barch & Dowd, 2010; Gold et al., 2008; Kring & Barch, 2014). Similarly, we found that d-prime context, a measure of working memory maintenance, was associated with DD in SZ but not HC (see Supplementary Material). A computational perspective argued that the elevated discounting rate in SZ might be a result of a shift away from effortful and costly model-based simulation of the future which would help resolve the uncertainty associated with delayed reward. It might be an adaptive strategy to focus on the present when SZ patients have had prolonged exposure to unstable and unpredictable environments in which future thinking, while computationally costly, may not secure delayed reward for them (Story, Moutoussis, & Dolan, 2015). Along this line, we found that after controlling for working memory maintenance (i.e. d-prime context) the DD group difference was no longer significant, suggesting that cognitive control did in part contribute to the elevated DD in SZ relative to HC. Nevertheless, for some studies the group difference remained after controlling for cognitive measures, suggesting that it is not the only reason for the observed steeper discounting in chronic SZ (Ahn et al., 2011; Brown et al., 2018; Yu et al., 2017).

On the other hand, four studies reported no DD difference between chronic SZ and HC (Avsar et al., 2013; MacKillop & Tidey, 2011; Wing et al., 2012). Specifically, while no group difference was observed between SZ and HC, one study found that pathological and recreational gamblers showed higher DD than non-gamblers within SZ (Fortgang, Hoff & Potenza, 2018). Interestingly, another study found that current and past smokers showed *lower* DD than nonsmokers in SZ (Wing et al., 2012), a pattern that is the opposite of the gamblers (Wing et al., 2012). Indeed, a variety of complications such as substance use, metabolic syndrome, and biological predisposition among chronic SZ patients may contribute to DD differences or null findings relative to HC or within subgroups of SZ. Surprisingly, one recent study using an outpatient sample found the unexpected result of SZ patients choosing larger delayed rewards more often (i.e., less impulsive) than controls. The authors argued that in an effort to match years of education for the groups they may have selected a HC sample with lower socioeconomic status (SES) who would choose more

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impulsively (Wang et al., 2018). Indeed, a tendency of choosing immediate rewards may not always indicate a trait-level deficit such as higher impulsivity but could also mean that the decision-makers need money more urgently (e.g., in order to pay rent). It is difficult to attribute the DD difference to a single construct or diagnosis without considering the long-term influences of all heterogeneous factors such as comorbidity or substance use for SZ.

While a significant difference was found in the Kirby DD task, we did not see any significant difference on the Decimal DD task. There are notable differences in the two versions of the task. First, the Decimal task has a much smaller reward magnitude (on average 10 dollars) which is still more than two times smaller than the average payoff in the small magnitude condition of the Kirby task (on average 26 dollars). Although we did not see a significant group by condition interaction for the Kirby task, suggesting that both groups showed similar trend of choices as magnitude of offers decrease, one recent report with reward magnitude (45 Yuan or around 7 US dollars) similar to our Decimal task showed that HC surprisingly chose more impulsively than an outpatient sample of SZ (Wang et al., 2018). A second difference between our two tasks is the length of the delay. The Kirby task has a median delay of 61 days (presented in number of “days”) whereas it is only 28 days for Decimal (presented in number of “weeks”). The ability to represent and forecast the future has been argued to be an important factor during intertemporal choice (Berns, Laibson, & Loewenstein, 2007; Hershfield, 2011; Peters & Buchel, 2010) and DD abnormalities in SZ were argued to depend on this ability (Gold et al., 2008; Heerey et al., 2007). A shorter perception of delay would facilitate patience or self-control (Lempert & Phelps, 2016), which could contribute to SZ showing higher DD than HC in the Kirby task. Finally, rewards in the Decimal task are shown with 4 digits (i.e. 2 decimal places), while there is no decimal place for rewards in the Kirby task (2 digits). Research employing transcranial direct current stimulation (tDCS) showed that stimulation on frontoparietal regions such as DLPFC enhanced proactive control (Boudewyn, Roberts, Mizrak, Ranganath, & Carter, 2019) and planning ability in SZ (Chang, Kao, Chao, & Chang, 2019). It might be possible that doubling the number of digits (4 digits instead of 2 in the Kirby task) contributed to a higher level of engagement in the Decimal task, which may serve as an internal “stimulation” to facilitate self-control during DD in SZ. Interestingly, one ADHD study comparing two DD tasks with either two choice options or five options found that ADHD children showed higher DD relative to typical developing children only with the two choice DD task (Patros, Alderson, Lea & Tarle, 2015). Presumably the five-choice task is more engaging which could result in normalized DD performance in ADHD. While differences between the two DD task parameters make it difficult to pinpoint the specific features that resulted in DD abnormalities in SZ on the Kirby, but not on the Decimal, our results suggest that for intertemporal choice with short delays and small monetary reward offers presented in a 4 digit decimal format, FE SZ may show comparable discounting relative to HC. Nevertheless, even with the same Kirby task, three previous studies did not find any group difference between chronic SZ and HC (Avsar et al., 2013; MacKillop & Tidey, 2011; Wing et al., 2012), demonstrating that the malleable DD processes (Lempert & Phelps, 2016) may be further complicated by the heterogeneity of SZ patients.

We did not observe the expected relationship of k and negative symptoms, despite its theoretical link with motivational deficits in SZ (Gold et al., 2008; Kring & Barch, 2014).

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Following the seminal work from Heerey and colleagues (2007) which showed a negative relationship between negative symptoms and discounting in chronic SZ, later studies failed to replicate this relationship (Ahn et al., 2011; Brown et al., 2018; Horan et al., 2017). Choices of different assessment scales may contribute to this discrepancy. Whereas Heerey and colleagues (2007) utilized the SANS as a measure for negative symptoms, all of later studies used the Positive and Negative Syndrome Scale (Kay, Fiszbein, & Opler, 1987). Similar to Heerey and colleagues (2007), we used the SANS, but generated more specific composite syndrome measures (Barch et al., 2003) to quantify negative symptoms. In detailed follow-up analyses, we also tested individual subscales of the SANS, as well as testing composite measures of experiential and expressive negative symptoms, but still did not see the relationship with our FE sample (see Supplementary Materials). Nonetheless, on a preliminary basis, we observed a previously unreported relationship that in which SZ patients with higher positive symptoms showed steeper discounting. Positive symptoms in SZ have been suggested to arise from hyperactivity of striatal phasic dopaminergic activity (Abi-Dargham et al., 2000; Kapur, 2003), which, interestingly, was also proposed to drive individuals choosing impulsively during DD (Volkow & Baler, 2015). It remains to be tested if abnormal striatal dopaminergic activity plays a role in the relationship between DD and positive symptoms in SZ. Note that our identified relationship between positive symptoms and DD is modest and would not survive correction for multiple comparisons. Therefore, more studies, especially with FE samples, are needed to test the validity of this preliminary finding.

For our BP patients, who were in a euthymic state, we found that in general there was no group difference in DD relative to HC. This null finding is in agreement with previous studies showing no group difference using an adolescence BP sample (Urosevic et al., 2016), and a young adult sample of individuals at risk for mania (Meyer et al., 2015). It is also consistent with studies showing that elevated impulsivity is usually found in a manic state in BP (Swan et al., 2003), and becomes normalized when switching to depression or euthymia (Strakowski et al., 2010). The current finding diverges from the very first study reporting DD results in a chronic BP sample, which found steeper discounting for BP than HC (Ahn et al., 2011). This discrepancy might be understood under the context of another study suggesting that BP patients did not show age-related improvement in DD observed in HC (Urosevic et al., 2016). If this is true, steeper discounting in chronic BP may be a result of this developmental abnormality. Indeed, individuals with BP also show a high prevalence of developing substance-use disorder (Swann, 2010), which was linked to impulsivity and steeper discounting (Bickel & Marsch, 2001). With our sample of FE BP and null DD finding, it may suggest that impaired DD in chronic BP could be a result of abnormal development acquired with disease progression.

The current study is not without limitations. First, we only found DD abnormalities in SZ for the Kirby but not the Decimal task. Given differences in several task attributes, it is difficult to precisely the specific attribute that most strongly contributed to the observed difference. Additional studies with FE samples employing tasks that explicitly manipulate variables such as reward delays, reward magnitudes and visual properties of the offers are needed to further shed light on DD in SZ. In addition, our BP patients were relatively euthymic and we were unable to find a link between clinical symptomatology (including mania) and

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discounting rates. Finally, the present study only includes BP patients with psychotic features; future studies would benefit from comparing BP patients with and without psychotic features to better understand DD processes across the mood and psychosis spectrum.

In summary, in the current study we examined DD in FE SZ and BP across two tasks. We found task-dependent DD abnormalities in SZ such that when tested in another task with choices having smaller rewards, shorter delays and a 4 digit decimal format, SZ performed comparably to HC. We also found a novel positive relationship between positive symptoms and DD in SZ. On the other hand, BP showed comparable DD relative to HC. We propose that the theoretical link between negative symptoms and DD in SZ may be in part mediated by the phase of the illness; positive symptoms which are more prone to state fluctuations could be a better predictor of DD abnormalities in FE SZ. Similarly, FE BP with normal DD may still show impairment as the individual moves towards the chronic phase.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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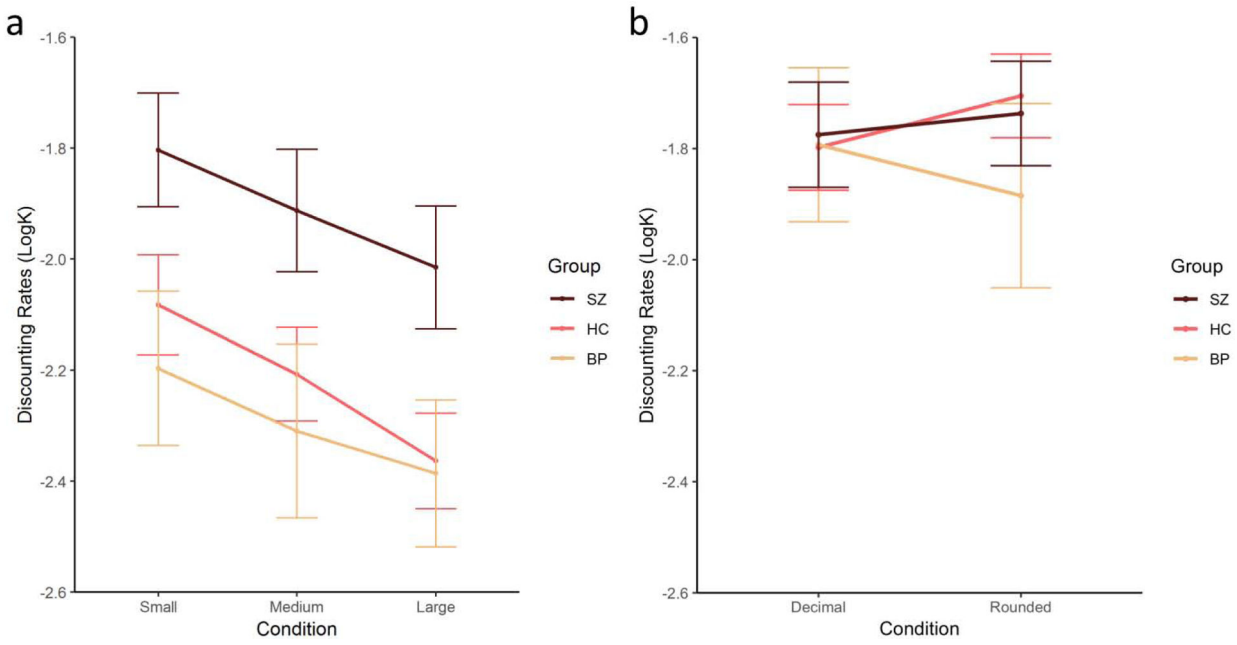

Fig.1.

a). Average log-transformed discounting rates for small, medium and large monetary magnitudes (S, M, L) on the Kirby task. b). Average log-transformed discounting rates for round and decimal offers on the Decimal task. Error bar represents plus and minus one standard error. HC – healthy control, SZ – schizophrenia spectrum disorder, BP – bipolar disorder.

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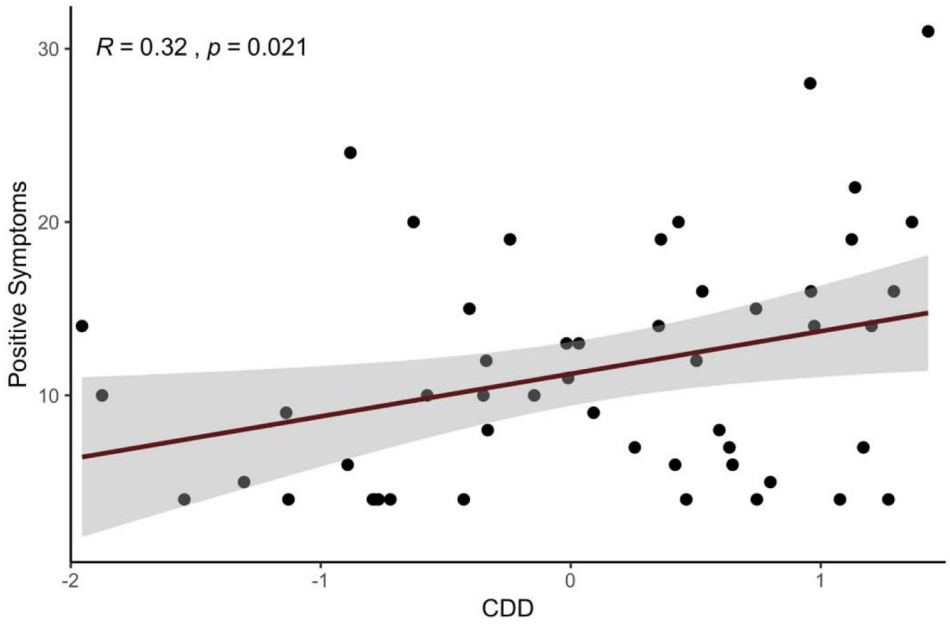

Fig. 2.

Scatter plot showing relationships between the composite delay discounting (CDD; see Method) measure and positive symptoms (reality distortion) in SZ. Note for CDD higher number implies steeper discounting.

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Table 1 —

Demographic variables.

Condition	HC (N = 73)	SZ (N = 72)	BP (N = 28)	F or χ^2 (p)
Age	21.63 (3.87)	20.67 (3.46)	20.47 (3.12)	1.63 (.20)
Gender (male)	57.53% (42)	69.44% (50)	57.14% (16)	2.59 (.27)
Handedness (right)	87.32% (62)	90.14% (64)	85.71% (24)	0.48 (.79)
Subject Education (years)	13.76 (2.97)	12.10 (2.35)	12.04 (2.33)	8.41 (<001)
Parental Education (years)	14.96 (3.05)	14.31 (2.57)	15.00 (2.13)	1.13 (.33)
WASI-IQ	116.44 (11.27)	100.50 (15.92)	108.96 (10.57)	25.30 (<001)