Discounting and Pathological Gambling

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Pathological gambling is a disorder characterized by excessive gambling. It often occurs in conjunction with substance use disorders, and research is beginning to examine the association between these disorders, especially with regards to impulsivity and discounting. This chapter initially reviews the diagnosis and prevalence rates of pathological gambling, including its comorbidity with substance use disorders. It then describes relations between personality measures of impulsivity and pathological gambling. Gamblers' patterns of choices on the Iowa Gambling Task and measures of delay and probability discounting are covered in depth. The degree to which these choices are uniquely associated with a gambling disorder, rather than a comorbid substance use disorder, is discussed. Recent theories regarding the role of discounting in the etiology of pathological gambling are described, as are suggestions for future research.

I. Pathological Gambling Diagnosis and Prevalence

The Diagnostic and Statistical Manual of Mental Disorders – Fourth Edition (DSM-IV) classifies pathological gambling as an impulse control disorder. This disorder involves persistent and recurrent gambling that is disruptive to one's personal life, family or vocation (American Psychiatric Association, 1994). To receive a diagnosis, an individual must endorse at least 5 out of 10 criteria, which include: 1) preoccupation with gambling; 2) need to gamble with increasing amounts of money to maintain excitement; 3) repeated unsuccessful attempts to stop or reduce gambling; 4) restlessness and/or irritability when attempting to reduce or stop gambling; 5) gambling as a way to escape unpleasant emotions; 6) chasing loses; 7) lying to others to hide the extent of gambling; 8) committing illegal acts to finance gambling or repay debts; 9) placing a relationship, job, educational or other opportunity in jeopardy by gambling; and 10) seeking assistance from others to relieve a dire financial situation caused by gambling.

Although not a formal diagnostic category, *problem gambling* is a term commonly used for individuals who meet some of the diagnostic criteria of pathological gambling, but who do not meet five criteria necessary for a diagnosis (Petry, 2005). The phrase *disordered gambling* will be used throughout this chapter to refer to the combined group of both pathological and problem gamblers.

Shaffer, Hall, & Vander Bilt, (1999) published a meta-analysis of North American prevalence studies of disordered gambling conducted before 1997. Most of these surveys were conducted in specific states, geographical regions or patient populations. They found lifetime prevalence rates of pathological gambling among adults to be 1.6%, and lifetime rates of problem gambling were 3.9%. Past-year prevalence rates were 1.1% for pathological and 2.8% for problem gambling.

Three more recent, and nationally representative, surveys of prevalence rates of pathological gambling find similar or somewhat lower prevalence rates, ranging from 0.4% to 2.0% (Gerstein et al., 1999; Petry, Stinson, & Grant, 2005; Welte, Barnes, Wieczorek, Tidwell, & Parker, 2001). In the National Gambling Impact Study, Gerstein et al. surveyed 2,417 randomly selected residents by phone. They found the lifetime prevalence rate of pathological gambling to be 0.8%, with 1.3% having lifetime problem gambling. Past year rates were 0.1% for pathological gambling and 0.4% for problem gambling. In another phone survey of 2,638 adults throughout the country, Welte et al. found lifetime prevalence rates of pathological and problem gambling of 2.0% and 2.8%, respectively, and past year rates of 1.3 and 2.2%. The most recent survey (Petry et al.), from the National Epidemiology Survey of Alcohol and Related Disorders (NESARC), is also the largest to date. This in-person survey of over 43,000 randomly selected adults throughout the United States estimated the lifetime prevalence rate of pathological gambling at 0.4%.

Comorbidity of gambling and substance use disorders

These national surveys also examined the associations between pathological gambling and other psychiatric conditions. In the National Gambling Impact Study, Gerstein et al. (1999) found that 9.9% of those with lifetime pathological gambling also had a lifetime diagnosis of alcohol dependence, compared with 1.1% of non-gamblers. Welte et al. (2001) noted that an even higher percentage of lifetime pathological gamblers (25%) had current alcohol dependence, compared with 1.4% of non-gamblers. Similarly, the NESARC study (Petry et al., 2005) reported alcohol dependence was 5 times higher in pathological gamblers than non-pathological gamblers. Beyond alcohol dependence, Petry et al. (2005) found that pathological gambling increased the odds of an illicit drug use disorder by 4.4 fold, with 38.1% of lifetime pathological gamblers having one or more illicit substance use disorder, compared with 8.8% of non-gamblers. Thus, these three nationally representative epidemiology studies found strong evidence for an association between pathological gambling and substance use disorders.

High rates of comorbidity are noted in treatment seeking samples as well. Shaffer et al.'s (1999) meta-analysis provided estimates of rates of pathological gambling among substance abusers. In 18 surveys of adults in treatment for substance use disorders, lifetime rates of pathological gambling were estimated at 14%, significantly higher than the 0.4-2.0% rate of lifetime pathological gambling in general population surveys (Gerstein et al., 1999; Petry et al., 2005; Welte et al., 2001). Several more recent studies have reported similar proportions, with generally 10-13% of substance-dependent treatment-seeking individuals also meeting diagnostic criteria for pathological gambling (e.g., Cunningham-Williams, Cottler, Compton, Spitznagel, & Ben-Abdallah, 2000; Langenbucher, Bavly, Labouvie, Sanjuan, & Martin, 2001; Toneatto & Brennan, 2002). Likewise, individuals seeking treatment for pathological gambling either through Gamblers Anonymous (GA) or through a professional treatment provider are more likely to meet the diagnostic criteria for a substance use disorder than the population at large (Ibanez et al., 2001; Ladd & Petry, 2003; Maccallum & Blaszczynski, 2002; Specker, Carlson, Edmonson, & Johnson, 1996). Thus, substantial evidence, and no contradictory data, indicates that substance use and gambling disorders co-occur. One explanation for the co-occurrence of these disorders is that both conditions may be manifestations of an underlying disorder of impulse control.

Personality measures of impulsivity in disordered gamblers and substance abusers

Longitudinal studies identify impulsivity in children as a risk factor for later development of substance abuse and gambling problems (Dawes, Tarter, & Kirisci, 1997; Vitaro, Arseneault, & Tremblay, 1997, 1999; White et al., 1994), and cross-sectional studies show levels of impulsiveness are associated with substance use and abuse, as well as gambling, in college students (Jaffe & Archer, 1987). Numerous cross-sectional studies demonstrate that substance-dependent patients score higher than controls on personality inventories of impulsivity (Allen, Moeller, Rhoades, & Cherek, 1998; Chalmers, Olenick, & Stein, 1993; Cookson, 1994; Eisen, Youngman, Grob, & Dill, 1992; McCormick, Taber, Kruedelbach, & Russo, 1987; Patton, Stanford, & Barratt, 1995; Rosenthal, Edwards, Ackerman, Knott, & Rosenthal, 1990; Sher & Trull, 1994). Although pathological gambling is classified as a disorder of impulse control, the relation between impulsivity and this disorder is mixed. While some research finds high levels of impulsivity on standardized personality measures in pathological gamblers (Blaszczynski, Steel, & McConaghy, 1997; Carlton & Manowitz, 1994; McCormick et al., 1987; Steel & Blaszczynski, 1998), others have reported either no difference or even lower scores on personality scales assessing impulsivity and related traits (Allcock & Grace, 1988; Blaszczynski, McConaghy, & Frankova, 1990; Blaszczynski, Wilson, & McConaghy, 1986; Dickerson, Hinchy, & Fabre, 1987). These discrepancies might be expected if impulsivity is correlated with substance-use disorders but not pathological gambling. Because up to 50% of pathological gamblers have a history of drug or alcohol use disorders (Petry et al., 2005), those studies reporting a relation between impulsivity and pathological gambling may simply have drawn a larger sample of substance-dependent gamblers than other studies. Failure to report drug use histories makes it difficult to assess this hypothesis with existing data.

Another possible explanation for the discrepant findings across studies is that impulsiveness is a multi-dimensional construct (Gerbing, Ahadi, & Patton, 1987) which includes orientation toward the present, diminished ability to delay gratification, behavioral disinhibition, risk taking, sensation seeking, boredom proneness, reward sensitivity, hedonism, and poor planning. Some types of impulsiveness may be characteristic of substance use disorders, such as sensation seeking, while other aspects may be more closely related to pathological gambling, such as sensitivity to probabilistic rewards. Other aspects of impulsiveness may be representative of both disorders, such as present orientation, disinihibition, and poor planning (e.g., Vitaro et al., 1999). To date, sufficient data are not available examining these multiple aspects of impulsivity in pathological gamblers both with and without substance use problems.

The use of behavioral tasks to assess impulsivity may have some benefits over personality inventories in uncovering the nature of impulsivity and its relation to various other disorders. Compared to personality questionnaires, behavioral tasks may serve as more construct-relevant indicators of impulsivity. Below, we describe some behavioral measures of impulsivity that have been examined in pathological gamblers, both with and without substance use disorders.

Iowa Gambling Task

One specific aspect of impulsiveness that can be measured behaviorally is the inability to tolerate long delays to reinforcer presentation, or preference for smaller more immediate rewards over larger but more delayed rewards (Rachlin & Green, 1972). Ainslie (1975) extended this behavioral definition of impulsivity to include preferences for small more immediate rewards at the expense of large delayed losses. This definition seems to characterize both substance abuse and pathological gambling. The choice to use drugs or gamble excessively may produce immediate pleasurable sensations or excitement but these most often come at the expense of substantial long-term deterioration in legal, financial and social status.

Bechara, Damasio, Damasio, and Anderson (1994) and Bechara, Damasio, Tranel, and Damasio (1997) developed a task that appears to capture some of Ainslie's (1975) definition of impulsiveness and has surface similarities to the long-term losses associated with heavy substance use and gambling. In the Iowa Gambling Task (IGT) subjects select cards from four different decks ranging in probability and magnitude of gains and losses. Drawing from two of the decks periodically yields a large gain (e.g., $100) but continuing to choose these decks results in a long-term net loss because of occasional substantial losses (e.g., $150-1250). Selecting these decks may reflect hypersensivity to large gains and/or insensitivity to large losses— two characteristics of addictive disorders. Cards drawn from the other two decks provide smaller gains (e.g., $50) but result in a log-term net gain because the low-probability losses are more modest (e.g., $25-250). A number of substance abusing populations make more impulsive choices on this task than controls, including heroin (Petry, Bickel, & Arnett, 1998), alcohol (Dom, De Wilde, Hulstijn, van den Brink, & Sabbe, 2006), and poly-drug dependent individuals (Verdejo-Garcia, Perales, & Perez-Garcia, 2007).

Several groups of investigators have administered the IGT with disordered gamblers. In the first of these studies, Petry (2001c) evaluated performance on this task of disordered gambling substance abusers (n=27), non-disordered gambling substance abusers (n=63), and non-disordered gambling/non-substance abusing controls (n=21). In addition to the IGT, subjects completed other measures including the Eysenck and Barratt scales— two commonly used personality measures of impulsivity. Principal components analyses revealed that the personality inventories measured three distinct aspects of impulsiveness: impulse control, novelty seeking, and time orientation. Choices on the IGT tapped a different dimension of impulsivity and loaded on a unique factor.

In this study (Petry, 2001c), and congruent with other research (Dom et al., 2006; Petry et al., 1998; Verdejo-Garcia et al., 2007), substance abusers, regardless of gambling histories, were more likely than controls to select cards from decks containing large gains but resulting in net losses (i.e., disadvantageous decks). Disordered gambling substance abusers selected cards from these disadvantageous decks significantly more often than their non-disordered gambling counterparts. The presence of disordered gambling and substance abuse had an additive effect on scores on the personality inventories of impulsivity as well. These effects may represent a hypersensitivity to reward on the part of those with addictive disorders as they preferred the decks with higher immediate payoff. They may also reflect a relative insensitivity to punishment as these high payoff decks were associated with greater overall losses.

Pathological gamblers without drug use disorders were not evaluated in the Petry (2001c) study, and some have suggested they may constitute a distinct population from those with substance use disorders (Blaszczynski & Nower, 2003). Recently, Goudriaan, Oosterlaan, de Beurs, & van den Brink (2006) reported that pathological gamblers with no history of drug or alcohol dependence chose from the IGT's disadvantageous decks significantly more often than non-disordered gambling controls. Patholocial gamblers also had a reduced skin conductance response prior to selecting cards from the disadvantageous decks, and they had a lower heart rate before selecting a card from an advantageous deck with compared with controls. After a card was selected and the winning or losing consequence revealed, all participants' heart rates decreased following a loss, but only controls evidenced an increased heart rate after drawing a winning card. The authors interpreted these differences as a reduction in reward sensitivity among the pathological gamblers.

Delay discounting

As noted above, and throughout this book, an important component of impulsivity is preference for a smaller-sooner over a larger-later reward Such a preference suggests that the value of the larger-later reward is subjectively discounted because of the delay to its delivery. In human studies measuring the discounting of delayed rewards, participants choose between a larger-later reward and an immediate reward, the magnitude of which is adjusted until the participant is indifferent between the two. At the indifference point, the magnitude of the smaller-sooner reward provides the subjective value of the larger-later reward. When indifference points are determined across a range of delay intervals, a curve can be plotted, describing the rate at which the value of a reward decreases with increasing delays to its receipt.

A hyperbolic function generally provides a good fit of these indifference points and is an easily interpreted description of delay discounting (Mazur, 1987):

$$V_d = A / (1 + kd) \qquad (1)$$

In this equation, V_d is the present value of the delayed reward (indifference point), A is the amount of the delayed reward, d is the delay duration, and k is an empirically-derived constant proportional to the degree of delay discounting.

The rate at which substance abusers discount delayed outcomes has been extensively studied and is covered more comprehensively by Yi, Mitchell, and Bickel in their chapter in this volume. Here it is important to note only that substance abusers discount delayed rewards more rapidly than controls. For example, Madden, Petry, Badger, and Bickel (1997), Bickel, Odum, and Madden (1999), and Vuchinich and Simpson (1998) found that heroin addicts, cigarette smokers, and heavy drinkers, respectively, discounted hypothetical amounts of money more rapidly than controls. Similar findings have been reported when there is a chance that one of the rewards selected will actually be delivered (e.g., Kirby, Petry, & Bickel, 1999).

A number of studies have examined the relation between delay discounting and pathological gambling. The first of these studies produced evidence suggesting that pathological gambling and substance use disorders have additive effects on rate of delay discounting (i.e., the value of *k* in Equation 1). Petry and Casarella (1999) investigated delay discounting of hypothetical monetary rewards among disordered gambling substance abusers, substance abusers with no history of gambling problems, and controls. Groups with one or more addictive disorders discounted the delayed rewards significantly more than the controls. Furthermore, substance abusers with gambling problems discounted delayed rewards at about 3 times the rates of substance abusers without gambling problems, and at nearly 10 times the rate of controls.

More recent studies have examined rates of delay discounting in disordered gamblers and non-gambling control groups. Two of these studies reported that disordered gamblers discount the value of delayed hypothetical monetary rewards at a higher rate than a non-gambling control group (Dixon, Marley, & Jacobs, 2003; MacKillop, Anderson, Castelda, Mattson, & Donovick, 2006) while one study reported no difference (Holt, Green, & Myerson, 2003). The reasons behind these discrepant findings are unclear. Dixon et al. asked their gambling group to complete the delay discounting task in an off track betting parlor, and their later research (Dixon, Jacobs, & Sanders, 2006) suggests this setting may increase rates of delay discounting when compared with the non-gambling settings in which control data were collected in their earlier study. To determine if disordered gamblers discount delay rewards more than non-gamblers when data are collected in comparable settings, we compared discounting measures in the two Dixon et al. studies and found that even when disordered gamblers completed the discounting task in a non-gambling setting, they discounted delayed monetary rewards at a significantly higher rate than non-gambling controls (one-way ANOVA, $p < .001$).

A shortcoming of each of these studies is that none of them reported prevalence of substance use disorders in their samples. This is concerning because of the high rates of comorbidity outlined earlier, and the known association between substance use disorders and delay discounting. Thus, across-study differences in prevalence of substance use disorders may underlie the discontinuity between some of these studies. For example, if disordered gamblers that Dixon et al. (2003) recruited from a gambling facility had high rates of drugs or alcohol problems, then it might help to explain why these gamblers discounted delayed rewards at such a high rate, despite having the lowest mean scores of any other reviewed study on the South Oaks Gambling Screen (SOGS; Lesieur & Blume, 1987), a common measure of gambling problems.

Other studies have examined the relation between delay discounting and pathological gambling while controlling for substance use status. For example, Petry (2001b) examined discounting rates in individuals with a primary diagnosis of pathological gambling separated into groups with and without substance use problems. Discounting rates were compared between the two groups of gamblers, as well as to a control group. As in the Petry and Casarella (1999) study, both groups of pathological gamblers evidenced higher delay discounting rates than controls, and gamblers with substance use disorders had the highest discounting rates. Strikingly, these two studies, comprised of entirely different patient populations, had nearly identical *k* values for individuals with the dual addictive disorders, whether their primary problem was pathological gambling or substance use. Pathological gamblers with a history of substance use disorders had median *k* values of 0.29 compared with 0.26 for the group with a substance use diagnosis who were identified as also having significant gambling problems. Likewise, median *k* values obtained from participants with one disorder (either pathological gambling or substance use) were almost identical (0.06 for 'pure' pathological gamblers and 0.05 for 'pure' substance abusers).

Together, these data lend some credence to the hypothesis that pathological gambling and substance use disorders lie along a continuum of delay discounting. That is, moderately high rates of discounting may be a risk factor for developing a problem with either drugs or gambling. Still higher rates of discounting might be expected to put an individual at risk of developing multiple impulse control problems such as pathological gambling and substance abuse.

Alessi and Petry (2003) re-analyzed data from the 62 treatment-seeking pathological gamblers who participated in the Petry and Cararella (1999) and Petry (2001b) studies. They evaluated the hypothesis that degree of delay discounting is associated with severity of gambling disorder as measured by the SOGS. In a regression analysis, the best predictor of delay discounting, even after controlling for demographics and substance use, was SOGS scores, which accounted for 12% of the variance in *k* values. Similar findings were reported by MacKillop et al. (2006) who reported significant or near significant ($p = .06$) differences in *k* values in groups separated by gambling severity. These results suggest that severity of gambling problems is closely linked with delay discounting.

The Role of Delay Discounting in Pathological Gambling

A number of researchers have hypothesized how delay discounting rates might be predictive of substance use disorders (Yi et al., and Carroll, Anker, Newman, & Perry; this volume), and some of these proposals may be equally applicable to pathological gambling. For example, if the delayed aversive outcomes typically associated with pathological gambling (e.g., loss of income, deterioration of social relations, and legal difficulties) are substantially discounted, then their diminished negative value may fail to deter gambling in much the same way that the long-term consequences of cigarette smoking or drug use fail to deter these behaviors in drug-dependent individuals (Odum, Madden, Badger, & Bickel, 2000; Odum, Madden, & Bickel, 2002).

As noted in Chapter 1 of this volume, the hyperbolic shape of the delay-discounting function (Equation 1) predicts preference reversals between self-control and impulsive choices. That is, tendencies toward self-control (e.g., going to the movies instead of the casino with the intention of having enough money to pay the rent at the end of the month) give way to impulsive choices as the benefits of these choices become more immediately available (e.g., while driving past the casino on the way to the theater). With the immediate thrills of gambling only moments away, their value far outweighs the discounted value of having enough money to pay rent at the end of the month. Because, according to Equation 1, higher rates of delay discounting increase the probability of preference reversals, pathological gamblers' delay intolerance would appear to make their road to recovery a difficult journey filled with relapses, despite their best intentions.

A related account of the importance of delay discounting rate in the origin of pathological gambling is Rachlin's (1990, 2000) *string theory*. According to this theory, gamblers take account of their wins and losses following wins. Sometimes wins occur following the first bet, and because they are immediate, they retain their full reward value. Other wins follow a string of losses such that the net income at the end of the string is a negative value. If these negative value events were only modestly discounted, they would deter gambling. However, high discounting rates characteristic of pathological gamblers render the delayed net loss inert. That is, when gamblers take a mental accounting of the sums of immediate undiscounted gains and delayed (and discounted) losses, the net value of gambling is substantially positive. In contrast, individuals who discount delayed outcomes at a lower rate are more likely to be affected by the net loss of funds following the long strings of losses leading up to a win. Their mental accounting may be closer to the reality that gambling is a net loss activity and this may be sufficient to keep them out of gambling settings altogether.

A final hypothesis is that the shape of the hyperbolic delay discounting function (i.e., Equation 1) predisposes individuals with high rates of discounting to gambling rewards (Madden, Ewan, & Lagorio, 2007). This account, illustrated in Figure 1, focuses on the unpredictable time intervals separating gambling wins. Although the time to the next gambling win is unpredictable and can fall anywhere along the x-axes of Figure 1, for the sake of simplicity we have plotted just five of these unpredictably delayed monetary rewards in each panel. The discounted values of these unpredictably delayed rewards fall along a hyperbolic discounting curve. In the top panel the curve was plotted using Equation 1 where the k-value was set equal to the median reported for non-drug-abusing pathological gamblers by Petry (2001b): $k = 0.07$. The lower curve was drawn using a k-value typical of non-gambling, non-drug-abusing humans ($k = 0.003$; see Kirby, 1997). The square data point in each panel corresponds to the discounted value of a reward of equivalent magnitude delivered after a predictable delay— a delay equivalent to the average of the five unpredictable delays.

----- Insert Figure 1 About Here -----

Mazur (1989) demonstrated with pigeons that the value of an unpredictably delayed reward was given by the following variant of Equation 1:

$$V_u = \sum_{i=1}^{n} P_i \left(\frac{A}{1 + kD_i} \right) \tag{2}$$

where V_u is the discounted value of unpredictably delayed rewards, D_i, each obtained at probability P. Because all of the delays shown in Figure 1 are equally probable, Equation 2 holds that the value of the five unpredictably delayed rewards is equal to the average discounted value of these rewards. This average is shown as the horizontal dashed line in each panel of Figure 1. Because of the deeply bowed shape of the pathological gamblers' hyperbolic function, the average discounted value of the unpredictably delayed gambling rewards is 133% greater than the value of the same reward delivered after a predictable delay. Thus, Equation 1 predicts that individuals who discount delayed rewards at a high rate will view gambling rewards as substantially more valuable than the benefits of waiting a predictable amount of time to obtain the same reward (e.g., two weeks until the next paycheck). By contrast, the non-gamblers' lower discounting rate renders their function approximately linear. For these individuals, the average of the unpredictably delayed rewards is only 2.5% greater than the predictable reward. We might, therefore, expect gambling to be an enjoyable activity but one that is more easily forgone.

----- Insert Figure 2 About Here -----

Figure 2 illustrates for a wide range of delay discounting rates (*k*-values) the percentage increase in value obtained by choosing the unpredictably delayed gambling-reward over the same reward obtained after a predictable delay. For the delay range shown in Figure 1 and at *k*-values of 0.03 to 0.43 (the range reported for pathological gamblers by Alessi & Petry, 2003) the individual obtains a 55-820% added subjective reward value by choosing to gamble. Thus, Equation 2 predicts that, all else being equal, discounting rates are predictive of the decision to gamble and those with higher discounting rates are at greater risk of developing pathological gambling.

Several findings are consistent with this prediction. For example, pigeons tend to have very high discounting rates (usually $k = 1.0$) and this species is known to strongly prefer unpredictably over predictably delayed food rewards (e.g., Mazur, 2007). Pigeons are also known to prefer the contingencies of reinforcement arranged by slot machines over predictable amounts of work to obtain food rewards (e.g., Madden & Hartman, 2006). Equation 2, which is critical to the hypothesized relation between delay discounting rate and gambling, has been empirically verified with animal subjects (e.g., Mazur, 1991; Mazur & Romano, 1992) but has yet to be tested with humans; nevertheless, substantial evidence indicates that Equation 1 well describes delay discounting in humans (see Green & Myerson, 2004). An important test of Equation 2 will determine if higher rates of delay discounting are predictive of stronger preferences for unpredictably delayed rewards and slot machine contingencies of reinforcement (i.e., random-ratio schedules). This research is currently underway in our laboratory.

Probability discounting

Perhaps of even more relevance to the study of pathological gambling is probability discounting. Probability discounting refers to the devaluing of a chance outcome, and it is typically studied in humans by presenting participants with a series of choices between some amount of guaranteed money (real or hypothetical) and a larger amount of money with varying probabilities of receipt. For example, participants may choose between \$20 guaranteed and a 40% chance of receiving \$40. Rachlin, Raineri and Cross (1991) proposed a hyperbolic equation that fits probabilistic discounting, in which Θ refers to the odds against, (1-*p*)/*p*, receiving the probabilistic reward:

$$V = \frac{A}{1 + h\Theta} \tag{3}$$

As in the delay discounting equation, this equation contains a single free parameter, *h*, which quantifies probability discounting rate. As the free-parameter value increases, the subjective value of the outcome is more steeply discounted.

One might predict that probabilistic monetary outcomes would be discounted less in those who gamble more. That is, probabilistic rewards should retain more of their subjective value in individuals prone toward gambling than for non-disordered gamblers. The single published study that has examined this hypothesis found that college student disordered gamblers discounted probabilistic rewards less steeply than non-disordered gambling college students (Holt et al., 2003). Indices of delay discounting and probabilistic discounting were not significantly correlated, suggesting that the two indices of discounting measured unique constructs.

We recently examined probability discounting in 19 male treatment-seeking pathological gamblers (mean SOGS score = 13.2 $\pm$3.2). We included only those pathological gamblers without a history of substance use problems to control for any putative effect of substance use on probability discounting. We compared probability discounting between these pathological gamblers and a group of 20 non-gambling, non-drug-using men matched on age, education, and income. Consistent with the study which used a less severe population of disordered gamblers (Holt et al., 2003), we found that pathological gamblers discounted probabilistic monetary wins significantly less than controls (Madden, Petry, & Johnson, under review). Unfortunately, across-study comparison of probability discounting values was impossible because the two studies arranged different reward amounts and probabilities and used different methods of quantifying probability discounting rates. Given the small number of studies that have examined probability discounting in disordered gambling populations, strong statements about the role of this process in gambling decisions must await further empirical investigations.

Summary and future directions

To summarize, most of the available data suggest pathological gambling is associated with steep discounting of delayed rewards and less steep discounting of probabilistic rewards. Some evidence suggests that more pronounced between-group differences in delay discounting are correlated with gambling severity and this outcome is predicted by Rachlin's (2000) string theory of gambling and by Equation 2 (Madden et al., 2007). As noted throughout this volume, substance use disorders are associated with higher rates of delay discounting and individuals with dual addictive disorders (pathological gambling and substance use disorders) have increased delay discounting compared to those with only one of the disorders. While this relationship has not been examined with respect to probability discounting, most of the available data suggest that the two forms of discounting are not closely associated and likely reflect different constructs of impulsivity (see Green & Myerson, 2004).

Importantly, the Iowa Gambling Task and delay and probability discounting measures may be helpful in elucidating the relation between impulsivity/discounting and the development of clinical disorders. One model for this work is Walter Mischel's longitudinal studies which suggested that the duration a 4-5 year old child would wait for a large reward was predictive of social and academic competencies over 10 years later (Mischel, Shoda, & Peake, 1988; Shoda, Mischel, & Peake, 1990). Longitudinal studies examining the relation between impulsivity and disordered gambling are thus far quite limited. One study (Vitaro et al., 1999) found that impulsivity, measured by a self-report questionnaire and a card-sorting task in early adolescence, predicted development of disordered gambling at age 17. Because questionnaire measures of impulsivity do not reliably correlate with delay discounting (e.g., Monterosso, Ehrman, Napier, O'Brien, & Childress, 2001), the role of early delay gratification abilities and subsequent development of disordered gambling remains an unstudied relation.

Tolerance for delays can be assessed in preschool children (Mischel & Metzner, 1962), and perhaps even infants (Darcheville, Riviere, & Wearden, 1993). Therefore, the means for conducting longitudinal studies focused on predicting addictive behaviors are available and may prove an important area of future research.

To date, the study of the relation between discounting and addictive behaviors has largely taken a trait approach (i.e., documenting the correlation between discounting and the variety of addictive disorders), but there is also evidence that experiential variables can affect discounting rates (see Odum & Baumann, this volume). Some researchers have speculated that high rates of delay discounting may be adaptive in environments in which delayed rewards are unlikely to be available after the delay (Stevens & Stephens, this volume; Williams & Dayan, 2005). Thus a lifetime of learning not to trust others to deliver what they promise in the future may play a role in delay discounting rates (Takahashi, Ikeda, & Hasegawa, 2007), and the tendency to take whatever is immediately available may be important in the decision to gamble or use drugs (Reynolds, Patak, & Shroff, 2007).

Consistent with a role of learning in discounting, Mischel's work suggests a number of cognitive strategies may help children better tolerate delays to a larger reward (Mischel, Shoda, & Rodriguez, 1989). Research conducted with animals likewise suggests that long-lasting patterns of delay tolerance can be taught even without mediating verbal strategies (e.g., Mazur &

Logue, 1978). That substance users might acquire self-control skills leading up to a successful quit attempt is supported to some extent by data suggesting that currently abstinent cigarette smokers, intravenous drug users, and alcoholics have lower delay discounting rates compared to active users (Bickel et al., 1999; Bretteville-Jensen, 1999; Petry, 2001a). Further evidence for this comes from two studies demonstrating that pre-quit delay discounting rates are predictive of success in interventions designed to promote cigarette abstinence (Dallery & Raiff, 2007; Yoon, Higgins, Heil, Sugarbaker, Thomas, & Badger 2007). The same hypothesis might be forwarded about the correlation between recent gambling frequency and rates of delay discounting. That is, acquired delay tolerance skills leading up to a quit attempt might be predictive of success.

Of course, an equally viable trait-based interpretation of these findings is that some individuals with lower discounting rates will, for unrelated reasons, develop a substance use or gambling disorder and their lower rate of discounting enhances their chances of a successful quit attempt. Whether more adaptive delay or probability discounting rates can be systematically taught, and the effects of such learning on clinical outcomes in pathological gambling, are important topics for future research.

A better understanding of how individuals discount rewards delayed in time and probabilistic outcomes may also serve as a theoretical construct for understanding pathological gambling. A wide literature demonstrates that small rewards are discounted more rapidly than large rewards (Kirby et al., 1999; Myerson & Green, 1995; Raineri & Rachlin, 1993). By the nature of gambling, the value of an individual bet is substantially lower than the value of a win, and therefore may be discounted much more rapidly. In other words, a $1 bet may lose half its subjective value in a matter of minutes, while a $1000 win will not lose half its subjective value for 1 year or more. The studies by Petry and Cassarella (1999), Petry, (2001a) and Holt et al.

(2003) all found disordered gamblers had greater discounting for smaller than larger monetary rewards. As Rachlin (1990) proposes, gamblers bet in "strings," in which subjective losses are not considered until the next win occurs. Within each string, the cumulative effects of previous bets may be greatly devalued due to the rapid discounting of these relatively small monetary amounts.

Also of potential importance to Rachlin's (1990) string theory of gambling is how delayed losses are discounted. Some studies (Goudriaan, Oosterlaan, de Beurs, & van den Brink, 2005; Goudriaan et al., 2006; Petry, 2001b; Petry et al., 1998) suggest that substance abusers and pathological gamblers are relatively insensitive to delayed losses. This sign effect, that outcomes that constitute a gain are discounted at higher rates than outcomes that constitute a loss, has not been widely investigated in substance abusing or pathological gambling populations. However, Baker, Johnson and Bickel (2003) found that current smokers discounted both gains and losses more rapidly than never smokers. If pathological gamblers discount delayed losses at a particularly high rate, string theory predicts this will make them all the more likely to gamble because the negative value of long strings of losses followed by a single win are so substantially discounted. Future examination of the sign effect in pathological gamblers, along with individuals with substance use disorders, is needed to better understand these associations.

The study of impulsivity, delay discounting, and probability discounting and their relation to disordered gambling is in its infancy. Important tests of how these processes might affect the decision to gamble have yet to be conducted. Should a particular type of discounting be shown to play an important causal role in pathological gambling, then new avenues of research investigating biological, pharmacological, and learning processes may help to establish effective interventions for this disorder.

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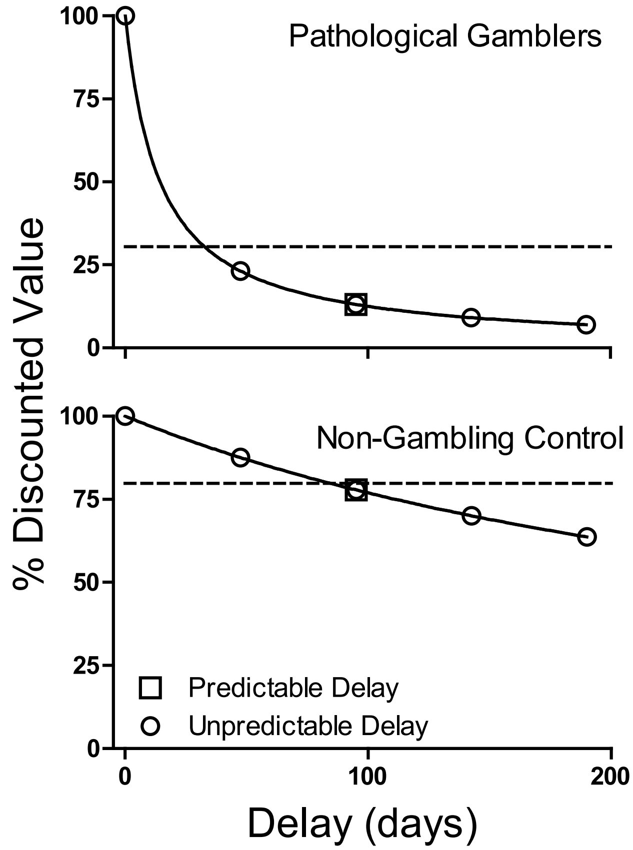

Figure 1. Hyperbolic discounting functions drawn using *k*-values reported for non-drug-abusing pathological gamblers and non-gambling non-drug abusing controls. The average value of the unpredictably delayed (gambling-like) rewards is given by the dashed line in each panel. For pathological gamblers, the discounted value of gambling like rewards exceeds that of the predictably delayed reward. The same is not true of controls with their lower rate of delay discounting.

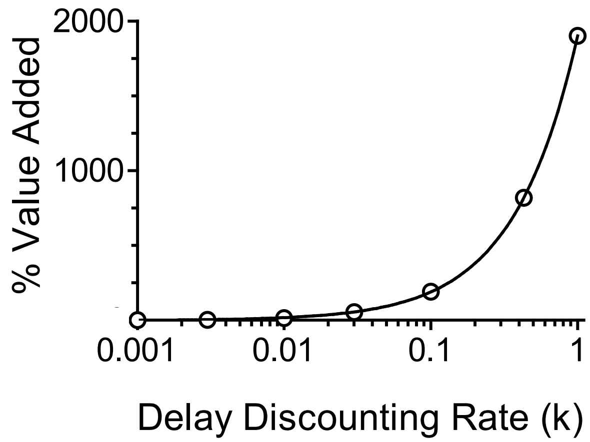

Figure 2. Predicted discounted value-added by selecting unpredictably delayed over predictably delayed rewards. Value added is shown as a function of the rate at which delayed rewards are discounted.

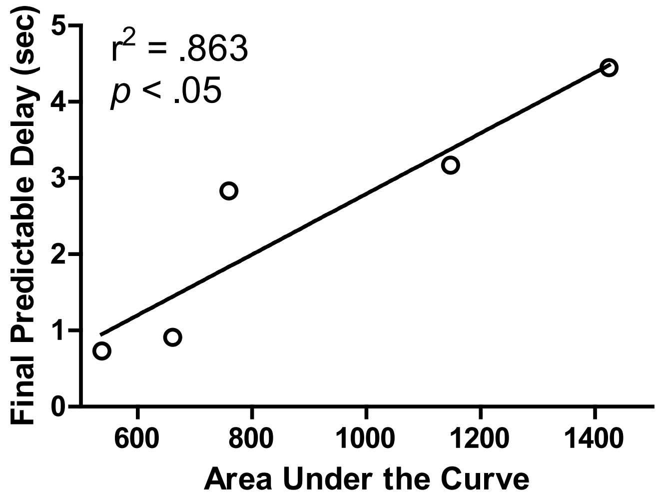

Figure 3. Correlation between area under the choice curve (lower values indicate greater delay discounting) and the final predictable delay (lower values indicated greater preference for unpredictably delayed rewards).