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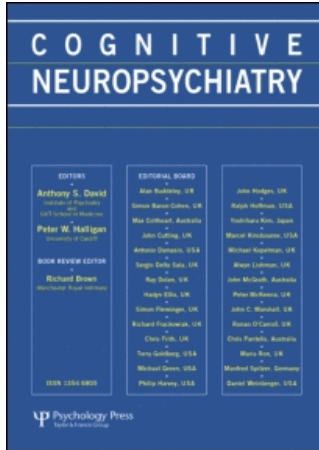
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## Delay discounting in schizophrenia

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*Background.* It is well known that individuals with schizophrenia have dopaminergic abnormalities as well as memory-related difficulties, both of which are associated with impulsive decision making. We used a delay discounting measure to test the degree to which patients make future-oriented decisions.

*Methods.* 42 patients with schizophrenia and 29 healthy participants completed a delay discounting measure along with tests of cognitive function and, in patients, symptom ratings.

*Results.* Patients discounted more steeply than did comparison participants. Discounting among patients related to memory capacity and tended to relate inversely to negative symptoms.

*Conclusions.* The impulsive decision making evidenced by patients suggests that they may be prone to choosing immediate over long-term rewards, even when their interests are better served by choosing the latter. Improving cognitive function may enhance their ability to make future-oriented decisions.

## BACKGROUND

Each of us is regularly confronted with choices involving outcomes that differ in magnitude or that are nearer or farther away in time. For example, one may choose to forgo purchasing a second car now, in favour of saving for future retirement (or vice versa). It is no surprise that when faced with such choices, the temporal remoteness of an outcome is related to the likelihood that it will be preferred. Indeed, numerous studies have shown that the more a reward is delayed the less subjective value it holds (e.g., Holt, Green, & Myerson, 2003; Kirby & Santiesteban, 2003; Petry,

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Kirby, & Kranzler, 2002). Thus, remote outcomes must be of relatively greater value to be preferred over temporally proximal ones.

The discounting of future outcomes among humans is most frequently characterised by a delay discounting (DD) function, which can be estimated from the degree to which an individual prefers smaller rewards sooner to larger rewards later. As the slope of the DD function increases, individuals become more susceptible to proximal rewards and begin to make decisions that are described as “temporally myopic” or “impulsive” (Kirby, Petry, & Bickel, 1999). Research has consistently demonstrated that DD is best described by a hyperbolic, rather than exponential function (e.g., Madden, Begotka, Raiff, & Kastern, 2003), according to the equation:  $V = A/(1 + kD)$ , where  $V$  represents discounted reward value;  $A$ , the undiscounted value;  $D$ , the delay length; and  $k$ , the DD parameter, which varies according to how quickly rewards are discounted (Kirby et al., 1999). Higher values of  $k$  indicate steeper discounting.

Several lines of evidence provide clues to the neurobiology of DD. Individuals who are dependent on heroin (Bornovalova, Daughters, Hernandez, Richards, & Lejuez, 2005), cocaine (Kirby & Petry, 2004), and alcohol (Mitchell, Fields, D’Esposito, & Boettiger, 2005) are more temporally myopic, as are individuals with damage to ventromedial cortex (Winstanley, Theobald, Cardinal, & Robbins, 2004; but see Fellows & Farah, 2005). Nucleus accumbens lesions also induce impulsive choice (Cardinal, Pennicott, Sugathapala, Robbins, & Everitt, 2001), suggesting that propensity to discount future outcomes may relate to reward processing and the dopaminergic system.

Research also points to a critical role of memory in DD. For example, increases in memory load during DD tasks cause future rewards to be more steeply discounted (Hinson, Jameson, & Whitney, 2003). Accordingly, functional imaging results show greater activity in dorsolateral prefrontal cortex (DLPFC) than ventromedial regions when individuals choose a delayed over an immediate reward and decreased DLPFC activity when they choose impulsively (McClure, Laibson, Loewenstein, & Cohen, 2004). Thus, there is converging evidence that the extent of preference for smaller immediate rewards over larger delayed rewards represents an important individual difference dimension that captures the relative contributions of different neural and cognitive systems to decision making.

Given their compromised memory (Lee & Park, 2005), impairment in DLPFC function (Cannon et al., 2005), and abnormalities in dopamine function (Kapur, 2003), one might expect patients with schizophrenia to demonstrate greater discounting of future rewards than healthy individuals. The present study was designed to test this prediction. Understanding reward discounting in schizophrenia may provide insight into why patients

frequently experience functional outcomes that are worse than typical cognitive assessments might predict.

## METHODS

### Participants

Participants included 42 outpatients with diagnoses of schizophrenia ( $n = 31$ ) or schizoaffective ( $n = 11$ ) disorder (SC) and 29 healthy comparison (HC) participants. Patient diagnoses were assessed with the Structured Clinical Interview for DSM-IV (SCID; First, Spitzer, Miriam, & Williams, 2002). All patients were receiving stable doses of antipsychotic medications with no medication changes for at least 4 weeks prior to participation (see Table 1 for

TABLE 1  
Participant characteristics

	<i>Healthy comparison participants (n = 29)</i>	<i>Schizophrenia patients (n = 42)</i>	<i>p-value</i>
Age	44.45 (10.57)	44.05 (9.13)	.865
Age at illness onset	—	22.75 (7.26)	—
Education	14.76 (2.50)	12.86 (2.28)	.001
Paternal education	13.28 (4.58)	13.51 (4.24)	.835
Gender (M:F)*	12:17	26:16	.098
Race*			.348
African American	8	16	
Caucasian	21	24	
Other	0	2	
Cognition			
WTAR	109.18 (13.26)	96.92 (17.01)	.002
LNS	15.62 (3.25)	11.95 (3.41)	<.001
SS	11.41 (2.23)	7.89 (2.98)	<.001
HVLT	29.31 (4.28)	21.55 (5.51)	<.001
Antipsychotic medication <sup>#</sup>			
Atypical antipsychotics	—	33	—
Typical antipsychotics	—	9	—
Atypical + Typical	—	1	—
Clinical ratings			
BPRS total	—	35.92 (8.52)	—
SANS total	—	29.76 (14.80)	—

Note: Table includes means and standard deviations. *T*-tests were conducted to determine group differences except where noted.

\*Group differences tested with chi-square.

<sup>#</sup>Several patients received adjunctive anticholinergic ( $n = 7$ ) or anti-anxiety medication ( $n = 6$ ).

sample characteristics). Patients were deemed clinically stable by their clinicians and were capable of providing informed consent, as assessed by a set of standard probes. Symptom assessments included the Brief Psychiatric Rating Scale (BPRS; Overall & Gorham, 1962) and the Scale for the Assessment of Negative Symptoms (SANS; Andreasen, 1989). HC participants were free of psychiatric diagnoses as indicated by SCID screening, receiving no psychiatric medications, and had no family history of psychosis. Potential participants were excluded if there was evidence of neurological injury/disorder, lifetime substance abuse/dependence, or other disorder capable of affecting symptoms or task performance. After study procedures were described, participants gave written informed consent. The University of Maryland's institutional review board approved the study.

## Procedure

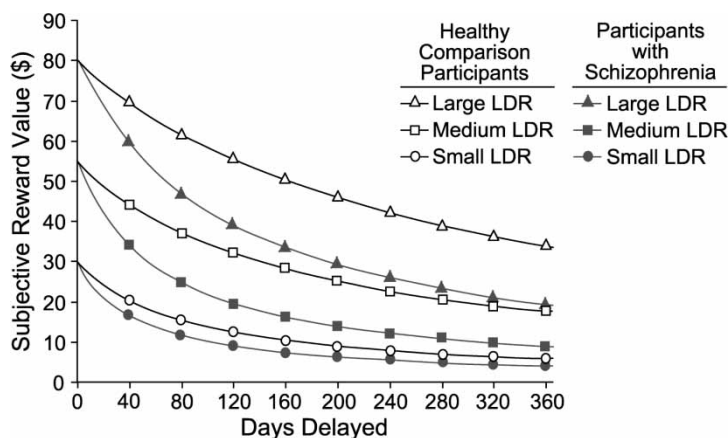
As part of a larger decision-making study, participants completed a computerised version of the monetary choice questionnaire for hypothetical monetary rewards (Kirby et al., 1999). The measure includes 27 items in which participants choose between a smaller immediate reward (SIR) and a larger delayed reward (LDR). LDR values included rewards of small (\$25–35), medium (\$50–60), and large magnitudes (\$75–85). SIR values ranged from \$11 to \$80 depending on  $k$  and the LDR.  $k$  was estimated according to methods reported by Kirby (2000). Briefly, the geometric mean of a window bounded by the largest  $k$ -value at which a participant chose the LDR and the smallest  $k$ -value at which a participant chose the SIR was calculated. For example, if a question's  $k$ -value was .0060 and a participant chose the LDR, a choice consistent with  $k$  smaller than .0060, and at the next smallest  $k$ -value (.0025) chose the SIR, then that participant's  $k$ -value was estimated by taking the geometric mean of  $k$ -values .0060 and .0025.  $k$ -values at small, medium, and large LDR sizes were estimated independently. Three SC participants were excluded at one or more LDR sizes due to inconsistent responding (fewer than seven items consistent with the estimated value of  $k$  in one or more LDR sizes, as in Kirby, 2000). In each excluded case individuals were consistent on six out of nine trials. Two cases were excluded at the medium LDR and one at both small and medium LDR sizes.

In addition to the task above, participants completed Spatial Span (SS), Letter-Number Sequencing (LNS; Wechsler, 1997), Hopkins Verbal Learning Test (HVLN; Shapiro, Benedict, Schretlen, & Brandt, 1999), and Wechsler Test of Adult Reading (WTAR; Wechsler, 2001).

RESULTS

Both groups responded to items with similar degrees of consistency, HC: mean = 97.3% consistent,  $SD = 0.03$ ; SC: mean = 95.6% consistent,  $SD = 0.06$ ;  $F(1, 66) = 2.20, p = .14$ . Data were approximately normalised using the natural log transformation, and the  $\log(k)$  values reasonably well distributed within groups. SAS<sup>®</sup> PROC MIXED was used to fit a mixed model for incomplete repeated measures of the form:  $\log(k) = \text{group} + \text{LDR size} + \text{group} \times \text{LDR size}$ . As shown in Figure 1, main effects were found for group (SC > HC),  $F(1, 69) = 4.94, p = .03; \eta_p^2 = .07$  and LDR size,  $F(2, 65) = 20.30, p < .001; \eta_p^2 = .26$ . Larger delayed rewards held their value better than smaller ones (small, medium, and large discount rates differed from each other; min  $p = .002$ ). The Group  $\times$  LDR size interaction was not significant,  $F(2, 65) = 0.92, p = .41; \eta_p^2 = .01$ .

To test the relationship between DD and cognition, an overall discounting factor was estimated from the geometric mean of  $k$  across all LDR sizes. This measure was correlated using Spearman's rho with cognitive function in each group and symptoms (SC only). Among SC participants, the DD estimate did not relate to WTAR or LNS,  $r_s < |.15|, p_s > .25$ . However, DD was inversely related to total HVL T score,  $r_s = -.33, p = .04$ , and tended to be inversely correlated with SS as well,  $r_s = -.29, p = .08$ . Thus, SC



**Figure 1.** Delay discounting by LDR size in participants with and without schizophrenia. Discount rates plotted over time. SC participants show significantly steeper discounting than HC participants at both medium and large LDR sizes. At small LDR sizes, patients show a nonsignificant trend towards steeper discounting ( $p = .14$ ). Geometric means for  $k$ s used in estimating slopes are as follows (standard deviations in parentheses). SC: large LDR = .039 (.076); medium LDR = .051 (.071); small LDR = .065 (.086). HC: large LDR = .010 (.024); medium LDR = .012 (.017); small LDR = .022 (.029). Graph symbols are placed every 40 days to allow easy visual discrimination of conditions. Slopes were estimated on a daily basis.

participants with better memory function demonstrated less severe discounting. Among HC participants, none of these correlations were significant,  $r_s < |.20|$ ,  $p_s > .30$ .

Although DD was not significantly related to positive symptoms,  $r_s = .09$ ,  $p = .58$ , it did tend to relate inversely to negative symptoms such that smaller  $k$ -values (i.e., more normal discounting) were associated with more negative symptoms (SANS total),  $r_s = -.31$ ,  $p = .07$ ; BPRS anergia,  $r_s = -.30$ ,  $p = .06$ . Thus, increases in negative symptoms tended to relate to decreased preference for smaller immediate rewards.

Finally, we conducted a post hoc analysis of patients' medications, grouped according to their affinity for dopamine receptors (see Kapur & Remington, 2001) to determine whether these results might be better explained by medication status. Results suggested that antipsychotic medication had no relationship to DD in the present sample,  $r_s = .11$ ,  $p = .36$ .

## DISCUSSION

Individuals with schizophrenia discount the value of future rewards at a significantly greater rate than do healthy individuals. Moreover, in the present sample, SC participants with better memory showed more normal DD and those with higher levels of negative symptoms tended to do likewise. DD was unrelated to positive symptoms.

Insofar as DD constitutes a measure of impulsive decision making, it has implications for understanding the clinical phenomenology of schizophrenia. In essence, patients have difficulty representing the value of future outcomes, preferring more immediate, albeit smaller rewards. This may explain, in part, the difficulty that patients experience in developing and following through with longer range educational and vocational programmes. Metaphorically, the pot of gold at the end of the rainbow simply does not shine brightly enough to justify the sacrifice of more proximal rewards.

The imaging data of McClure et al. (2004) suggest that the tendency towards more impulsive responding results from a reduced role of dorsolateral PFC over limbic regions in the regulation of decision making. The abundance of dopaminergic neurons in both prefrontal and limbic areas suggests that dopamine may play a role in DD. Indeed, lesions of the nucleus accumbens core have been found to increase myopic choice (Cardinal, Winstanley, Robbins, & Everitt, 2004). However, reductions in nucleus accumbens dopamine do not affect impulsivity (Winstanley, Theobald, Dalley, & Robbins, 2005) and, in the present sample, the dopaminergic

affinity of participants' medications was unrelated to DD, although we note that antipsychotics affect other neurotransmitters as well.

Another explanation for the present results relates to memory. It may be the case that individuals with better capacity to retain information "online" also have better ability to evaluate the rewards associated with each item in a set of options. Previous research has shown that introducing a memory load increases impulsivity in healthy individuals (Hinson et al., 2003). The present findings suggest that patients with better memory capacity also had more normal DD. Thus, better ability to invoke the value of future rewards may decrease the desire for smaller immediate rewards.

Surprisingly, elevations in negative symptoms tended to relate to more future-oriented decision making. Although it seems paradoxical that symptoms as debilitating as anergia might be protective, it is nonetheless possible that these reflect a disorder in sensitivity to reward (Shurman, Horan, & Nuechterlein, 2005). Negative symptoms then, may serve to dampen the pleasure associated with immediate rewards (Juckel et al., 2006), making impulsive choices easier to resist.

One caveat to these results relates to SC participants' medication status. Although DD performance did not relate to medication, subtle treatment effects may have been captured. However, patients with schizophrenia are routinely treated with antipsychotic medications. For this reason, it is likely that the present results index important aspects of patients' clinical function. Although these results may confound aspects of schizophrenia with aspects of treatment, they offer insight into how treated patients respond to rewarding stimuli in the environment. Replication of these results with patients who are medication-free and who differ in symptom presentation will help to clarify this issue.

## CONCLUSIONS

Individuals with schizophrenia discount future rewards to a greater degree than do healthy individuals. Although replication of the present findings will be necessary, ideally using real rather than hypothetical rewards and rewards of different types, it appears that memory capacity, and possibly negative symptoms, affect the degree to which individuals with schizophrenia are able to resist the pull of an immediate reward. These results suggest that helping people with schizophrenia focus on short-term, rather than long-term goals, and making long-term rewards more tangible, may improve outcomes.

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