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Delay discounting and gambling☆

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ABSTRACT

Delay discounting describes the decline in the value of a reinforcer as the delay to that reinforcer increases. A review of the available studies revealed that steep delay discounting is positively correlated with problem or pathological gambling. One hypothesis regarding this correlation derives from the discounting equation proposed by Mazur (1989). According to the equation, steeper discounting renders the difference between fixed-delayed rewards and gambling-like variable-delayed rewards larger; with the latter being more valuable. The present study was designed to test this prediction by first assessing rats' impulsive choices across four delays to a larger-later reinforcer. A second condition quantified strength of preference for mixed- over fixed-delays, with the duration of the latter adjusted between sessions to achieve indifference. Strength of preference for the mixed-delay alternative is given by the fixed delay at indifference (lower fixed-delay values reflect stronger preferences). Percent impulsive choice was not correlated with the value of the fixed delay at indifference and, therefore, the prediction of the hyperbolic model of gambling was not supported. A follow-up assessment revealed a significant decrease in impulsive choice after the second condition. This shift in impulsive choice could underlie the failure to observe the predicted correlation between impulsive choice and degree of preference for mixed- over fixed delays.

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Delay discounting describes the devaluation of an event as the delay to that event increases. Steep delay discounting describes a specific form of impulsive choice: preference for a smaller-sooner over a larger-later reward and the opposite preference involving aversive events. A number of studies using human participants have revealed a correlation between the degree to which the value of delayed monetary events is discounted and substance use disorders (see review by Yi et al., 2010). What underlies this correlation is not well understood. Evidence suggesting that steep delay discounting is predictive of drug taking comes, for example, from studies demonstrating that steep discounting of delayed food rewards precedes and predicts drug self-administration in rodents (see review by Carroll et al., 2010). The opposite, though not incompatible, relation would be supported if acute or chronic drug administration increases impulsivity and/or renders delay discounting curves steeper. At present, the effects of acute drugs of abuse on delay discounting are mixed; with ethanol and nicotine producing the most consistent increases in impulsive choice when assessed with nonhuman animals (see review by de Wit and Mitchell, 2010). Less work has explored chronic drug administration, but some evidence suggests chronic nicotine and cocaine increase impulsive choice after dosing or self-administration concludes (see review by Setlow et al., 2009).

A less extensive literature suggests a similar relation exists between steep delay discounting and gambling disorders in humans (see Table 1). Most studies of this relation have recruited participants based on their answers to the South Oaks Gambling Screen (SOGS; Lesieur and Blume, 1987). Scores of 5 and above are widely regarded as indicative of pathological gambling (for a discussion of the possible leniency of this criterion see Stinchfield, 2002). In the first of these studies, Petry and Casarella (1999) reported that substance abusers with SOGS scores of 5 and higher more steeply discounted delayed monetary rewards than did substance abusers who rarely gambled, and more than controls who had no prior history of substance use or gambling disorders. Dixon et al. (2003) reported a similar outcome when they compared delay discounting between gamblers in an off-track betting facility and controls in a non-gambling setting. A follow-up study revealed less steep delay discounting when gamblers completed the task in a non-gambling context (Dixon et al., 2006); nonetheless, the difference between gamblers and controls remained significant when

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Table 1
Characteristics of, and findings reported in studies evaluating the relation between delay discounting and gambling.

Authors	Mean SOGS scores (*N*)			Discounting	Delayed	Results
	Gamblers	Controls	Other	Task	Outcomes	
Petry and Casarella (1999)	9.5 (29)[a]	NR (18)	<1 (34)[b]	Rachlin et al. (1991)	\$100 & \$1000 (hypothetical)	Problem gambling substance abusers discounted more steeply than other groups.
Petry (2001)	12.0 (39)[c]	0.7 (26)	13.8 (21)[a,c]	Rachlin et al. (1991)	\$1000 (hypothetical)	Significant linear contrast with steepest discounting among substance abusing pathological gamblers.
Dixon et al. (2003)	5.8 (20)[d]	0.7 (20)		Rachlin et al. (1991)	\$1000 (hypothetical)	Steeper discounting among gamblers
Holt et al. (2003)	6.5 (19)	0.3 (19)		6-Choice adj-amount	\$1000 & \$50,000 (hypothetical)	No significant effect of group on delay discounting. Significant difference in probability discounting.
Dixon et al. (2006)	6.6 (20)[d]			Rachlin et al. (1991)	\$1000 (hypothetical)	Within-Ss design: Steeper discounting when gamblers completed task in gambling setting.
MacKillop et al. (2006)	7.7 (24)	0.0 (40)	1.8 (41)	Rachlin et al. (1991)	\$1000 (hypothetical)	Gamblers discounted more steeply than controls. No other differences were significant.
Ledgerwood et al. (2009)	7.1[e] (30)	0.2[e] (41)	7.4[e] (31)[a]	Rachlin et al. (1991)	\$1000	Both groups of gamblers discounted (hypothetical) more steeply than controls, but no difference between gamblers with and without history of substance use disorder.
Madden et al. (2009)	13.3 (19)[c]	0.8(19)		Kirby and Maraković (1995)	≤\$85 (hypothetical)	Steeper discounting in pathological gamblers approached significance when differences in education and ethnicity were included as covariates.

NR, not reported.
[a] Substance abusing gamblers.
[b] Substance abusers who rarely or never gambled.
[c] DSM-IV or NODS diagnosis of pathological gambling.
[d] Delay discounting assessed in an off-track betting facility.
[e] Prior year NODS score (SOGS scores not reported). A NODS score of ≥5 is indicative of pathological gambling according to DSM IV criteria.

context was constant across groups (see reanalysis by Petry and Madden, 2010).

Two studies have examined the relation between gambling and delay discounting among college-student gamblers. Holt et al. (2003) reported no difference in delay discounting between gambling and non-gambling students. Based on the SOGS scores shown in Table 1, this is a somewhat surprising finding because mean SOGS scores were in the range reported for gamblers in the Dixon et al. (2003, 2006) studies. Using similar methods with larger sample sizes, and assigning participants to groups using a slightly more stringent SOGS criterion, MacKillop et al. (2006) reported that student gamblers more steeply discounted delayed monetary outcomes than did non-pathological gambling controls.

A final category of these studies are those comparing delay discounting between controls and gamblers meeting either the DSM IV (American Psychiatric Association, 1994) criteria for pathological gambling or the National Opinion Research Center DSM Screen for Gambling Problems (NODS; Gerstein et al., 1999). Petry (2001) reported the steepest delay discounting among dual-diagnosed substance abusing pathological gamblers, less steep discounting in pathological gamblers with no history of substance-use disorder, and more-shallow discounting among controls. Ledgerwood et al. (2009) systematically replicated the difference in discounting between pathological gamblers and controls, but not between gamblers with and without a diagnosed substance-use disorder. Finally, Madden et al. (2009) examined delay discounting among pathological gamblers and matched controls using the brief paper and pencil measure developed by Kirby and Maraković (1995). The between-group difference in estimated discounting rate approached, but did not achieve statistical significance. Thus, with few exceptions (Holt et al., 2003; Madden et al., 2009) there is a positive relation between steep delay discounting and problem gambling. Indeed, Alessi and Petry's (2003) reanalysis of data collected by Petry and Casarella (1999) and Petry (2001) revealed that the best predictor of degree of delay discounting was severity of the gambling disorder (as measured by the SOGS).

A shortcoming of this literature is that delay discounting is assessed after participants have engaged in problem gambling. Thus, we know these tendencies are positively correlated, but we do not know if (a) steep delay discounting precedes and predicts a stronger preference for gambling, (b) prolonged gambling activity affects the discounting of delayed outcomes, or (c) a third variable accounts for the correlation.

Available theories regarding this relation speculate on why steep delay discounting may affect subsequent decisions to gamble. A general addiction-related theory was suggested by Odum et al. (2000). They suggested that steeply discounting the delayed losses associated with any addiction (e.g., eventual loss of vocation, spouse, friends) would render these prospective losses inert in the decision to continue the behavior.

In a more gambling-specific account known as "string theory," Rachlin (1990) suggested that the functional unit in the gambling milieu is the temporally extended string of wagers concluding in a win. The string may be as short as a single wager ending in a win and has no upper bound on the number of losses that may precede the win that terminates the string. According to string theory, the value of the gambling prospect is the sum of the discounted values of previously experienced strings; we have represented this using the equation proposed by Mazur (1989):

$$V = \sum_{i=1}^{n} P_i \left(\frac{N}{1 + kD_i} \right) \tag{1}$$

In Eq. (1), V is the value of the prospective gambling string and P_i is the probability of experiencing each different delay, D_i (string length), to a gambling win. The net value of the string, N, is the sum of the win and the losses (if any) in the string (e.g., assuming three \$1 and one \$2 wagers are lost before a \$10 win, the net value of the string is \$5). Finally, k is the discounting parameter which increases as the delay discounting curve descends more steeply.

String theory's account of the relation between steep delay discounting and propensity to gamble is as follows. Short strings have

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