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Delay of gratification and delay discounting in rats

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Abstract

Delay discounting (DD) and delay of gratification (DG) are two measures of impulsive behavior often viewed as reflecting the same or equivalent processes. However, there are some key differences in the contingencies of reinforcement between the procedures that may have implications for understanding impulsivity. This study used DD and DG procedures to determine if differences in contingencies of reinforcement specified by DD and DG alters how much organisms discount the value of delayed reinforcers. Twenty-four water-deprived rats performed one of two Adjusting Amount procedures, which consisted of repeated choices between a fixed amount of water (250 μl) delivered after a delay (0, 4, 8, 16, or 32 s) and an adjusting, usually lesser amount delivered immediately. Half of the rats ($n = 12$) performed a DD procedure designed to assess preference for immediate over delayed reinforcers in which they had discrete choices between the immediate and delayed amounts of water. A DG procedure was used for the other half of the rats ($n = 12$). In the DG procedure rats also selected between immediate and delayed alternatives, but if they chose the delayed alternative they could switch to and receive the immediate alternative at any time during the delay to the larger reward. In the DD procedure switching responses were not reinforced but were still recorded and used for analyses. The DD functions of the two groups did not differ significantly. However, at the longer delays, the DG group made significantly fewer switching responses than the DD group. A possible role of response inhibition in the DG procedure is discussed.

Keywords: Delay discounting; Delay of gratification; Willpower; Self-control; Impulsivity; Choice; Delayed reinforcement; Nose poke; Rat

1. Introduction

A range of experimental procedures have been developed to assess impulsive behavior, but it is not known to what extent these procedures measure the same, or different, underlying processes. One procedure commonly used is the delay of gratification task (DG), which involves 'sus-

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tained choice'. Sustained choice procedures require both the choice of a delayed reward and the ability to sustain this delayed choice. A key aspect of these procedures is that the organism must sustain its choice for a delayed reinforcer once the choice has been made without defecting to a smaller, more immediate reinforcer during the delay period (e.g. Grosch and Neuringer, 1981; Mischel, 1966; Mischel et al., 1989). A lesser ability to sustain an initial choice for a large delayed reward is considered to be a measure of impulsiveness.

A second procedure commonly used to measure impulsive behavior is delay discounting (DD), which involves 'commitment choice'. In commitment choice procedures, the organism makes discrete and irreversible choices for either the delayed or immediate reinforcer on each trial. Discounting by delay is the extent to which the value of a reinforcer decreases as a function of the delay to its delivery (Mazur, 1987). This tendency to devalue delayed reinforcers is universal across species and may be adaptive in natural environments (e.g. Green et al., 1994; Kagel et al., 1986; Logue, 1988). However, when the tendency to prefer immediate rewards is exaggerated, as in highly impulsive individuals, it may lead to maladaptive behavior (e.g. Bickel et al., 1999; Petry and Casarella, 1999; Vuchinich and Simpson, 1998).

Typical patterns of reinforcer devaluation as a function of increasing delay have been studied in humans of different ages (e.g. Green et al., 1994), in humans with different clinical diagnoses (e.g. Bickel et al., 1999; Crean et al., 2000), in pigeons (e.g. Mazur, 1987), and in rats (e.g. Richards et al., 1997). The devaluation of delayed reinforcers is assessed by obtaining indifference points, or the point at which a larger delayed reinforcer is judged to be of equivalent value to a smaller, more immediate reinforcer. Indifference points associated with different delays can be used to calculate the rate of discounting that occurs as a function of delay. Discount curves for delayed reinforcers in humans, rats, and pigeons are best described by the hyperbolic function (Mazur, 1987):

$$V = \frac{bA}{(1 - kD)}, \tag{1}$$

where V represents the value of the delayed reinforcer, and A and D are the amount of reinforcer and length of delay to its delivery, respectively. The k and b values are free parameters. The k parameter indicates the steepness of the discount curve, with higher k-values indicating more rapid discounting; and the b parameter has been used in previous research (e.g. Richards et al.) to indicate bias towards larger or smaller reinforcers independent of the delay to the larger reinforcer. The value of k obtained has been proposed as an operational definition of impulsivity with larger values of k indicating a greater preference for smaller more immediate reinforcers over larger delayed reinforcers (e.g. Evenden, 1999; Logue, 1988; Monterosso and Ainslie, 1999; Richards et al., 1999). Higher k-values reflect a preference for more immediate, smaller reinforcers, which results in an overall decrease in the total amount of reinforcers earned.

In DG procedures, the factor of primary interest is the organism's ability to sustain its choice of the delayed reinforcer while the smaller, immediate reinforcer is continually available (e.g. Mischel, 1966). In the most commonly used DG procedures with children, participants are presented with a choice between a more preferred (larger or more favored) reinforcer and a less preferred reinforcer (e.g. Mischel and Baker, 1975; Mischel and Ebbesen, 1970). Participants are instructed that they can have the more preferred reinforcer when the experimenter returns (the delay to which is not specified but usually is within 15–20 min) or that they can have the less preferred reinforcer immediately or at any time during the delay period by ringing a bell. If they choose the immediate reinforcer or ring the bell during the delay period they can no longer receive the delayed reinforcer. The length of time a participant is able to wait before ringing the bell is taken as a measure of 'self-control' or 'willpower', and shorter times are an index of impulsivity. Thus, in the DG procedure the participant initially chooses the delayed, larger reward and the primary outcome measure is the ability to sustain that choice over the entire delay period (e.g. Metcalfe and Mischel, 1999; Sethi et al., 2000).

Although both DD and DG procedures may serve as useful measures of impulsive behavior, the commonalties and differences between these two conceptions of impulsivity have not been examined in detail. As noted above, DD and DG procedures may measure different aspects of impulsive behavior, which lead to different conclusions. To illustrate the possible inconsistency between DD and DG, the top panel of Fig. 1 shows a common portrayal of the Hyperbolic Temporal Discounting Model (e.g. Rachlin, 2000). The subjective value of a smaller sooner reinforcer at the time of initial choice (T_0) increases in its value as the time to its possible delivery (T_1) decreases. It is important to note that the subjective value for the reinforcer increases as a function of the time to its delivery decreasing. Put another way, the value of the reinforcer increases for the subject as it is about to

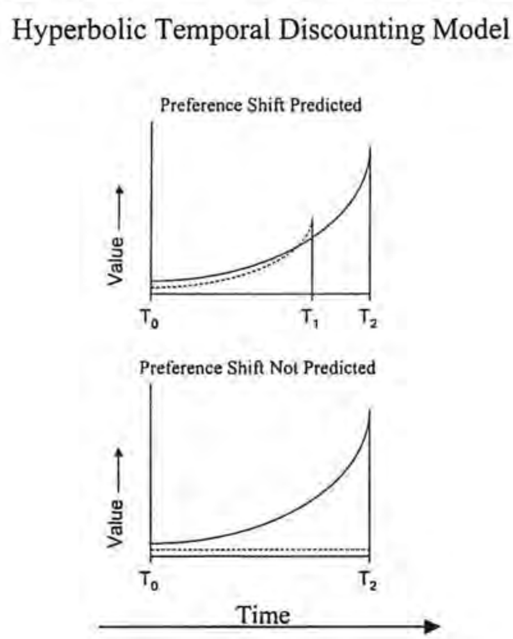

Fig. 1. The top panel indicates the prediction of the Hyperbolic Temporal Discounting Model when preference shifts are likely to occur. The bottom panel indicates the prediction of the Hyperbolic Temporal Discounting Model under circumstances when preference shifts are not likely to occur. The dashed lines show the values of smaller, more immediate reinforcers, and the solid lines show the values of the larger, more delayed reinforcers.

become available. This model shows that as the subjective value for the smaller sooner reinforcer increases there will be a preference shift to the smaller, initially less preferred reinforcer where the two curves intersect. This preference shift has been demonstrated in the laboratory and provides a convincing explanation of the occurrence of impulsive behaviors associated with drug abuse or over eating (Ainslie, 1975; Logue, 1988; Rachlin, 1995). However, because the preference shift depicted in the upper panel of Fig. 1 occurs prior to the possible delivery of either the smaller sooner or larger later reinforcer (i.e. prior to T_1), it is not clear that the Hyperbolic Temporal Discounting Model explains the preference shift (or defection) observed in DG procedures. The bottom panel of Fig. 1 shows what would be predicted from the Hyperbolic Temporal Discounting Model when using a DG procedure. Since the smaller, less preferred reinforcer is available at the time of initial choice (T_0) and throughout the delay, unlike in the top panel where both reinforcers are initially temporally delayed, the smaller sooner reinforcer should not increase in subjective value in the same way as depicted in the top panel of Fig. 1 where value increases as the possible delivery of the reinforcer draws near. From the bottom panel of Fig. 1, temporal shifts in preference as defined by the Hyperbolic Temporal Discounting Model should not occur, yet such shifts clearly do occur in DG procedures. Therefore, the Hyperbolic Temporal Discounting Model does not seem to aptly characterize the preference shift observed in DG procedures.

To date, the authors know of no published empirical comparison between DD and DG procedures. The present study was designed to examine task performance similarities or differences between DD and DG procedures. Two groups of rats were trained on and performed two versions of the Adjusting Amount (AdjAmt) task (Richards et al., 1997). One version was a DD procedure where just initial choice preferences could be examined. Under the DD condition, rats could not receive the immediate reinforcer after having chosen the larger delayed reinforcer by defecting during the delay period. However, for this condition, defection responses (i.e. unreinforced responses to the adjusting alternative dispenser during the delay period to the larger reinforcer) were still recorded and used for group comparison analyses. The other version of the AdjAmt task used a DG procedure that did reinforce defection responses by delivering the immediate reinforcer if a defection response was made during the delay period to the larger reinforcer. As described above for DG procedures, this procedure required the rats to sustain a choice for a larger delayed reinforcer without defecting to a smaller immediate reinforcer that was continually present.

2. Method

2.1. Subjects

Twenty-four male Sprague–Dawley rats (Holtzman), weighing between 350 and 450 g at the beginning of training, were used. The rats were housed two per cage, and lights were on in the colony room from 07:00 to 19:00 h. Food (Harlan Teklab Laboratory Diet #8604, Harlan Sprague–Dawley Inc., Indianapolis, IN, USA) was available at all times. Testing days were Monday through Friday, and non-testing days were Saturday and Sunday. The rats received access to water for 20-min at the end of testing sessions on Monday through Thursday, then received unlimited access to water from the end of testing on Friday until 10:00 h Sunday. The West Virginia University Animal Care and Use Committee reviewed and approved all protocols involved in this experiment.

2.2. Apparatus

Twelve locally constructed experimental chambers were used (Richards et al., 1997). The chambers had stainless steel grid floors, aluminum front and back panels, and Plexiglas sides and tops. The aluminum front test panel had two water dispensers on either side of a snout poke hole. The snout poke hole was centered between the two water dispensers. Stimulus lights were mounted on the test panel over both water dispensers and the center snout poke hole. The lights over the water dispensers were positioned so that they would be aligned with the rat's eyes when its snout blocked an infrared beam running through the center snout poke hole. A Sonalert tone generator (Model #SC628, Newark Electronics) with a frequency of 2900 cps was mounted above the stimulus light over the left water dispenser. Infrared detectors were used to monitor activity in the center snout poke hole and in the water dispenser holes. The water dispensers were calibrated to deliver precise amounts of water under the control of a computer program.

A 133 Mhz Pentium computer using a MED Associates interface was connected to the 12 experimental chambers. The contingencies were programmed using the MED-PC programming language with a temporal resolution of 0.01 s.

2.3. Procedure

The AdjAmt procedure used for the present study is fully described in Richards et al. (1997). The rats were divided into two experimental groups: the DD group ($n = 12$) and the DG group ($n = 12$). The two groups were exposed to different experimental conditions, described below. Each experimental session consisted of 60 distinct choice trials and a variable number of forced trials (see below). Each trial was separated by an inter-trial interval (ITI). The total amount of time between the start of each trial was 40 s plus the time elapsed while the rat made a choice response. All the stimuli in the chamber were off during the ITI. To signal the start of a trial, the light above the center snout poke hole was turned on. The first response to the center snout poke hole following the illumination of the stimulus light caused the center light to be turned off and the stimulus lights over the water dispensers to be turned on. The rats were then required to respond to either the right or left water dispenser. A response to the left dispenser (standard alternative) resulted in the delivery of 250 μl of water after delays of 0, 4, 8, 16, or 32 s.

Delays associated with the standard were not changed during a session but were different between sessions. The order of the different delays to the standard was counterbalanced between sessions so that each delay was tested every 5 days (see Richards et al., 1997). A response to the right dispenser (adjusting alternative) resulted in the immediate delivery of a variable amount of water—usually a smaller amount of water than delivered from the standard dispenser. For every response to the standard alternative, the amount of water dispensed on the next response to the adjusting alternative was increased by 15% of the most recent adjusted amount of water dispensed from the adjusting side. Conversely, for every response to the adjusting alternative, the amount of water dispensed on the next response to that alternative was decreased by 15% of its most recent amount. Each session started with 125 μl of water dispensed on the adjusting alternative. The adjusting alternative was always presented on the right side and the standard was always presented on the left side.

For the DD group, when a response was made to the standard alternative, the light over the adjusting alternative was turned off, indicating that water could no longer be obtained from that dispenser. Responses to the immediate adjusting alternative had no effect but were still recorded. The light over the standard dispenser, along with a tone that started immediately after the response to the standard alternative, stayed on for the duration of the delay period (i.e. 0, 4, 8, 16, or 32 s). Following the delay, 250 μl of water was delivered, and the tone and standard light were turned off for the remainder of the ITI period.

A similar procedure was used for the DG group. The main difference between the DG procedure and DD procedure was that rats in the DG group could 'defect' after choosing the delayed alternative by responding to the immediate adjusting alternative during the delay to reward period. After a response to the delayed standard alternative, the lights over both the immediate adjusting alternative and delayed standard alternative stayed on. This signaled that at any time during the delay to reward period, the rat could still respond to the immediate adjusting alternative (defection) and receive the immediate amount of water. Following a defection, the lights over both dispensers and the tone turned off for the remainder of the ITI period, and the AdjAmt was decreased by 15% for the next trial. The standard reinforcer was not delivered following a defection.

Forced trials occurred following two consecutive responses to either the standard or adjusting alternative. Forced trials were always to the opposite alternative of the previous two consecutive responses. Defections for the DG group were counted as responses to the adjusting alternative in determining the occurrence of forced trials. On forced trials only the light above the forced alternative was turned on and only responses to the forced alternative were reinforced. Responses to the unlighted alternative were ignored in both the DD and DG groups. The DG group rats were not allowed to defect during the delay to reward period in forced trials. Forced trials insured exposure to the consequences of responding to both alternatives.

2.4. Initial training sessions

Training started with the ITI at 10 s and the standard at 250 μl of water delivered immediately. Training took place during daily 1 h sessions under these conditions until the rats completed 60 trials within the 1-h period. The rats learned to make the center snout poke response and to respond to the standard and adjusting alternative water dispensers within 2–5 days. The ITI was then set at 40 s, and the experimental conditions were implemented. No further shaping by the experimenter was required.

2.5. Experimental sessions

After initial training, the two groups were exposed to their respective versions of the AdjAmt procedure for 13 weeks. The last 5 weeks of testing were used for the data analysis.

2.6. Data analysis

The median amount of water dispensed from the adjusting alternative during the last 30 trials of each 60-trial session was used as an estimate of the indifference point (i.e. the value of the delayed reinforcer). When rats failed to complete all 60 trials of a session, the indifference point was estimated using those trials completed after the 30th trial. Only sessions in which the rats completed at least 40 trials were included in the data analyses. Forced trials were not included in the calculations.

The hyperbolic discount equation, $b250/(1+kD)$ (see Section 1), was fit to the five delay indifference points using a nonlinear curve-fitting program (ORIGIN 6.0, 1999). This curve-fitting program determined the best-fitting values for b, k and the coefficient of determination indicating the goodness of fit (R^2). To test for differences in discounting between the DD and DG groups, the b, k, and R^2 values of the hyperbolic curve fitting data were compared using an independent samples t-test. Log(10) transformed k-values were used for t-test comparisons.

The DD and DG groups were compared for group differences in indifference points at the five different delay levels using a two-factor mixed within-subjects analysis of variance (ANOVA). Delay (five levels) was considered the within-subjects factor, and group (two levels) the between-subjects factor.

Defections were calculated as the proportion of trials on which subjects made at least one response to the immediate reinforcer alternative after making a choice of the delayed reinforcer alternative. For the DD group, this response had no scheduled consequences. For the DG group, this response led to an immediate reinforcer. Defections are reported here as a percentage of the number of opportunities to control for differences in the frequency of responding to the delayed reinforcer alternative. The percentage was calculated by dividing the total number of defections during a session by the number of responses to the standard alternative (opportunities) during the session. Only the first defection was recorded on each trial. The same rule was used to define a defection in both the DD and DG groups, although defections had no programmed consequences for the DD group. The DD and DG groups were compared for differences in per-opportunity defection percentages at the five different delays using a mixed within-subjects factorial ANOVA. As with the indifference point analysis, delay was the within-subject factor and group was the between-subjects factor.

Latencies to defection were compared between the DD and DG groups using a mixed within-subjects factorial ANOVA. Latency to defection was the elapsed time between a response to the delayed standard alternative and a defection.

3. Results

Fig. 2 shows the median amount of dispensed water from the immediate adjusting alternative plotted as a log (10) function for the DD and DG groups over the final 5-week period for each delay. The log transformation of these data takes into account the variable amount of water adjustment for the adjusting alternative from trial to trial (e.g. an increase or decrease of 15% of 100 μl vs. an increase or decrease of 15% of 10 μl). The log transformation shows that the rats reached distinct indifference points for each of the five delays. The relatively flat portions of the plots (trials 31–60) indicate that the rats were choosing both alternatives with equal frequency, indicating that they had reached a point of indifference. Both groups were similar in their rapid adjustment towards

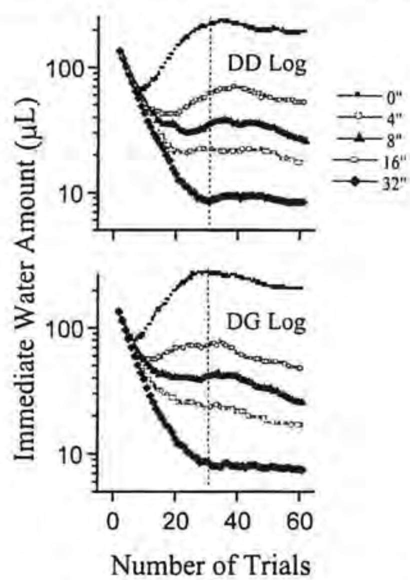

Fig. 2. The two panels show a log(10) transformation of the median amount of water that would have been immediately available per trial for the DD and DG groups. The dashed lines demarcate 30 trials for each graph.

indifference points across trials as a function of delay duration. Further, from Fig. 2, both groups appear to be similar in their indifference points for each delay.

Table 1 shows group percentage of choices to the adjusting alternative over the five different delay conditions. A value of 50% means that the standard and adjusting alternatives were chosen with equal frequency during the last 30 trials of the session. Table 1 shows that both groups had average choice percentages close to 50%.

Figs. 3 and 4 show individual-animal discount functions for both the DD and DG groups, respectively. For the DD group, the coefficients of determination ranged from 0.97 to 0.99 (see Fig. 3). The values of k ranged from 0.23 to 1.41, with larger k values representing more discounting as a function of delay. The values of b ranged from 0.58 to 1.14. These values represent a bias towards either the standard ($b > 1.0$) or the adjusting alternative ($b < 1.0$). One rat had a b-value greater than 1.0, and the other 11 rats had b-values less than 1.0. For the DG group, the coefficients of determination ranged from 0.89 to 0.99 (see Fig. 4). The k-values for the DG group ranged from 0.22 to 2.19, and the b-values ranged from 0.49 to 1.31. Eight of the rats had b-values less than 1.0, and four of the rats had b-values greater than 1.0

The data from Figs. 3 and 4 were combined for each group and compared for overall group differences in k and b values. There were no significant group differences for k or b values ($P > 0.05$).With the same combined data, a Pearson product-moment correlation coefficients was performed to identify any relation between k and b values. Values of k and b were not significantly correlated ($P > 0.05$).

Table 1
Percent choice of the adjusting alternative during the last 30 trials

	Length of delay to 250 μl of water (in s)				
	0	4	8	16	32
DD group Avg.	46.6	48.8	50.8	47.6	46.8
DG group Avg.	50.8	52.8	53.3	49.9	42.5

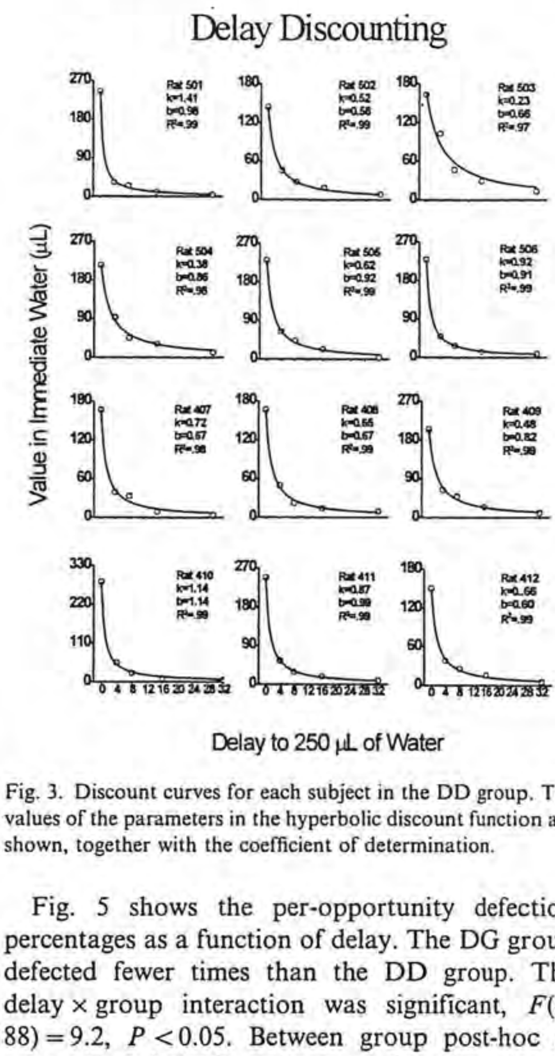

Fig. 3. Discount curves for each subject in the DD group. The values of the parameters in the hyperbolic discount function are shown, together with the coefficient of determination.

Fig. 5 shows the per-opportunity defection percentages as a function of delay. The DG group defected fewer times than the DD group. The delay × group interaction was significant, $F(4, 88) = 9.2$, $P < 0.05$. Between group post-hoc t-tests revealed significantly more defections in the DD group at the 4 s delay, $t(22) = 2.35$, $P < 0.05$, at the 16 s delay, $t(22) = 2.81$, $P < 0.05$, and at the 32 s delay, $t(22) = 3.45$, $P < 0.05$. The groups did not differ significantly at the 0 and 8 s delays. The significant interaction can be explained by noting, from Fig. 5, that the rate of per-opportunity defections increased 'faster' as a function of increasing delay for the DD group than for the DG group. The relation between defection percentages and values of k was examined using Pearson product-moment correlation coefficients. No significant correlation between per-opportunity defections and k-values was found ($P > 0.05$). The mean latencies to defection for both experi-

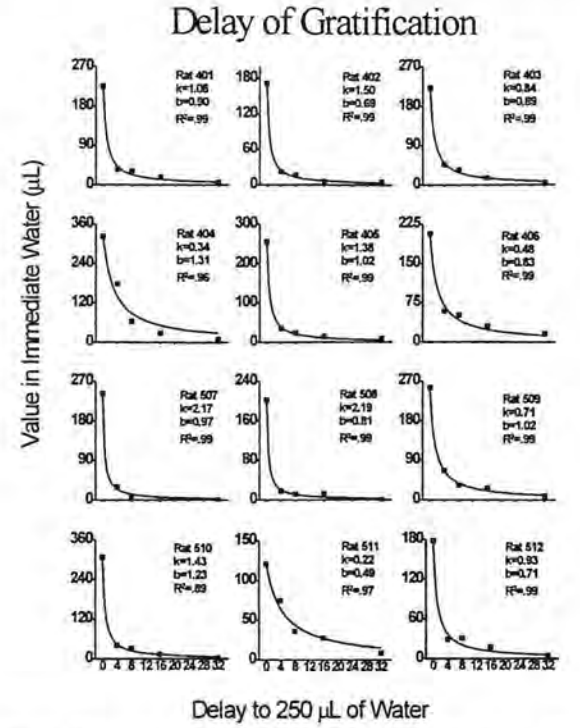

Fig. 4. Discount curves for each subject in the DG group. The values of the parameters in the hyperbolic discount function are shown, together with the coefficient of determination.

mental groups are listed in Table 2. The delay × group interaction was not significant, and there was no group main effect.

4. Discussion

Two primary comparisons were made between the DD and DG procedures. The first involved the rate of discounting as a function of delay. It was found that the DD and DG groups did not differ significantly in rates of discounting as a function of delay. The discount function for both the DD and DG groups were well described by the hyperbolic discount function. There was a tendency for the animals in the DG group to discount at a higher rate (the DG group had the four largest k-values, see Figs. 3 and 4); however, there was no statistically significant difference between the DD and DG groups in the rate of discounting.

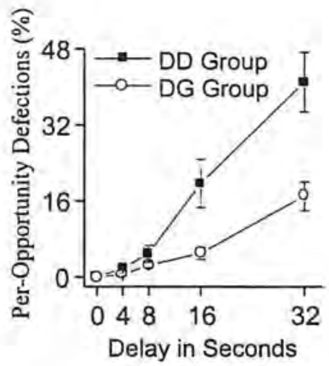

Fig. 5. The per-opportunity percentage of defections for the DD and DG groups as a function of delay to the standard reinforcer.

The second primary comparison involved the percentage of defections (i.e. delay-interval responses to the immediate alternative) per opportunity. Significant group differences in per-opportunity defections were found. The DG group made fewer per-opportunity defections than the DD group—especially during the longer delays. Since defection responses had no programmed consequences for the DD group, the higher rate of occurrence of these responses in the DD group may be taken to reflect a baseline level of defection responses. The finding of fewer defection responses for the DG group suggests that these animals learned to inhibit defecting to the immediate alternative in order to receive the previously chosen delayed reward. However, this interpretation can only be tentatively made because there may have been unprogrammed consequences that maintained the high rate of defection responses under the DD condition. One possibility is that intermittent reinforcement of responses to the adjusting alternative (compared with the DG condition, which reinforced every response to the adjusting alternative, both initial responses and defection responses) led to a higher response rate (i.e. more defections) to the adjusting alternative.

Although there were no differences in discount rates between the DD and DG groups, the occurrence of defection responses by the DG group was not predicted by the bottom panel of Fig. 1. The smaller adjusting alternative was immediately available at the time of initial choice,

Table 2
Group means and standard deviations (S.D.) for latencies to defection during the last 30 trials

	Length of delay to 250 μl of water (in s)				
	0	4	8	16	32
DD group Avg.	[a]	0.53 (0.34)	1.18 (0.49)	4.02 (2.66)	8.81 (3.07)
DG group Avg.	[a]	0.25 (0.20)	0.66 (0.59)	2.51 (1.51)	8.35 (3.81)

[a] Represents no defections.

and yet on trials when defections did occur was not initially chosen. Given that at the time of initial choice the adjusting alternative was not of greater value relative to the larger later reinforcer, it should not have later become more valuable than the delayed larger reinforcer, as illustrated in the bottom panel of Fig. 1. However, on trials when defections did occur, the adjusting alternative did seemingly become more valuable than the delayed larger reinforcer.

4.1. Delay discounting versus delay of gratification

Using DD procedures with humans, it has been found that chronic cigarette smoking (e.g. Bickel et al., 1999; Mitchell, 1999), excessive alcohol consumption (Vuchinich and Simpson, 1998), opioid dependent drug abuse (Madden et al., 1997; Petry and Casarella, 1999), and the clinical diagnoses of substance dependence and abuse, borderline personality disorder, or bipolar disorder (Allen et al., 1998; Crean et al., 2000) all have been positively related to rate of discounting. Paper and pencil measures of impulsivity also have been related to rate of discounting as a function of delay (e.g. Crean et al., 2000; Richards et al., 1999). These findings support DD as a measure of impulsive tendencies in behavior.

Similarly, using DG procedures, longitudinal research with humans has revealed predictive positive relations between a preschooler's ability to sustain a choice for a delayed preferred reinforcer and later parental ratings during adolescence for academic and social competency, ability to deal with stress and frustration, and ability to pursue goals (Mischel et al., 1988). Significant positive relations also have been found between early ability to sustain a less immediately gratifying choice and later verbal and quantitative SAT scores (Shoda et al., 1990). Further, longitudinal links have even been found between measures of DG in preschool and later measures of social and cognitive competencies and ability to self-regulate in early adulthood (Ayduk et al., 2000). Such findings also argue for the use of DG as a measure of self-control or impulsivity.

As already discussed, analyses in the present study comparing rate of discounting by delay between the DD and DG groups revealed no significant differences in discounting rate. This finding occurred despite the fact that defections for the DG group were the same as making an initial choice for the adjusting alternative. Had the DG group made enough defections, the rate of discounting also would have been increased. The finding of no group differences in rate of discounting between the two different procedures supports arguments that the processes measured by DD and DG procedures are the same (e.g. Rachlin, 2000), at least in rats.

However, in the observed differential rates of defection between the DD and DG groups, the present study points to an importance in being able to sustain choices for delayed consequences. In real life, one can easily find examples where being able to sustain an earlier choice in the face of continually present alternative options becomes critical to the 'optimal functioning' of an individual. The requirement of sustaining the choice for an initially preferred reinforcer in the DG procedure may be more analogous to some real life situations than considering only the initial choice preferences of DD procedures. For example, a person who is trying to lose weight by restricting caloric intake is required to resist eating high calorie foods that are frequently available. Making the initial choice to lose weight by restricting caloric intake is an important factor in actually losing weight. However, as time goes on, the person is required to sustain that choice by resisting high calorie foods that are immediately available (e.g. in the refrigerator at home or vending machines at work). In this example, the ability to sustain an earlier choice to lose weight clearly requires the ability to inhibit defecting to immediately available options, which would ultimately lessen the likelihood that weight would be lost. Another similar example is the recovering alcoholic who arrives at a party and says 'no' to the offer of an alcoholic beverage. The recovering alcoholic must not only say 'no' to a drink upon arrival but must also sustain the choice of abstinence by continuing to say 'no' to immediately available drinks while at the party.

For optimal functioning, these examples illustrate the importance of being able to sustain a choice for a preferred, but delayed, reward. These examples also highlight the possibility that choice preference (as emphasized in DD procedures) and ability to sustain a choice (as emphasized in DG procedures) may represent different aspects of impulsive behavior.

Pre-commitment strategies, which prevent the occurrence of responses due to preference reversal such as those described by the Hyperbolic Temporal Discounting Model in Fig. 1, have been discussed in detail by Ainslie (1975, 1992) and Rachlin (1995). For example, individuals may use physical restraint to prevent a shift in preference by committing themselves to a drug treatment facility or use punishment to prevent defections by telling a colleague they will have a paper done by a certain deadline. However, as these authors note, these examples of commitment require an external agency in order to prevent defection. Rachlin (1995) has proposed that development of temporally extended behavioral patterns may be one way to prevent defections without resorting to physical restraint or punishment. According to this approach, linking together individual responses into a single behavioral pattern is another way to control the occurrence of defections. The behavioral pattern is perceived by the organism as a single behavioral unit, and, therefore, does not require repeated choices. Since the pattern of behavior is seen as a single behavior, which is extended over time rather than a series of short duration responses, the perceived opportunity for defections after each individual component of the behavioral pattern is reduced. For example, an individual who establishes a pattern of not eating fatty foods will be more resistant to breaking the pattern than an individual who has failed to establish such a pattern. Furthermore, because the pattern is extended in time, the large, delayed consequence of a decrease in weight is more likely to occur and reinforce the pattern. A problem with this approach is that it is unclear how such patterns would initially develop, given the pull of immediate payoffs for the initially smaller units of behavior.

4.2. Summary

Comparisons within the present study of the DD and DG models of impulsive behavior indicate that rate of discounting was very similar between the two procedures; however, the number of defections between the two procedures differed significantly. Also, none of the correlations between rate of discounting (the values of k) and the number of per-opportunity percentage defections were significant. A possible implication of this null finding is that the ability to sustain a choice, as emphasized in DG, is independent from initial choice preferences emphasized in DD. The question still remains, then, as to whether preference and the ability to sustain a choice represent two related, but different, aspects of impulsive behavior. As suggested by Rachlin (1995), choice of delayed consequences could be sustained through development of extended patterns of behavior. However, behavioral patterns are likely to be susceptible to disruption by factors other than preference shifts. This opens the possibility that the tendency to defect could occur because of a failure to sustain the choice of the delayed consequence independent of preference shifts due to the interaction between the values of delayed and more immediate reinforcers. Some support for this hypothesis is found in a study (Richards et al., 1998) that compared the effects of serotonin (5HT) lesions on DD and DG groups using procedures similar to the procedures reported in this paper. Only the DG group was impaired by the 5HT lesion. The increase in impulsive behavior in the DG group (and the absence of an increase in the DD group) after serotonin (5HT) lesions indicates that the requirement of sustaining a choice for a delayed alternative may be an important determinant of impulsive behavior in some individuals.

Future research more directly examining the relation between initial choices and the ability to sustain choices for delayed reinforcers is needed in order to increase our understanding of the tendency to behave impulsively. If these two aspects of impulsive behavior vary independently, it is conceivable that some individuals who consistently make choices for more immediate reinforcers will also be unable to sustain choices for delayed reinforcers when such choices are actually made, or some individuals may make more choices for delayed reinforcers but similarly be unable sustain such choices. Conversely, other individuals may frequently make choices for delayed reinforcers and then be able to sustain such choices with little difficulty. A more detailed behavior analysis of the relation between DD and DG procedures is needed in order to build a model of impulsive behavior that includes both initial choices and ability to sustain such choices once they are made.

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