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THE ATTRACTION OF GAMBLING

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If a repeated gamble is subjectively structured into units each consisting of a string of consecutive losses followed by a single win, longer strings will necessarily be less valuable. Longer, less valuable strings will be discounted by delay more than will shorter, more valuable strings. This implies that the whole gamble's expected, delay-discounted value will increase as delay discounting increases. With this restructuring, even games of (objectively) negative expected value, such as those at casinos, may be subjectively positive. The steeper the delay discounting, the greater the subjective value of the gamble (over normal ranges of discounting steepness). Frequent gamblers, who value gambles highly, would thus be expected to discount delayed rewards more steeply than would nongamblers.

Key words: addiction, delay discounting, gambling, patterning of behavior, probability discounting, restructuring, variable-ratio schedules

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Even strictly economic models of addiction (e.g., Becker & Murphy, 1988) presume the existence of a commodity that addicts consume at an unusually high rate. An alcohol addict consumes alcohol; if wine is preferred but unavailable, whiskey or beer will do. If a person has an unusually strong preference for immediate over delayed consumption of some commodity, the person would be unusually susceptible to addiction to that commodity. But in the case of gambling there is no immediately consumable commodity to be addicted to. Winning money is not like drinking alcohol; alcohol is a primary reinforcer while winning money depends on potential exchange for its value. While a pathological gambler may also be a "big spender," spending in no way substitutes for gambling; it cannot be said that gamblers consume money in the way alcoholics consume alcohol. Pathological gamblers do seem to seek risk, but risk is not a commodity so much as a pattern of interaction between behavior and environment. Nevertheless pathological gambling has many properties of an addiction. Just as heroin, alcohol, and smoking addicts discount delayed rewards more steeply than do nonaddicts (Odum, 2011), so pathological gamblers discount delayed rewards more steeply than do nongamblers (Alessi & Petry, 2003; Dixon, Marley, & Jacobs, 2003; Petry, 2001; Petry & Madden, 2010; Reynolds, 2006). It is not clear why this should be the case. When there is a delay between a bet and its outcome (as at a racetrack) one might think that a person with a steep delay discount function would prefer the lesser amount of money that they have (zero delay) to the larger but delayed amount that they might win. How then might an abnormally high valuation of immediate over delayed rewards result in an abnormally high preference for gambles over sure things? This article's purpose is to answer that question.

Just as delay decreases reward value, so does uncertainty. The choice between certain and probabilistic rewards parallels the choice between immediate and delayed rewards. However, behavioral as well as cognitive studies of individual choice between small-certain rewards and larger probabilistic rewards (e.g., Kahneman & Tversky, 1979; Rachlin, Raineri & Cross, 1991) often find risk avoidance (i.e., discounting of probabilistic rewards below their expected value). They generally do not find the risk-seeking that would explain why a person would choose a gamble over a nongamble. Myerson, Green, Hanson, Holt, and Estle (2003) did find that college students who said they gambled discounted probabilistic rewards significantly *less* steeply than students who

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said they did not gamble. The (nonpathological) college-student gamblers nevertheless discounted probabilistic rewards (over much of the range of probabilities tested) below their expected value. Any single gamble, even one of zero or positive expected value, involves taking a risk. One might expect gamblers to take such risks. However, the gamblers, in this study, although less risk-averse than nongamblers, still frequently avoided risk in gambles with both zero and positive expected values.

A problem with basing a theory of gambling on probability discounting is that the fundamental unit of a probability-discounting test is a single one-shot choice between a certain reward and a probabilistic reward. As stated above, people typically avoid risk when choosing among one-shot alternatives with positive outcomes. Keren and Wagenaar (1987) found, however, that preferences reversed (people preferred risk) with the same alternative to be repeated ten times. One-shot laboratory gambles thus differ in an important way from the sequences of bets common among gamblers.

The present theory takes as its fundamental behavioral unit, not a one-shot choice with a set of possible outcomes, but a series of choices with a fixed outcome. Once gambling is viewed as a series of events in time (few gamblers bet once and quit), the delay to an outcome assumes importance (Rachlin, Castrogiovanni, & Cross, 1987; Rachlin, Logue, Gibbon, & Frankel, 1986). A theory of the attractiveness of gambling should account for the effect of delay on choice in an extended series of gambles rather than in a one-shot bet.

THE STRUCTURE OF A GAMBLE

According to Skinner (1953) gambling has the structure of a variable-ratio (VR) schedule of reinforcement—a series of operant strings all culminating in the same event—positive reinforcement. Mowrer and Jones (1943), studying lever presses of rats, found that the average number of responses required by a variable-ratio (VR) schedule of reinforcement was reflected in the number of responses emitted during extinction. For instance, during extinction after a VR5 schedule, a rat would emit an equal number of response units in extinction as after a VR10 schedule, but half the number of actual lever presses.[1]

The relevant probabilistic element in such a view is not the outcome of a given act (win or lose) but the length of the string of losses culminating in a win. For a given probability (p) of a gamble the average number of operants in a string is $1/p$ [the VR, or random-ratio (RR), value]. The key assumption of the present theory is that the fundamental behavioral unit is the string. An individual loss has no negative valence at the moment it occurs; the individual loss is a subunit of a string, and only the string has value. The value of an outcome is therefore a function of (a) the probability of occurrence of a given string, (b) the delay embodied by the string, and (c) the net amount of the reward (the win minus the losses that led to the win). Another way of putting this assumption is that the gambler's accounting system (Thaler, 1981) is such that wins and losses are added up only after a win (at the end of each string), and then the system is reset. Consider, for instance, a string of $1 bets with an individual probability of winning equal to .25, paying out $3 on a win. The expected value (*EV*) of this bet ($3 x ¼ - $1 x ¾) is zero. Table 1 shows the 25 most probable strings and indicates their probabilities and individual expected values. The sum of the expected values of the 25 strings is +2¢. Of course, since the bet is of zero expected value, the rest of the negative strings, from 26 to infinity, would exactly counterbalance that quantity, with an expected value of -2¢. Let us ignore these low probability strings (probability <.0003) for the present.[2]

The important point to note about Table 1 is that all of the positive strings are short and all of the negative strings are long. For the person about to gamble, all of the positive outcomes will occur soon while all of the negative outcomes will occur later; the better the outcome, the sooner it will occur. This is a necessary consequence of the fact that the strings are organized as losses followed by a win.

[1] We are concerned here with the relation between whole units and reinforcement. The question, what generates and maintains response units and patterns, is beyond the scope of the present article (see Locey & Rachlin, 2013 for evidence that extended response sequences may be reinforced as units).

[2] Table 1 illustrates a gamble of zero expected value. For corresponding gambles of negative expected value, such as at casinos, the sum of the expected values of the strings would be negative.

Table 1

Expected and discounted values of the 25 likeliest strings in a \$1 gamble with 0.25 chance of winning \$3 (l = \$1; p = 25; w = \$3)

# of Losses	String	Net Payoff (A_i)	Probability of String (p_i)	Expected Value of String $(EV)_i$	Discounted Value of String (V_i)
D_i		$W\text{-}(D_iL)$	$p(1\text{-}p)^{Di}$	A_ip_i	$\frac{(EV)_i}{1+kD_i}$
0	W	+3	0.25	0.75	0.75
1	LW	+2	0.19	0.38	0.19
2	LLW	+1	0.14	0.14	0.05
3	LLLW	0	0.11	0.00	0.00
4	LLLLW	−1	0.08	−0.08	−0.02
5	LLLLLW	−2	0.06	−0.12	−0.02
6	LLLLLLW	−3	0.04	−0.13	−0.02
7	LLLLLLLW	−4	0.03	−0.13	−0.02
8	LLLLLLLLW	−5	0.03	−0.13	−0.01
9	LLLLLLLLLW	−6	0.02	−0.11	−0.01
10	LLLLLLLLLLW	−7	0.01	−0.10	−0.01
11	–	−8	0.01	−0.08	−0.01
12	–	−9	0.01	−0.07	−0.01
13	–	−10	0.01	−0.06	0.00
14	–	−11	0.00	−0.05	0.00
15	–	−12	0.00	−0.04	0.00
16	–	−13	0.00	−0.03	0.00
17	–	−14	0.00	−0.03	0.00
18	–	−15	0.00	−0.02	0.00
19	–	−16	0.00	−0.02	0.00
20	–	−17	0.00	−0.01	0.00
21	–	−18	0.00	−0.01	0.00
22	–	−19	0.00	−0.01	0.00
23	–	−20	0.00	−0.01	0.00
24	–	−21	0.00	−0.01	0.00
25	–	−22	0.00	0.00	0.00
SUM				0.02	0.85

Note. The table lists the values for the 25 most likely strings of wins and losses in a gamble with a \$1 loss (L) and 0.25 chance of a \$3 win (W). The expected value for the bet is 0, but the discounted value (here calculated for simplicity with $k = 1$) is positive.

Research on humans (e.g., Loewenstein & Prelec, 1992; Rachlin, Raineri & Cross, 1991) and nonhumans (Mazur, 1987) indicates that a delayed outcome of a given amount (A) is discounted by the hyperbolic function:

$$V = \frac{A}{1 + kD} \tag{1}$$

where V is discounted value, D is delay to outcome, and k is a parameter reflecting steepness of delay discounting.[3]

[3] Empirical studies have found that the denominator (or a term in the denominator) is exponentiated by a constant somewhat less than 1 (Myerson et al., 2003). We ignore this exponent here. Its inclusion would not change any of the implications of the present theory.

Mazur (2001) found, with nonhuman subjects, that the discounted value of a set of n delayed rewards with different probabilities (V_n) could be expressed as the sum of the amounts, each discounted by its delay as given by Equation 1, each simply weighted by its probability (p_i). Equation 2 shows this discounted value:

$$V_n = \sum_{i=1}^{n} p_i \left(\frac{A_i}{1 + kD_i} \right) \tag{2}$$

The last column of Table 1 gives the discounted value of each string with (for simplicity's sake) $k = 1$. The sum of the discounted weighted values of all 25 strings, the subjective value of the gamble as a whole (V_n), is now +85¢. Because delay discounting acts more strongly on the more-delayed, net-loss strings than on the less-delayed, net gain strings, the subjective value of the (zero expected value) gamble is positive. The upshot of this organization of repeated gambles is that individual losses are valued less than individual wins, consistent with the findings of Zentall and Stagner (2011) and Killeen, Sanabria, and Dolgov (2009) with pigeons, and Molet et al. (2012) with humans. As Zentall and Stagner say (p. 1203), "…choice behaviour mimics human monetary gambling in which the infrequent occurrence of a stimulus signaling the winning event…is overemphasized and the more frequent occurrence of a stimulus signaling the losing event…is underemphasized, compared with the certain outcome associated with not gambling…" We now address this article's main question: Why do problem gamblers have higher *k*-values (discount delayed rewards more steeply) than do nongamblers?

Figure 1 shows subjective values of a series of zero expected-value gambles of different probabilities as a function of degree of delay discounting (k). Note that (over most of the range of *k*-values) the higher is k, the higher is the value of a given gamble; people with high *k*-values will value gambles more and thus tend to gamble more than will people with lower *k*-values. As delay discounting increases indefinitely ($k \to \infty$), all strings other than the first (at $D = 0$) will eventually be discounted to nothing and the subjective value of the gamble as a whole (the sum of the subjective values of all strings) will approach an asymptote equal to the value of the first (undelayed) string. For the gamble illustrated in Table 1, for instance, the asymptote would be at $+.750$.[4]

But what about the downward sloping part of the curve in Figure 1 with high k-values? According to the present model, the critical factor that gives positive value to gambles is the mode of response structuring and accounting—adding up wins and losses only after a string of bets culminating in a win, together with temporal discounting. What value should k realistically take for these strings? On the one

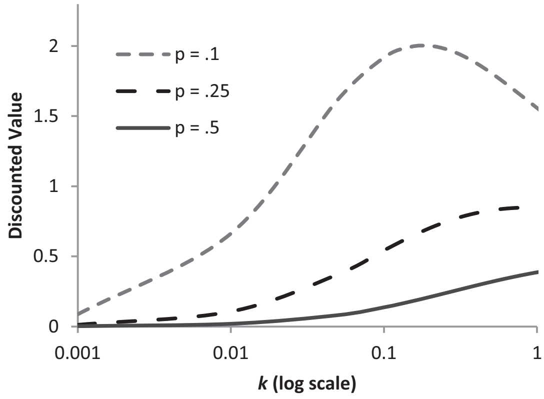

Fig. 1. Sums of discounted values for three zero-expected-value gambles, with $1 bet on each gamble, and differing probabilities of winning (p) as functions of the discounting parameter k. With expected-value at zero, the lower the probability, the higher the amount won, and the more it adds to the sum of the values of the discounted strings.

hand, the actual delays in a string of gambles are degrees of magnitude less than the months and years of delay used in obtaining human delay discount functions with hypothetical rewards (Odum, 2011). At a casino, intervals between wins would be measured in minutes rather than days (one hopes). On the other hand, while days and months of typical delay-discounting measures are presumably filled with everyday activities, at least some of which are pleasant, the strings of losses experienced by gamblers are unpleasant (as are periods between cigarettes for smokers or between drinks for alcoholics; see Johnson, Herrmann, & Johnson, 2015; Paglieri, 2013). Bickel, Odum, and Madden (1999) measuring in terms of months found *k*-values of about 0.0025 for nonsmokers choosing between immediate and delayed monetary rewards, and about 0.20 for smokers choosing between immediate and delayed cigarettes. The delays in the Bickel et al. study were measured in months. It is unlikely that a gambler will wait months, or even days between gambles—let us say rather hours, minutes, or seconds. To compare a gambler's *k*-values with Bickel et al.'s *k*-values we would have to divide the latter already fractional k's by the number of minutes in a month (43,200). Thus, *k*s as measured for gamblers as well as nongamblers would be safely on the upward-going leg of the functions shown in Figure 1; *k*-values for

[4] Note that in Equation 2 the probability of the string is not itself discounted. Probability of the string (p_i) is not the probability of the gamble but part of the account of the effect of that probability. To discount probabilities within the discount function would lead to an infinite regression since probabilities are themselves variables in the discount function.

gamblers would be higher than those of nongamblers, and these higher *delay* discount constants would be consistent with the very strong preferences for risky rewards that characterize pathological gambling.[5]

ALTERING STRINGS

Consider the string at $D=9$ in Table 1. Suppose a gambler has already lost nine times in a row and is considering a 10th bet. As it stands, even if the 10th outcome were to be a win, the string would be negative (a loss of $6). A method of converting the string to a positive one would be to increase the payoff for the tenth bet by decreasing the odds—by playing a long shot. This would decrease the probability that the very next gamble would be a win but provide the possibility that the string as a whole would be positive. If the string and not the individual gamble is the basic unit, gamblers should tend to increase risk after losing. Wagenaar (1988, p. 53) found that roulette players did indeed increase risk after losses and it is well known that, at the race track, while long shots are generally overbet, they are overbet even more on late races when, presumably, more players are in the midst of losing streaks (McGlothin, 1956).

One can generalize this observation to the case of sunk costs (Northcraft & Wolf, 1984). In a probabilistic situation strings of losses are, effectively, investments that may be "protected" by increasing risk. Speculating further, the writer whose manuscripts have been repeatedly rejected needs, more and more, to produce a masterpiece. The situation is identical with respect to delay—the longer one has waited for a reward, the bigger that reward has to be to justify the wait. Writer's block may be a situation where the subjective size of the achievable reward is always just insufficient to justify the time and effort already spent in trying to achieve it.

PATHOLOGICAL GAMBLING

As children grow older they become capable of delaying gratification longer; furthermore, individual differences in ability to delay gratification may persist from childhood at least through adolescence (Mischel, Shoda, & Rodriguez, 1989). One way to characterize these individual differences is in terms of the delay-discounting measure, *k*, as we have done throughout this article. However this does not necessarily imply that *k* may be changed directly in a meaningful way. It may be that *k* is a measure of a more fundamental aspect of behavior (as a thermometer reading is a measure of temperature). One candidate for this fundamental aspect is the extent and complexity of behavioral structure (Rachlin, 2000). Suppose, as in the Mischel et al. (1989) experiments, a 4-year-old boy takes and eats an immediately available single cookie instead of waiting 10 min (with the cookie exposed in front of him) for two cookies, but a 6-year-old boy waits for the two cookies. The younger boy may be thought of as incapable of organizing his behavior into a unit as much as l0-min long; in that case he would have to repeatedly reject the immediate reward. The older boy, however, who can organize behavior during the waiting period into a 10-min unit, needs to reject the smaller reward only once. Correspondingly, adults (who may sacrifice years of income studying for a college degree) may be said to organize their behavior over a large span of time and to count up the benefits and subtract the losses only after very long anticipated or experienced temporal units. Some behavioral and economic theories of self-control based on studies with humans and nonhumans (Herrnstein & Prelec, 1992; Logue, 1988; Rachlin, 2000; Thaler, 1981) have come to view self-control in this way. If such viewpoints are valid, adults may be said to have learned to control themselves in various situations through the action of mechanisms (unspecified by the theories) that serve to increase the temporal extent of the behavioral unit.

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[5] In the case of lotteries, the many people who bet and never win, essentially never settle accounts. Lottery players do not consider their losses because they would almost always be wiped away by an eventual win. For a gamble of a constant expected value, increase of probability of winning (hence, decrease in amount won) decreases the number of positive strings before a negative string is reached. For the gamble of Table 1 (probability of win = .25) there are three positive strings. If Probability of winning were .5, there would be only one positive string. Conversely, in the case of lotteries, there would be an effectively infinite number of positive strings. A model of lottery gambling consistent with the present model (Rachlin, Siegel, & Cross, 1994) makes use of a delay horizon. If a person bought one million-dollar, zero expected-value lottery ticket per week at odds of one-millionth (of course the expected value of an actual lottery would be much lower) he could expect to win in a million weeks (or about 19,000 years). The delays implied by such low probabilities may be subjectively rounded up to say 60 years yielding much higher subjective values.

There may be structural systems that could check pathological gambling. If the behavioral units were fixed numbers of gambles or fixed units of time, and if accounts were settled after each of such units, positive units would occur no sooner than negative ones. This sort of restructuring, however, requires not mere expansion of strings but reconstruction of units on the basis of a given number of gambles or time spent gambling. With random-ratio structuring (such as in Table 1) the signal indicating the end of a unit (a win) is intrinsic to the activity itself. Count-based or time-based restructuring would require count or time signals not typically provided within the gambling situation (although running out of money would be one such signal—unfortunately a belated one). Gradual expansion of the number of required variable-ratio responses in the animal laboratory has supported variable ratios of hundreds (occasionally thousands) of responses with no reinforcement (Ferster & Skinner, 1957). A history of such reinforcement patterning (ratio "stretching") might conceivably characterize pathological gamblers. For such individuals, restructuring on the basis of extrinsic count-based or time-based signals might be particularly difficult.

Rachlin (2000) proposed a restructuring technique to reduce the salience of wins vis à vis losses. Let us call it the two-pocket method. Gamblers go to the casino or racetrack with a fixed stake—an amount of money that they could presumably afford to lose. Normally, a gambler would bet the stake and then bet any winnings, and then bet the winnings of the winnings, and so on until (as at a racetrack or a casino where all bets are of negative expected value) all the money was gone. With the proposed control method, the stake goes in one "pocket." Each bet is taken from this stake, and the stake is kept separate from winnings (which go in a separate "pocket"). That is essentially all there is to the method. To illustrate, suppose a gambler using this method bet \$10 on a horse paying 2:1, and won \$20 (a return of \$30 at the window). She would then replace the \$10 in her stakes pocket and put \$20 in her winnings pocket. All bets are taken from the stakes pocket, and all winnings are put into the winnings pocket (after returning the stake to the stakes pocket). When the stakes pocket is empty she goes home. If the winnings pocket has more money than the original stake, she won that day. If the winnings pocket has less money than the original stake, she lost that day, proportional to the difference. This method (if a gambler could train herself to follow it) should reorganize the betting experience in terms of days at the track rather than losses followed by a win. We do not expect that this method will be capable of reducing pathological gambling. However, such reorganization of betting sequences might be capable of preventing its development.

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