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BRIEF REPORT

Imagining the Future: Degraded Representations of Future Rewards and Events in Schizophrenia

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Over the course of life, most people work toward temporally distant rewards such as university degrees or work-related promotions. In contrast, many people with schizophrenia show deficits in behavior oriented toward long-term rewards, although they function adequately when rewards are more immediately present. Moreover, when asked about possible future events, individuals with schizophrenia show foreshortened future time perspectives relative to healthy individuals. Here, we take the view that these deficits are related and can be explained by cognitive deficits. We compared the performance of participants with schizophrenia ($n = 39$) and healthy participants ($n = 25$) on tasks measuring reward discounting and future event representations. Consistent with previous research, we found that relative to healthy participants, those with schizophrenia discounted the value of future rewards more steeply. Furthermore, when asked about future events, their responses were biased toward events in the near future, relative to healthy participants' responses. Although discounting and future representations were unrelated in healthy participants, we found significant correlations across the tasks among participants with schizophrenia, as well as correlations with cognitive variables and symptoms. Further analysis showed that statistically controlling working memory eliminated group differences in task performance. Together these results suggest that the motivational deficits characteristic of schizophrenia relate to cognitive deficits affecting the ability to represent and/or evaluate distant outcomes, a finding with important implications for promoting recovery from schizophrenia.

Keywords: schizophrenia, reward, time perspectives, delay discounting, cognitive function

Despite decades of research, schizophrenia remains a mysterious illness, which is often characterized by significant disability (Lehman et al., 2004; Novick, Haro, Suarez, Vieta, & Naber, 2009). One of the major impediments to recovery for many individuals is a failure to sustain long-term patterns of goal-oriented behavior, especially when associated rewards are distant. For example, many people with schizophrenia find it difficult to maintain involvement with vocational rehabilitation programs that offer longer term rewards (e.g., a paycheck after one or two weeks' work; Zito, Greig, Wexler, & Bell, 2007). In contrast, research shows that in situations such as token economies, in which behaviors and/or goals are rewarded on a daily or hourly basis, people with schizophrenia engage quite readily (Dickerson, Tenhula, & Green-Paden, 2005; Silverstein et al., 2009). Thus, the critical issue does not appear to be whether individuals with schizophrenia are sensitive to rewards per se but rather that they have difficulty organizing and engaging in the behaviors required to obtain temporally distant rewards.

Accordingly, we have shown that in schizophrenia, rewards that are not immediately present in the environment quickly lose their ability to modulate behavioral responses and that the degree to which they do so correlates with working memory (Heerey & Gold, 2007). This idea suggests that individuals with schizophrenia may undervalue delayed relative to immediate rewards because of difficulties maintaining reward-value representations over time. Insofar as this ability is compromised, individuals should prefer the more clearly represented immediate choices. Indeed, we have reported that individuals with schizophrenia discount or devalue temporally distant rewards to a greater degree than do healthy individuals (Heerey, Robinson, McMahon, & Gold, 2007). Notably, although steeper discounting is usually interpreted as reflecting impulsivity (Petry, 2001; Reynolds, 2006), cognitive impediments, including the introduction of working memory loads, also degrade it (Hinson, Jameson, & Whitney, 2003).

It is interesting that the ability to represent future time, which is impaired in schizophrenia (e.g., Eack, George, Prasad, & Keshavan, 2008; Suto & Frank, 1994; Wallace, 1956), may also hinge on the ability to maintain and use abstract representations (Klapproth,

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2008) and therefore be influenced by working memory–related processes (Addis, Wong, & Schacter, 2007). Thus, according to this formulation, reduced preferences for distant rewards in schizophrenia should relate to foreshortened future time perspectives because events further in the future (e.g., distant rewards) are poorly represented relative to more proximal events (e.g., immediate rewards).

Notably, this prediction differs from the pattern observed in individuals with orbitofrontal cortex (OFC) lesions. Specifically, Fellows and Farah (2005) demonstrated that people with OFC injuries had impaired future time perspectives but did not discount delayed rewards more steeply than did other lesion groups or healthy participants. Thus, discounting and time perspectives were dissociable in the OFC group. In contrast, we expect a relationship between discounting and time perspectives in schizophrenia because we think that global impairments in the ability to represent nonimmediate experiences, including distant rewards and events, may underpin both deficits.

The goals of this research were to (a) replicate previous findings showing increased delay discounting (Heerey et al., 2007) and foreshortened future time perspectives in schizophrenia (Wallace, 1956); (b) understand the relationship between delay discounting and future time perspectives in schizophrenia; and (c) link time perspectives and discounting to symptoms, cognitive ability, and functional outcomes. We predict that in participants with schizophrenia, time perspectives and discounting will be correlated and will relate to cognition, symptoms, and functioning.

Method

Participants

Participants included 39 outpatients with schizophrenia (SC) and 25 healthy comparison (HC) participants. Schizophrenia diagnoses were confirmed with the Structured Clinical Interview for *DSM–IV* (First, Spitzer, Miriam, & Williams, 2002). SC participants were deemed clinically stable by their clinicians and received stable doses of antipsychotic medicine with no medication changes for more than 4 weeks before participation. Symptom and functioning assessments included the Scale for the Assessment of Negative Symptoms (Andreasen, 1989), the Brief Psychiatric Rating Scale (Overall & Gorham, 1962), and the Level of Functioning Scale (J. S. Strauss & Carpenter, 1972). HC participants were receiving no psychiatric medications and were confirmed free of psychiatric diagnoses on the basis of the Structured Clinical Interview for *DSM–IV*. Potential participants were excluded if there was evidence of neurological injury or disorder, substance abuse or dependence other than nicotine within the 4 months before study enrolment, or other disorder capable of affecting task performance. All participants gave written informed consent. The University of Maryland Institutional Review Board approved the study. Participant characteristics appear in Table 1.

Procedures

Participants completed two tasks in the context of a larger study. The first was a computerized delay-discounting task,

Table 1
Participant Characteristics

Characteristic	Healthy comparison participants	Participants with schizophrenia	*p*
N	25	39	
Age in years	47.00 (10.18)	45.16 (10.03)	.47
Age at illness onset		23.41 (7.56)	
Education	14.29 (1.98)	12.23 (1.94)	<.001
Paternal education	12.42 (4.31)	12.50 (4.23)	.94
Gender[a] (male:female)	17:8	31:8	.36
Race[a]			.69
African American	9	11	
Caucasian	16	26	
Other	0	2	
Cognitive performance			
Working memory	16.15 (3.92)	11.38 (3.18)	<.001
Verbal learning	28.46 (3.95)	20.43 (4.99)	<.001
Test of adult reading	106.04 (15.90)	94.77 (17.05)	.01
Antipsychotic medicine			
Atypical		32	
Typical		6	
Both		1	
Clinical symptoms			
SANS avolition/anhedonia		3.49 (1.85)	
BPRS total		27.76 (7.53)	
Level of Functioning Scales			
Social		3.54 (2.53)	—
Work		2.79 (2.63)	—

Note. Unless otherwise noted, the values on the table represent means, and standard deviations appear in parentheses. Also except where noted, group differences were tested with *t* tests. SANS = Scale for the Assessment of Negative Symptoms; BPRS = Brief Psychiatric Rating Scale.
[a] Group differences tested with chi-square.

measuring the degree to which rewards lose their value as they move further into the future. In delay-discounting tasks, participants choose between smaller, more immediate rewards and larger rewards at later times (e.g., $10 today or $20 in 28 days). Discounting is estimated according to the hyperbolic discounting equation, $V = \frac{A}{1 + kD}$, in which V is a future reward's discounted value, A is its undiscounted or immediate value, D is the delay interval, and k is the discounting parameter, which varies according to how quickly rewards are discounted (Kirby, 2000). For example, assuming a k value of .01 and a delay of 28 days, $20 would have a discounted value of $15.63. Higher k values indicate steeper or faster discounting.

We have shown that SC participants discount distant rewards more steeply, which may indicate impulsivity. We therefore included a condition in which the smaller, sooner reward (SSR) was not immediate. That is, on some trials of the task, participants were asked whether they preferred, for example, a smaller reward in 7 days or a larger reward in 14 days. This procedure, known as *subadditive delay discounting* (Read & Roelofsma, 2003), equates the amount of time that lapses between the decision point and the proximal reward with the amount of time that lapses between the proximal and distal rewards (delay intervals ranged from a minimum of 5 days to a maximum of 6 months). Theoretically, subadditive discounting procedures reduce impulsive choice by enforcing patience (i.e., a delay before reward receipt; Green, Myerson, & Macaux, 2005; Read, 2001), as research in both humans (Kirby & Herrnstein, 1995) and animals (Ainslie, 1974) shows. We therefore reasoned that a Group $\times$ Condition interaction, in which SC participants showed normal subadditive discounting but steeper immediate discounting, would demonstrate that their immediate decisions were indeed more impulsive, whereas no interaction would point away from simple impulsivity as a factor in the SC deficit.

On each trial of the task, participants chose between an SSR and a larger, later reward (LLR) using a keypress. Participants were told that they would not actually receive the rewards they chose but were nonetheless asked to choose as if each trial was a choice between genuine rewards. We used this procedure because many previous studies have failed to find differences between hypothetical and real rewards (e.g., Bickel, Pitcock, Yi, & Angtuaco, 2009; Lagorio & Madden, 2005; Madden, Begotka, Raiff, & Kastern, 2003).

In the immediate condition, participants chose between an SSR with no delay ("today") and an LLR available after a variable number of days. In the subadditive condition, they chose between rewards in which the delay between the SSR and LLR was the same as that between today and the SSR. To determine the point of subjective equality for each condition, we presented participants with choices at values of k ranging between 0 and 1, using separate adaptive staircases in which the k values started at 1 and moved, step by step, toward 0 or vice versa, allowing us to gradually increase the precision of our k estimates. We used two staircases per condition (one starting at $k = 0$ and the other at $k = 1$), each of which provided an independent estimate of the point of subjective equality by reversing direction each time participants switched between choosing the SSR and choosing the LLR (e.g., if k was increasing before the preference shift, it now decreased). For example, one staircase started at $k = 0$ (no discounting; i.e., the SSR and the LLR held the same monetary value, e.g., "$34 today or $34 in 60 days"), meaning that participants should choose the SSR. On this staircase, k increased by .10 on each successive trial until participants chose the LLR, at which point k began to decrease until there was another preference shift. The step size decreased by 20% with each preference shift (e.g., .10, .08, .064), allowing us to narrow the window within which participants' k estimates fell. There were 20 trials per staircase. Trials presenting choices from each of the four staircases were randomly intermixed. This procedure has three advantages over procedures using fixed k intervals (e.g., Kirby, Petry, & Bickel, 1999). First, it allows precise estimates of discounting parameters by testing increasingly narrow k intervals. Second, it identifies participants who adopt idiosyncratic response strategies such as choosing only the SSR. Third, this procedure is robust against inconsistent responding (e.g., accidentally pressing the wrong button), which is an issue for SC participants and can produce artificially inflated or deflated k estimates.

Finally, our LLR values ranged from $75 to $85, as we have found that SC participants discount LLRs in this value range much more steeply than do HC participants. This meant that our SSR values had a large range: from $0 to $85.

The second task participants completed was a future time perspective interview, designed to produce an estimate of the average time window within which participants view future events. Using procedures adapted from Fellows and Farah (2005) and Wallace (1956), we asked participants to list 10 events that they believed would occur in their futures using a standard probe: "I'd like you to spend some time thinking about your own future. Please think of ten events that may happen to you during the rest of your life." Participants responded verbally and responses were recorded verbatim. Participants received general positive feedback after each item and were encouraged to keep thinking until they had generated 10 events. All participants except one SC participant named 10 events. The experimenter then reviewed events one at a time and asked participants to estimate how far in the future they thought the event would occur. To estimate average time horizon, we calculated the length of time between the date of the interview and the estimated time of each event's occurrence in months and took the mean time estimate of the events. We also report the maximum extension of participants' time horizons (i.e., the most distant event).

In addition to the tasks above, participants completed the letter–number sequencing test and the Hopkins Verbal Learning Test to measure verbal working memory and verbal learning. These measures are recommended in the MATRICS (Measurement and Treatment Research to Improve Cognition in Schizophrenia) Consensus Cognitive Battery (http://www.matrics.ucla.edu) and the Wechsler Test of Adult Reading (Wechsler, 2001) to estimate current and premorbid function.

Data Analysis

To estimate k in both discounting conditions (immediate, subadditive), we computed the geometric mean of the final k values of the two staircases measuring that condition. There were three participants (two SC, one HC) for whom k could not be estimated because they never varied their choices. These participants were excluded from discounting analyses. The log-transformed k values were analyzed with a mixed model analysis of variance with group (HC, SC) as the between-subjects variable and condition (immediate, subadditive) as the within-subjects variable. Time horizons were not normally distributed even after log transformation, so group comparisons and correlations used nonparametric analyses. Post hoc analyses use Bonferroni's correction for multiple comparisons.

Results

Delay Discounting

Figure 1 shows participants' estimated k values in immediate and subadditive conditions. As predicted, we found a main effect of group such that SC participants showed steeper discounting than did HC participants, $F(1, 59) = 5.03$, $p = .03$, $\eta_p^2 = .08$, replicating our previous findings. There was also a strong main effect for condition such that all participants benefited in the subadditive condition, $F(1, 59) = 96.41$, $p < .001$, $\eta_p^2 = .62$. That is, discounting was less steep when choosing between two delayed choices rather than an immediate and a delayed choice. Post hoc analyses showed that SC participants discounted more steeply in both immediate ($p = .04$) and subadditive conditions ($p = .02$), meaning that the introduction of a delay before the SSR improved discounting in both groups similarly. There was no Group × Condition interaction, $F(1, 59) < .01$, $p = .99$, suggesting that SC participants' steeper immediate discounting cannot simply be attributed to impulsivity.

Future Time Perspectives

Two coders (unaware of participants' diagnoses) classified events into a set of categories including household chores (e.g., spring cleaning), health-related events (e.g., potential illness or relapse, attending a swimming class), leisure (e.g., seeing a film, vacation), financial (e.g., reaching a savings target), religion (e.g., attend prayer group), hobbies or interests (e.g., photography class), and family events (e.g., nephew's graduation; Cohen's κs > .72). It is interesting that there were no differences in the frequency with which participants reported events across categories ($ps > .17$). However, as anticipated, SC participants reported events that were both on average, Mann–Whitney $U = 292$, $p = .008$, and maximally, Mann–Whitney $U = 354$, $p = .036$, nearer in the future than HC participants' events. One reason that SC participants report nearer future events might be that their reports are weighted toward events that repeat daily or weekly and are therefore easily reported (e.g., "eat supper tonight," reported by one HC and four SC participants; "clean the house," reported by two HC and five SC participants). If this explanation is the cause of the time-horizon differences, participants' event distributions should be similar after removing immediate events. Alternatively, if the distributions are still different after immediate-event removal, then the cause of the difference cannot be simple ease of reporting. To examine this idea, we tallied events falling into 10 time bins for both groups (see Figure 2). A chi-square goodness-of-fit test confirmed that in general, SC participants' events were distributed differently than HC participants' events, $\chi^2(9) = 37.95$, $p < .001$. To examine the degree to which this pattern held for nonimmediate events, we did the same analysis excluding events in time bins one week or sooner in the future. Results again showed that SC participants' events were nearer than were HC participants' events, $\chi^2(5) = 23.24$, $p < .001$. These results mirror the discounting results and suggest that SC participants' reports are biased toward more proximal events.

To support this idea, we correlated the log-transformed, average k value with the average log transformed time horizon. Among HC participants, there was no relationship between discounting and time horizon, $r = .06$, $p = .76$. However, among SC participants, we found a significant relationship between average time horizon and discounting, $r = -.35$, $p = .04$, such that longer time horizons correlated with less discounting impairment.

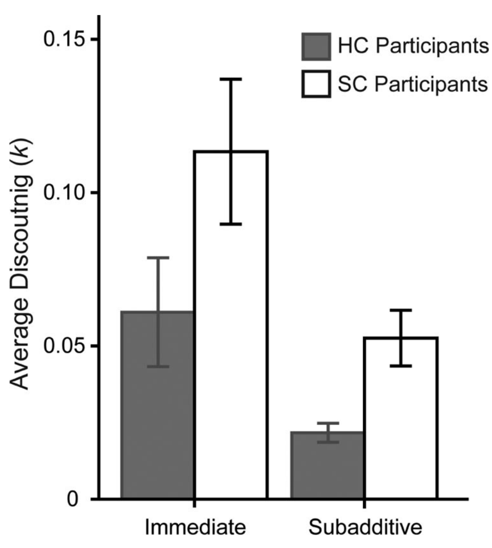

Figure 1. Discounting constants for healthy comparison (HC) participants (gray bars) and outpatients with schizophrenia (SC; white bars) in the immediate and subadditive conditions. Error bars show ±1 standard error of the mean.

Cognitive and Symptom Predictors of Task Performance

To better understand the factors contributing to the group differences in both tasks together, we computed a composite score by converting the log-transformed average time horizon and the log-transformed average k value to z scores and averaging these. Among HC participants, the composite future-representation score correlated with working memory, $\rho_{Spearman} = .44$, $p = .02$, and verbal learning, $\rho_{Spearman} = .40$, $p = .04$; among SC participants, future representation related to working memory, $\rho_{Spearman} = .45$, $p = .003$, but not verbal learning, $\rho_{Spearman} = .23$, $p = .15$, suggesting that better cognitive resources correspond to better representations of future time and events. Current and premorbid verbal function did not correlate with future representation in either group ($ps > .23$).

To better understand how cognitive differences underpin group differences in task performance, we conducted a hierarchical multiple regression with the composite future-representation score as the dependent variable and entered the cognitive variables (working memory and verbal learning) at Step 1 and diagnostic status (0 = HC, 1 = SC) at Step 2 as predictors. At Step 1, working

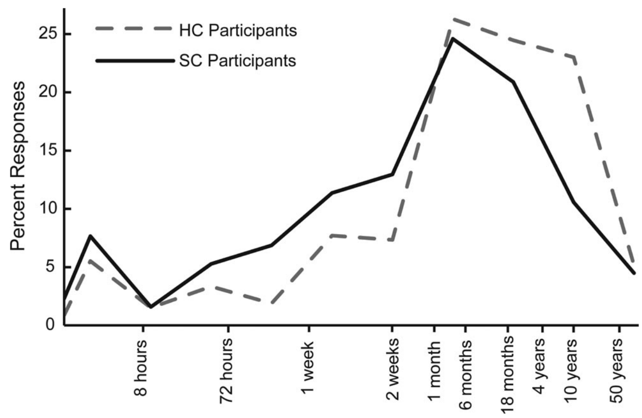

Figure 2. Percentage of responses across time for healthy comparison (HC) participants (dashed line) and outpatients with schizophrenia (SC; solid line). Note that time is shown on a logarithmic scale.

memory significantly predicted task performance, $\beta = .39$, $t(59) = 2.88$, $p = .005$, but verbal learning did not, $\beta = .19$, $t(59) = 1.36$, $p = .18$. However, after controlling for cognitive performance, we found the group difference at Step 2 was no longer significant, $\Delta R^2 = .002$, $p = .70$.

Finally, we examined the relationships between the composite future-representation score, general functioning, positive symptoms, and avolition/anhedonia in the SC group. Future representation correlated with Level of Functioning Scale work functioning, $\rho_{\text{Spearman}} = .33$, $p = .04$, and tended to relate to social functioning, $\rho_{\text{Spearman}} = .27$, $p = .10$, but did not correlate with positive symptoms, $\rho_{\text{Spearman}} = -.04$, $p = .82$. To examine avolition/anhedonia, we created a composite score using the avolition global score and the anhedonia global score from the Scale for the Assessment of Negative Symptoms. Future representations correlated with avolition/anhedonia, $\rho_{\text{Spearman}} = -.32$, $p = .05$, such that participants with more avolition/anhedonia showed reduced performance.

Discussion

As anticipated, results showed that SC participants had foreshortened time perspectives and discounted rewards more steeply than did HC participants. We also found that these processes were related in SC but not HC participants, such that SC participants with shorter average time horizons valued future rewards less. After controlling for cognitive performance, specifically working memory, the group differences in task performance disappeared. These findings hint at the possibility that a common factor underpins both deficits. What might this factor be? We suggest two possibilities.

The most obvious suggestion for the relationship between discounting and time horizons in SC participants is that they are more impulsively reward focused than HC participants are. High levels of reward focus reduce the ability to attend to future rewards (Mitchell, Fields, D'Esposito, & Boettiger, 2005; Perry & Carroll, 2008) and to the future more generally (Bechara, Dolan, & Hindes, 2002). Although previous research concludes that schizophrenia is associated with impulsive decision making (Enticott, Ogloff, & Bradshaw, 2008), the present results do not support this view. If the subadditive condition had normalized SC participants' discounting, this would have suggested that poor delay tolerance or impulsivity was responsible for the result (Ainslie, 1974; Kirby & Herrnstein, 1995). However, the delay enhanced both groups' performance equally. Moreover, avolition and anhedonia correlated with task performance, suggesting that simple impulsiveness is not sufficient to explain these results.

Alternatively, we argue that cognitive deficits present in the SC group may adversely affect the ability to represent both future time and future rewards. We found a relationship between working memory and performance in both tasks such that participants with better working memory showed less task-related impairment (for similar results, see G. P. Strauss et al., 2010). Working memory, which is impaired in schizophrenia (Barch, 2005), may support the integration of cognitive with affective information (Becerril & Barch, 2010) and serve to maintain reward representations over time. This idea is in keeping with other research showing deficits in the ability to represent future rewards in schizophrenia (Gard, Gard, Kring, & John, 2006). Indeed, the results of our regression analysis suggest that working memory deficits may underpin difficulties in representing future rewards and events, which in turn may have functional consequences (Gard, Fisher, Garrett, Genevsky, & Vinogradov, 2009). Indeed, SC participants' work-related functioning declined as their task performance worsened.

It is interesting that the future representation and negative symptom and cognitive correlations in the present study diverge slightly from our previously reported results (Heerey et al., 2007). In that study, surprisingly, we found that higher negative symptom levels tended to predict less impaired discounting. In the present study, we found the opposite relationship. Specifically, higher negative symptom levels correlated with more impaired future representations. This discrepancy may relate to SC participants' symptom levels, which were lower in the present study, suggesting that the current participants suffered from fewer symptoms at the time of testing than did our previous participants. Thus, the present research may have undersampled participants with extremely high negative symptom levels. Additionally, our previous report showed that verbal learning and spatial working memory predicted task performance and, in the present study, verbal working memory alone accounted for the group differences in future-representation ability, although we note that the verbal learning correlation tends toward this without reaching statistical significance.

There are two important caveats to these findings. First, all of our SC participants were receiving antipsychotic medicine. We therefore remain agnostic about whether the present results are characteristic of schizophrenia or its treatment. Second, participants completed the task for hypothetical rewards. In some ways, the use of hypothetical rewards mirrors life in that people make decisions about future rewards that are only imagined until they actually occur (e.g., investment dividends). Although this may alter decision making relative to tasks involving tangible rewards, especially among SC participants, it is also more compatible with the future time perspectives task in which participants speculated about possible but not certain future events. Regardless, these findings have consequences for understanding some of the motivational and functional deficits characteristic of the illness. Specifically, they suggest that treatment programs promoting functional recovery should place emphasis on short- and medium-term goals with gradual shifts to organizing and working toward longer term outcomes. It is interesting that these results are fully compatible with the effectiveness of token economy treatment approaches documented 40 years ago (Lloyd & Abel, 1970). This suggests that the challenges faced by people with schizophrenia when tight contingency control is reduced must be replaced by the ability to produce and use self-generated mental representations to drive the push toward future goals.

The power of distant rewards to drive behavior is an important element in functional outcomes. In summary, we found that participants with schizophrenia showed foreshortened future time perspectives and steeper discounting, which related to working memory deficits. These results are important because they suggest that cognitive deficits may underpin the ability to represent future time and rewards, thereby impinging on functional adjustment such as engagement with work and the pursuit of pleasurable activities. Thus, at least among medicated individuals, improving the ability to look toward and act on future rewards may improve functional outcomes.

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