

Hyperbolic discounting of delayed social interaction

Shawn R. Charlton · Edmund Fantino ·
Bradley D. Gossett

Published online: 5 October 2012
© Psychonomic Society, Inc. 2012

Abstract The temporal discounting literature has demonstrated that the loss in value for delayed outcomes is most accurately modeled using a hyperbolic discounting equation. The hyperbolic-shaped function not only describes the shape of discounting for monetary outcomes, but also for other tangibles, such as alcohol, candy, CDs, erotica, cigarettes, cocaine, books, and DVDs. Furthermore, this hyperbolic shape has important theoretical implications. Despite the broad list of outcomes that are hyperbolically discounted, one class of outcomes has only recently received attention: social interactions. For the present study, we used standard binary-choice discounting procedures to explore the function that most accurately describes the change in value of delayed social interactions. The results from the present study suggest that, for 93 participants, the same equations (exponential, hyperbolic, and hyperboloid) used to describe the discounting of nonsocial commodities also describe the relation between delay and the value of social interaction. Similar to previous findings for nonsocial outcomes, the hyperbolic-shaped models provide a fit to the data superior to that of the exponential model.

Keywords Discounting · Human learning · Social interaction · Social learning

Temporal (or delay) discounting is a process that describes the decrease in the reinforcing value of an outcome as a function of the delay until its receipt/occurrence (Critchfield & Kollins, 2001). Temporal discounting has been shown to correlate with real-world contexts such as substance dependence (Ainslie, 2001; Bickel & Johnson, 2003; Bickel & Marsch, 2001), impulse control (Critchfield & Kollins, 2001; Petry, 2001a; Raineri & Rachlin, 1993), pathological gambling (Dixon, Marley, & Jacobs, 2003; Petry, 2001b), and risky choice behavior (O'Donoghue & Rabin, 2001). In addition to the influence of individual differences, the degree to which delay affects the value of future outcomes (i.e., the discount rate) varies as a function of contextual variables. For example, larger outcomes are discounted less steeply than are smaller outcomes (the *magnitude effect*; Green, Myerson, & McFadden, 1997); financial gains are discounted less steeply than losses (the *sign effect*; Baker, Johnson, & Bickel, 2003); and, of the most direct relevance to the present study, different outcomes are discounted at different rates (the *commodity effect*; Charlton & Fantino, 2008).

A critical characteristic of discounting is the shape of the discounting curve. Traditional economic approaches to discounting have modeled the loss of value over time using exponential equations such as

$$V_p = Ve^{-kD}, \quad (1)$$

where V_p is the current value of the outcome, V is its absolute value, D represents the delay to the outcome's occurrence, and k is the discount rate. Although the exponential model is a popular normative model of economic behavior, it does not appear to accurately describe individual decision-making (Green et al., 1997; Kirby, 1997; Kirby & Marakovic, 1995; Kirby & Santiesteban, 2003; Rachlin & Green, 1972; Vuchinich & Simpson, 1998).

Due to the descriptive shortcomings of the exponential equation, a second model based on Mazur's (1987)

S. R. Charlton (✉) · B. D. Gossett
Department of Psychology & Counseling,
University of Central Arkansas,
201 Donaghey Avenue,
Conway, AR 72035, USA
e-mail: scharlton@uca.edu

E. Fantino
Department of Psychology, University of California, San Diego,
La Jolla, CA, USA

hyperbolic discounting equation has been advocated. This hyperbolic model can be described as

$$V_p = V/(1 + KD). \quad (2)$$

Each of the variables in this model serve the same function as in the exponential model. However, the hyperbolic model provides a better description of individual behavior (Myerson & Green, 1995). For instance, hyperbolic discounting posits that the rate of discounting decreases as delay increases. This inconsistency in discount rates allows for *preference reversals*, in which choice shifts from a small, more immediate outcome to a larger, more delayed outcome as a constant difference is added to both.

While hyperbolic functions are typically found to be more accurate than exponential models in describing the change in reinforcing value for delayed outcomes, more recent work has suggested that an even more accurate description of intertemporal choice requires the inclusion of an additional parameter. This revised hyperboloid model (Green, Fry, & Myerson, 1994) is

$$V_p = V/(1 + KD)^s. \quad (3)^1$$

This equation is identical to the hyperbolic model—where the variables serve the same functions as in the exponential and hyperbolic models—except for the inclusion of the exponent s . The additional free parameter, s , is conceptualized as an index of individual sensitivity to delay (McKerchar, Green, & Myerson, 2010; McKerchar et al., 2009). A growing literature suggests that the inclusion of the additional free parameter does provide a significantly better fit to discounting data than do either the exponential or the hyperbolic model (see Green & Myerson, 2004, for a review). Also, McKerchar and colleagues (McKerchar et al., 2010; McKerchar et al., 2009) argued that the hyperboloid model of Eq. 3 has important theoretical implications, as the added parameter s is consistent with the individual psychophysical scaling of Stevens' (1957) power law and is similar to the generalized matching law (Baum, 1974).

Support for the hyperbolic function has come mainly from studies that focus on monetary and other exchangeable, consumable commodities. For example, discounting has been demonstrated for a broad range of outcomes, such as alcohol (Estle, Green, Myerson, & Holt, 2007), candy (Estle et al., 2007), cigarettes (Bickel, Odum, & Madden, 1999; Johnson, Bickel, & Baker, 2007), erotica (Lawyer,

2008), cocaine (Coffey, Gudleski, Saladin, & Brady, 2003), entertainment items (books, CDs, DVDs; Charlton & Fantino, 2008), and food (Odum & Rainaud, 2003; Rasmussen, Lawyer, & Reilly, 2010).

While a number of commodities have been shown to be hyperbolically discounted, one class of outcomes has only recently received attention from discounting researchers: delayed social interactions. As happens for tangible commodities, interactions set to occur in the future are perceived as being less valuable than if they were to occur more immediately (Charlton, Gossett, & Charlton, 2012). To illustrate this, consider receiving the news that a good friend from out of town will be arriving in one month for a one-week visit. This news elicits a certain amount of excitement. However, the excitement for this upcoming visit is likely to mount as the arrival of the friend approaches. While the duration of the upcoming visit remains fixed (one week), the influence of this outcome on your behavior increases as the delay to its occurrence decreases. The discounting of delayed social interaction may also be at play when one chooses to send a text (a short, immediate interaction) while driving, rather than waiting until arriving at the destination to engage in a longer social interaction.

Several studies have provided empirical support for the discounting of hypothetical delayed social interactions. Tayler, Arantes, and Grace (2009) asked participants to choose between socially, sexually, and emotionally fulfilling relationships either for an immediately available brief interaction or for a delayed, extended period of interaction. In congruence with findings for nonsocial commodities, participants in this study reported a greater willingness to accept the more immediate relationship as the delay to the longer relationship increased. Similarly, research by Lawyer, Williams, Prihodova, Rollins, and Lester (2010) suggested that the value of sexual encounters decreases also as a product of increasing delay to availability. Finally, Charlton et al. (2012) demonstrated discounting for delayed face-to-face conversations across one of four qualitatively different social targets. Furthermore, the rate of discounting of the delayed interaction increased as the “quality” of the social target increased.

In addition to direct studies of the value of delayed social interactions, recent interest in *social discounting* (Jones & Rachlin, 2006; Rachlin & Jones, 2008) has highlighted the importance of social variables in decision-making. *Social discounting* refers to the change in the value of a commodity as the quality of the relationship between the participant and the recipient is varied (Grace, McLean, & Bragason, 2002). Accordingly, the social-discounting paradigm uses social distance as a general index (typically ranging from 1, *very close*, to 100, *very distant*) of the quality of relationship between the decision-maker and the social target, in place of temporal delay (D) in the discounting equation. Of

¹ Rachlin (2006) suggested an alternative hyperboloid model that places the s parameter on the delay (D) only. Because McKerchar and colleagues (McKerchar et al., 2010; McKerchar et al., 2009) have found that the model presented in Eq. 3 and the Rachlin model provide highly similar fits to both group and individual data, in the present study we examined only Eq. 3 above.

critical importance to the present study, Jones and Rachlin (2006) demonstrated that a hyperbolic model provides a better description of the change in value across social distances than does an exponential model—consistent with findings from the temporal discounting literature.

As the shape of the discounting function has important behavioral implications, the objective of the present study was to evaluate the quality of fit provided by both the hyperbolic and hyperboloid models for delayed social interactions. This comparison provides a theoretical extension of previous studies that have demonstrated a similarity between the discounting of monetary outcomes and social interactions. In addition to the comparison of the two hyperbolic models, we also made a comparison to the exponential model.

Method

Prestudy: Value of social interaction

Prior to testing the effect of delay on social interaction, it was first necessary to establish that longer social interactions are viewed as more valuable than shorter interactions. As a first measure of the value of social interaction, 57 undergraduate students (no demographic data were collected) completed a 20-question paper-and-pencil survey that presented questions of the form, “What is the most you would be willing to pay to talk with [name of social target] for [duration of interaction]?” The social target in these questions was a self-selected individual who fit the following instructions: “Please take a moment to think of the person with whom you feel the most socially connected. This person should be the primary person with whom you share intimate personal details, from whom you seek advice and comfort, and whose company you most often seek.” The duration of the proffered social interactions ranged from 5 to 100 min in an ascending order of 5-min increments. The participants were instructed to write the maximum dollar amount that they would be willing to spend in order to engage in the listed amount of social interaction to the immediate right of each question. The participants were further instructed to imagine that if they did not make the payment, they would not be able to engage in a conversation with the social target for some time.

The results from this prestudy indicated a general increase in the value of social interaction (demonstrated by the amount that the participants were willing to spend) as the duration of the interaction increased (see Fig. 1). As is evidenced by the increasing width of the interquartile range bars, the longer the social interaction, the greater the variability in the price estimates. For example, the median payment for a 5-min social interaction was \$10, with the 25th percentile at \$5 and the 75th percentile at \$20.

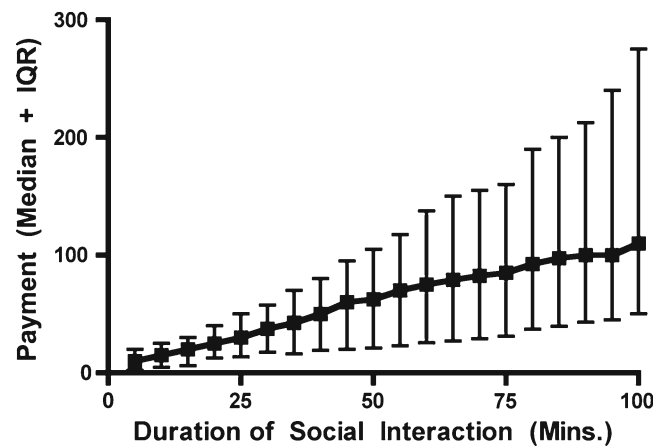


Fig. 1 Medians and interquartile ranges for the maximum amount that respondents were willing to pay to spend 5–100 min (x -axis) interacting with a close personal friend

However, the values for the 100-min social interaction were \$105 (median) and \$42 to \$250 (25th and 75th percentiles, respectively).

While these values support the general conclusion that social outcomes increase in perceived value as their magnitude increases, the magnitude of the values is most likely not an accurate representation of their true value. Rather, it is likely that the participants: (1) overestimated the perceived value and/or (2) the instructions created a perceived deprivation of interaction with the individual that artificially inflated the reported value of these interactions. Fortunately, even if the values do not represent the actual amount that the participant would pay for the social interaction, the relative change in value across the magnitudes observed in this prestudy remains consistent with the notion that longer-duration social interactions—within the range of the durations used in the present study (0–100 min)—are viewed as being more valuable than shorter-duration interactions.

Main study: Discounting of delayed social interactions

Participants A group of 93 undergraduate students (52 female, 41 male) completed the experiment. Their mean age was 20.16 years ($SD = 1.48$), and they displayed no between-gender age differences [$t(92) = 0.66, p = .50$]. One hour of experimental credit was provided as compensation for participation. The participants completed the experiment on computers located either in a small room with four PCs or in one of two individual testing rooms. The computers in both testing locations were arranged so that only the monitor associated with that computer was visible to the participant.

Experimental procedures Participants completed a computer-administered version of the fast-adjusting temporal

discounting procedure (cf. Charlton & Fantino, 2008; Critchfield & Atteberry, 2003; Johnson & Bickel, 2002). Throughout the procedure, the participants chose between pairs of hypothetical face-to-face social interactions. Within each trial, one choice option presented an immediate face-to-face social interaction with a specified social target, while the other offered a longer-duration social interaction with the same individual, but set to occur after a specified delay. The duration of the immediate social interaction ranged from 0 to 100 min, while the delayed interaction was held at a constant 100 min. The delay until the occurrence of the social interaction was set within a range of 1 day to 1 year (the exact values are listed below).

To generate the names of the social targets used throughout the testing procedure, each participant was asked to spend several minutes thinking about individuals with whom they have weekly contact who fit the following instructions:

As you think of these individuals, start making a list of the individuals with whom you feel the most socially connected. These should be the individuals with whom you would share personal experiences and intimate personal feelings, from whom you would seek help and/or counsel during times of personal difficulty, and with whom you wish to share good news and successes as soon as possible.

Participants were not given a time limit for compiling their lists (data were not collected on the time to completion for the list or on the number of names generated). Finally, participants were asked to rank the names on their list, with the person ranked first as the person who best fit the description above.

The instructions were presented at the beginning of the session and explained that all choices were hypothetical and that each choice should be made “as if” the choices were real and mutually exclusive. All instructions remained visible at the top of the screen throughout the session. In each trial, participants were presented with the following options (one on each side of the screen):

Left side of screen: [X] min talking with [Social target] available NOW
 Right side of screen: 100 min talking with [Social target] available in [DELAY]

The participants indicated their selection by clicking directly on the section of the screen displaying the preferred outcome. Following each choice, the duration of the immediately available outcome, [X], was adjusted according to a predetermined decision tree (see Charlton & Fantino, 2008). According to this algorithm, selection of the immediately available interaction on the current trial decreased the duration of the immediate interaction [X] on the next trial. Conversely, a choice of the delayed social interaction on

the current trial increased the duration of the immediate interaction [X] on the subsequent trial. This adjusting process allowed rapid determination of an *indifference point* (V_p in Eqs. 1, 2, and 3): the duration of immediate social interaction that the participant perceived as being subjectively equivalent to, in this case, a 100-min face-to-face interaction occurring after the specified delay. Indifference points were calculated at seven delays, [DELAY]: 1 day, 2 days, 1 week, 1 month, 2 months, 6 months, and 1 year (presented in this order for all participants).

Results

Table 1 shows the median numbers of minutes of immediate social interaction (V_p) that were perceived as being equal to 100 min of delayed social interaction (the indifference points) for each of the seven delays, for females, males, and pooled across participants. A visual comparison of the median indifference points for all participants (see Fig. 2) reveals that the medians decreased or stayed equal at each of the seven delays, indicating a general downward trend in the value of the delayed social interaction as delay increased. The degrees to which the seven indifference points for each participant were consistent with temporal discounting were computed by summing the total number of adjacent pairs (1 day–2 day, 2 day–1 week, etc.) at which the indifference point for the shorter delay was greater than or equal to the indifference point for the longer delay (range of 0 to 6, with higher scores indicating greater consistency). The mean consistency score was 5.13 ($SD = 0.99$), with no differences in overall consistency across genders (females, $M = 5.21$, $SD = 0.92$; males, $M = 5.02$, $SD = 1.08$; $t(91) = 0.90$, $p = .37$). Together, the visual analysis (Table 1 and Fig. 2) and the high mean consistency scores suggest that the value of delayed social interactions is subject to delay discounting. The distribution of indifference points at each of the seven delays was nonnormal, with a strong positive skew for short delays that transitioned into a strong negative skew for long delays.

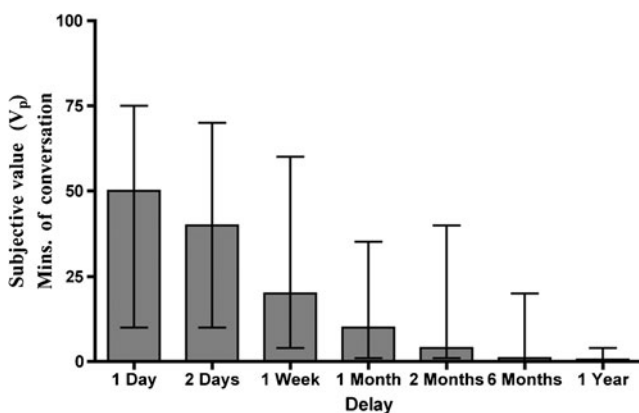
To determine the best-fit discounting equation for these data, nonlinear regressions using the exponential (Eq. 1), hyperbolic (Eq. 2), and hyperboloid (Eq. 3) models (calculated using GraphPad Prism 5.04) produced discount estimates for the seven indifference points for each participant. Figure 3 shows the best-fit lines, estimated k value, and variance accounted for (VAC, measured as r^2) for the fit to the median subjective value (indifference point) for each of the seven delays. In order to provide a general description of the distribution of the estimates for each parameter, Table 2 shows the median and interquartile scores generated by the nonlinear fits to the seven subjective values produced by individual participants. Each of the three models provided a good fit to the observed indifference points. However, as

Table 1 Medians and interquartile ranges for male, female, and pooled indifference points at each of seven delays

	Delay						
	1 Day	2 Days	1 Week	1 Month	2 Months	6 Months	1 Year
Females							
75 %	75.00	70.00	60.00	25.00	30.00	15.00	1.00
Median	50.00	40.00	20.00	4.00	4.00	1.00	0.60
25 %	15.00	10.00	4.00	1.00	1.00	0.20	0.20
Males							
75 %	75.00	75.00	60.00	50.00	45.00	30.00	15.00
Median	30.00	30.00	20.00	10.00	10.00	4.00	1.00
25 %	5.50	10.00	4.00	1.00	1.00	0.20	0.20
Overall							
75 %	75.00	70.00	60.00	40.00	35.00	20.00	4.00
Median	50.00	40.00	20.00	10.00	4.00	1.00	0.60
25 %	10.00	10.00	4.00	1.00	1.00	0.20	0.20

Table 2 shows, the quality of the fit was best for the hyperboloid model, followed by the hyperbolic, and finally by the exponential model. This conclusion is supported by two pieces of information: (1) the median VAC (r^2) was greatest for the hyperboloid model (.97), followed by the hyperbolic (.95), and finally the exponential model (.93); and (2) the interquartile range was smallest for the hyperboloid model (.90–.99), followed by the hyperbolic model (.77–.99) and exponential model (.71–.98).

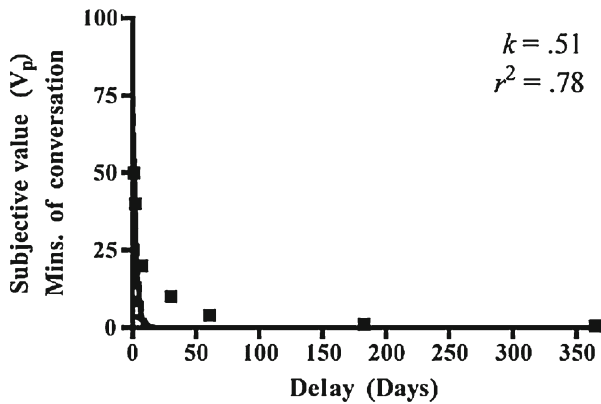
Due to the nonnormal distribution of VAC values, Wilcoxon signed-rank tests were used to compare the quality of fit of the exponential model to the fits observed for the hyperbolic and hyperboloid models. These comparisons identified significant differences between the exponential and hyperbolic discounting models ($z = -5.84$, $p < .001$) and between the exponential and hyperboloid models ($z = -6.54$, $p < .001$). In both cases, the VAC for the hyperbolic-shaped models exceeded that of the exponential model.

**Fig. 2** Medians and interquartile ranges of the subjective values for each of the seven delays

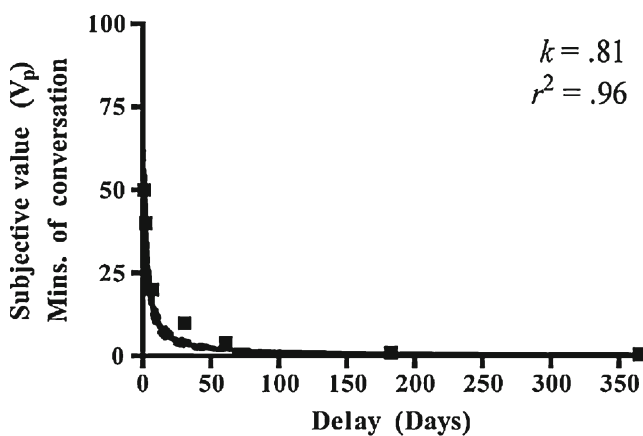
Because the hyperbolic and hyperboloid models were nested, an F test was used to compare the VAC for the hyperbolic and hyperboloid models for the subjective values generated by each participant. This was done to determine whether the increase in VAC resulting from the inclusion of the additional parameter in the hyperboloid model was justified. F tests were calculated for the best-fit parameters for both the hyperbolic and hyperboloid models for each participant. The results of the F test supported rejecting the null hypothesis (i.e., the hyperbolic model; $p < .05$) in 28 (30.1 %) of the individual fits. The null hypothesis was retained in the remaining 65 cases (69.9 %). The value of 28 cases in which the null hypothesis was rejected was significantly greater than would be expected by chance [$\chi^2(1) = 60.64$, $p < .0001$]. The distribution of the s parameter for the 28 participants for whom the hyperboloid model provided an improved fit as compared to the hyperbolic model had a median of 0.28 (interquartile range: 0.03–0.55), and 22 of the 28 had an estimated s value less than 1.0 [$\chi^2(1) = 9.14$, $p = .002$]. The mean p value for participants among whom the F test supported the hyperboloid model (reject the null) was $p = .02$ ($SD = .01$). For participants among whom the hyperbolic model was supported (fail to reject), the mean was $p = .44$ ($SD = .31$). The results of this analysis support the use of the hyperboloid model, with its additional free parameter, to describe the change in subjective value for delayed social interactions.

Additional support for the hyperboloid model is provided by the distribution of the s parameter. As is shown in Table 2, the median estimate of the s parameter was 0.39 (interquartile range of 0.09 to 1.25). The distribution of the s parameter showed a strong positive skew, with estimates ranging from <0.01 to 8,963.94. However, the estimated s parameter was less than

Eq. 1: Exponential Discounting Model



Eq. 2: Hyperbolic Discounting Model



Eq. 3: Hyperboloid Discounting Model

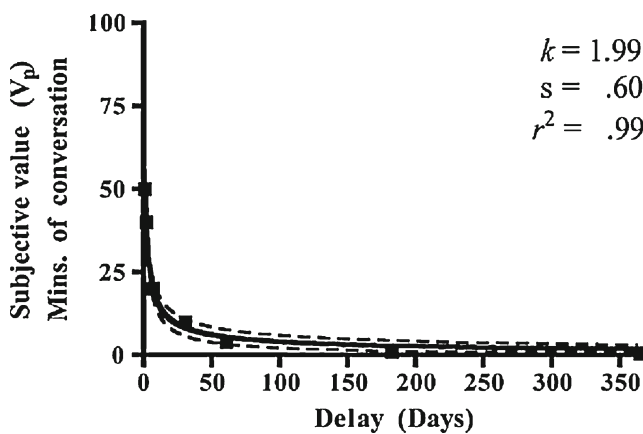


Fig. 3 Best-fit lines for the exponential, hyperbolic, and hyperboloid models to the median subjective values of a delayed 100 min of social interaction

1.0 for 64 of the 93 participants [68.8 %; $\chi^2(1) = 13.17, p < .001$]. In order to test for s parameters that deviated significantly from $s = 1.0$, the t ratio described by McKerchar et al. (2009, p. 257) was calculated for each participant. The results from this comparison revealed that the s parameter was

Table 2 Best-fit parameters for the individual fits to the exponential, hyperbolic, and hyperboloid discounting models, as well as area under the curve (AUC)

	Individual		
	25 %	Median	75 %
Exponential			
k	0.04	0.61	2.12
r^2	.71	.93	.98
Hyperbolic			
k	0.06	0.93	5.44
r^2	.77	.95	.99
Hyperboloid			
k	0.04	1.94	344.02
s	0.09	0.39	1.25
r^2	.90	.97	.99
AUC	.02	.06	.22

Each row of the table characterizes the distribution of a parameter, independent of the values of the other parameters in the model, using the median and interquartile range.

significantly different from 1.0 for 53 participants [$t > 2.57; \chi^2(1) = 2.84, p = .09$]. Of the 53 participants with s parameters different from 1.0, the mean estimate was 0.31 ($SD = 0.56$), and 51 of the s parameters were less than 1.0. Estimated s parameters of less than 1.0 are frequently found for discounting of monetary outcomes (McKerchar et al., 2010; McKerchar et al., 2009). Overall, while both the hyperbolic and hyperboloid models provide a better fit to the observed data than does the exponential model, the inclusion of the additional s parameter in the hyperboloid model appears justified, as it improves both the quality of the fit (VAC), and the s parameter is less than 1 in the majority of cases.

An independent-measures t test using the log-transformed hyperbolic discounting rates showed no difference in the rates of discounting between males and females [$t(91) = -0.07, p = .95$]. Similarly, the area under the curve (AUC; Myerson et al., 2001) did not differ across genders (Mann–Whitney $U: z = -1.14, p = .26$; see Table 2 bottom row). However, Mann–Whitney U tests of the VACs for the three discounting models (hyperboloid, hyperbolic, and exponential) across females (.98, .96, and .96, respectively) and males (.96, .95, and .93, respectively) found that all three models provided a better fit for data from the females than from the males ($z = -2.44, p < .05; z = -2.21, p < .05; z = -2.00, p < .05$, respectively). Despite the improved VAC for females, the earlier test of consistency across the seven delays failed to find a significant difference between males and females. These results suggest that females may have been more systematic in their responses, but that both genders discount delayed social interactions similarly.

Discussion

The present study has demonstrated that the indifference points, or subjective values, of delayed face-to-face social interactions (1) decrease as the delay to the interaction increases and (2) are best described using one of the two hyperbola-like discounting models. Furthermore, the hyperboloid model (Eq. 3) provided a significant improvement in fit over the hyperbolic model. Overall, these findings suggest that delayed social interactions, like delayed nonsocial commodities, lose reinforcing value as the time to their occurrence increases, and that these changes are described better by a hyperbolic-shaped function than by an exponential function.

The finding that a hyperbolic function provides a strong description of the change in value for delayed social interactions has several implications. First, Eqs. 2 and 3, which provided excellent fits to the present data, are the same equations that describe the relation between delay and nonsocial commodities. The similarity in the shapes of the discounting functions for social and nonsocial commodities may indicate that these qualitatively different outcomes are functionally similar. Previous studies of the commodity effect (Charlton & Fantino, 2008; Estle et al., 2007; Odum & Rainaud, 2003) demonstrated that while qualitatively different commodities (e.g., food, money, and/or entertainment items) are discounted at distinct rates, a moderate correlation is typically observed between commodity types. Given the similarity in the shapes of the discounting functions, it seems reasonable that future research directly comparing social and nonsocial outcomes may reveal a positive correlation between the changes in value for nonsocial and social outcomes.

Although the similarity in the shapes of the functions describing both social and nonsocial outcomes suggests similarity in the evaluations of these outcome types, prior evidence has indicated distinctiveness in the observed discount rates for these different outcome types. Specifically, Tayler et al. (2009) found greater correlations within a commodity type (money, companionate relationships, or sexual relationships) than between commodity types. These results suggest that while the same factors may be responsible for the discounting of both social and nonsocial commodities, the different commodity types may be viewed as functionally distinct.

Second, the observed discount rates in the present study are larger than those typically observed in studies of discounting for nonsocial outcomes. Adding a delay of just one day, for example, decreased the median value of a 100-min conversation by 50 % (see Table 1). Charlton and Fantino (2008) suggested that discount rates could be viewed as occurring on a continuum from money (the slowest discounting) to metabolically consumable commodities, such as food and drugs, at the high end. While it is difficult to make comparisons across the discount rates observed in different studies, the discount rates observed in the present

study are extremely high, suggesting that social interactions would fit at the high end of the discounting continuum. Some evidence for this hypothesis has been provided by Tayler et al. (2009), who found greater within-subjects discount rates for sexual and companionate relationships than for monetary outcomes (no difference was observed between the two relationship types; these comparisons are limited by difficulties in scaling across social and nonsocial commodities).

A number of possible explanations could account for the steep discounting of delayed social interactions observed in the present study. One possible explanation is that participants viewed the selection of the delayed interaction as a *loss* of immediate social interactions, and subsequently selected the immediate outcome in order to avoid these aversive losses (see Charlton et al., 2012, for an in-depth discussion of this possibility). Another possibility is that there is little motivation to wait for social interactions because they are readily available and of relatively low cost. Moreover, participants were encouraged to think of a person with whom they have frequent contact. The discount rates might have been much lower if the participants were asked to decide between an immediate, short interaction and a longer, more delayed interaction with a person with whom they have infrequent/limited contact. Finally, it is possible that the elevated discount rates for social interactions are due to the type of social target employed. The instructions given to the participants encouraged them to come up with someone with whom they felt both socially and emotionally connected. Charlton et al. found that the discount rates for social outcomes are elevated for close social contacts as compared to more distant contacts. For some participants, these contacts may have involved romantic partners, confidantes, and others who elicit strong emotional responses. Further work will be needed to determine the variables responsible for the elevated discount rates observed here and in other studies of discounted delayed social interaction.

A consistent finding with hyperbolic discounting models (including the hyperboloid model used here) is *preference reversals* when a constant is added to both choices in a delay-to-reinforcement situation (Green, Fisher, Perlow, & Sherman, 1981; Green et al., 1994; Kirby & Herrnstein, 1995). For instance, individuals may prefer to receive \$100 today to waiting for 1 year to receive \$150. However, if the option were presented as \$100 in 1 year or \$150 in 2 years, a significant proportion of these same individuals would now prefer to wait the additional year. The hyperbolic shape of the social outcome discounting curve suggests that a similar preference reversal should occur for delayed social interactions. For example, if a student were presented with the choice of whispering to a friend now or waiting 30 min until recess for a more in-depth conversation, it would be anticipated that they would show greater preference for the

immediate outcome than if they were presented the choice of a shorter conversation with a friend in an hour or a longer conversation in an hour and a half.

Individual differences in the rates of discounting for delayed social interactions may provide useful clinically relevant information for working with individuals with social deficiencies/disorders and for understanding problematic social behaviors. One possible line of future inquiry may be to investigate differences in the rates of discounting for delayed social interactions across a number of individual factors. For instance, individuals exhibiting social anxiety or those with Asperger syndrome may display differing patterns of responding as compared to the average population. Another possibility is that individuals who exhibit high rates of social discounting (cf. Jones & Rachlin, 2006) might also discount delayed social interactions differently than those with shallower social discount rates. Finally, individuals with elevated rates of delay discounting for social interactions may also be more likely to engage in dangerous social behaviors, such as texting while driving (a short, immediate interaction), rather than waiting until they arrive at their destination to engage in a longer social interaction. Thanks to the increased availability and immediacy of social interactions, there is a growing recognition of the social problems related to failures to delay social interaction.

Despite the utility of the present investigation, several limitations are worth noting. First, the conclusions are based on hypothetical social interactions. For hypothetical monetary outcomes, several studies have demonstrated that real and hypothetical outcomes produce approximately the same results (Johnson & Bickel, 2002; Lawyer, Schoepflin, Green, & Lenks, 2011; Madden, Begotka, Raiff, & Kastern, 2003). However, a similar correspondence between hypothetical and real delayed social interactions has not been established. An experiential discounting task for delayed social interactions would provide interesting insights into the relevance of the present findings. An interesting model for such a task might involve the choice between a single send/reply exchange on a computer-based chat or waiting a delay for a series of exchanges (the number of back-and-forth exchanges could be manipulated as an independent variable).

Second, the data displayed a high level of between-participants variability (see the interquartile ranges reported in Tables 1 and 2), which may be a product of the novelty of the social decision. While participants are familiar with making decisions between monetary outcomes, as is typical in a discounting task, it is less common to make explicit, hypothetical decisions regarding social interaction. A second possibility is that the variability is a product of qualitative differences in the relationship between the participant and the social target. While participants were given instructions as to what type of persons should be on their ranked

list, individual differences in the interpretation of these instructions and in social skills/connections may have contributed to the observed variability. These limitations do not call into question the main conclusion of the present article, but they do highlight the need for further research to better understand the dimensions of discounting for delayed social interactions.

Two major conclusions result from this successful extension of the discounting methodology to the exploration of social behavior: (1) The similarity in discounting for social and nonsocial commodities suggests that a single process may be involved in both social and non-social decision-making (e.g., should I snack now or wait for dinner? Or, should I text now or wait until I can talk later?) and (2) the present findings suggest that future studies and models of social behavior need to be sensitive to the effect of temporal delay on the perceived value of the social interaction. The continued exploration of the role of temporal discounting in complex social behavior provides a unique method by which to study both the basic understanding of behavioral processes and the development of models of social behavior.

Author note B.D.G. is now at Idaho State University. Special thanks to Danielle Umland for assistance with the manuscript and to the undergraduate research staff of the Behavioral and Social Decisions Laboratory at the University of Central Arkansas for assistance with data collection. Portions of these data were presented at the annual meeting of the International Association for Behavior Analysis in May 2008. Support for this study was provided by a University Research Council grant to the primary author and by NIMH Grant No. 5R01MH057127 to the second author.

References

- Ainslie, G. (2001). *Breakdown of will*. Cambridge, U.K.: Cambridge University Press.
- Baker, F., Johnson, M. W., & Bickel, W. K. (2003). Decision-making in state lotteries: Half now or all of it later? *Psychonomic Bulletin & Review*, *10*, 965–970. doi:10.3758/BF03196559
- Baum, W. M. (1974). On two types of deviation from the matching law: Bias and undermatching. *Journal of the Experimental Analysis of Behavior*, *22*, 231–242.
- Bickel, W. K., & Johnson, M. W. (2003). Delay discounting: A fundamental behavioral process of drug dependence. In G. Loewenstein, D. Read, & R. Baumeister (Eds.), *Time and decision: Economic and psychological perspectives on intertemporal choice* (pp. 419–440). New York, NY: Sage.
- Bickel, W. K., & Marsch, L. A. (2001). Toward a behavioral economic understanding of drug dependence: Delay discounting processes. *Addiction*, *96*, 73–86.
- Bickel, W. K., Odum, A. L., & Madden, G. J. (1999). Impulsivity and cigarette smoking: Delay discounting in current, never, and ex-smokers. *Psychopharmacology*, *146*, 447–454.
- Charlton, S. R., & Fantino, E. (2008). Commodity specific rates of temporal discounting: Does metabolic function underlie differences in rates of discounting? *Behavioural Processes*, *77*, 334–342.

- Charlton, S. R., Gossett, B. D., & Charlton, V. A. (2012). Effect of delay and social distance on the perceived value of social interaction. *Behavioural Processes, 89*, 23–26.
- Coffey, S. F., Gudleski, G. D., Saladin, M. E., & Brady, K. T. (2003). Impulsivity and rapid discounting of delayed hypothetical rewards in cocaine-dependent individuals. *Experimental and Clinical Psychopharmacology, 11*, 18–25.
- Critchfield, T. S., & Atteberry, T. (2003). Temporal discounting predicts individual competitive success in a human analogue of group foraging. *Behavioural Processes, 64*, 315–331.
- Critchfield, T. S., & Kollins, S. H. (2001). Temporal discounting: Basic research and the analysis of socially important behavior. *Journal of Applied Behavior Analysis, 34*, 101–122.
- Dixon, M. R., Marley, J., & Jacobs, E. A. (2003). Delay discounting by pathological gamblers. *Journal of Applied Behavior Analysis, 36*, 449–458.
- Estle, S. J., Green, L., Myerson, J., & Holt, D. D. (2007). Discounting of monetary and directly consumable rewards. *Psychological Science, 18*, 58–63.
- Grace, R. C., McLean, A., & Bragason, O. (2002). Can altruism be understood in terms of socially-discounted extrinsic reinforcement? *The Behavioral and Brain Sciences, 25*, 259–260.
- Green, L., Fisher, E. B., Perlow, S., & Sherman, L. (1981). Preference reversal and self control: Choice as a function of reward amount and delay. *Behaviour Analysis Letters, 1*, 43–51.
- Green, L., Fry, A. F., & Myerson, J. (1994). Discounting of delayed rewards: A life-span comparison. *Psychological Science, 5*, 33–36.
- Green, L., & Myerson, J. (2004). A discounting framework for choice with delayed and probabilistic rewards. *Psychological Bulletin, 130*, 769–792. doi:10.1037/0033-2909.130.5.769
- Green, L., Myerson, J., & McFadden, E. (1997). Rate of temporal discounting decreases with amount of reward. *Memory & Cognition, 25*, 715–723. doi:10.3758/BF03211314
- Johnson, M. W., & Bickel, W. K. (2002). Within-subject comparison of real and hypothetical money rewards in delay discounting. *Journal of the Experimental Analysis of Behavior, 77*, 129–146. doi:10.1901/jeab.2002.77-129
- Johnson, M. W., Bickel, W. K., & Baker, F. (2007). Moderate drug use and delay discounting: A comparison of heavy, light, and never smokers. *Experimental and Clinical Psychopharmacology, 15*, 187–194.
- Jones, B. A., & Rachlin, H. (2006). Social discounting. *Psychological Science, 17*, 283–286.
- Kirby, K. N. (1997). Bidding on the future: Evidence against normative discounting of delayed rewards. *Journal of Experimental Psychology: General, 126*, 54–70. doi:10.1037/0096-3445.126.1.54
- Kirby, K. N., & Herrnstein, R. J. (1995). Preference reversals due to myopic discounting of delayed reward. *Psychological Science, 6*, 83–89.
- Kirby, K. N., & Marakovic, N. N. (1995). Modeling myopic decisions: Evidence for hyperbolic delay-discounting within subjects and amounts. *Organizational Behavior and Human Decision Processes, 64*, 22–30.
- Kirby, K. N., & Santiesteban, M. (2003). Concave utility, transaction costs, and risk in measuring discounting of delayed rewards. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 29*, 66–78.
- Lawyer, S. R. (2008). Probability and delay discounting of erotic stimuli. *Behavioural Processes, 79*, 36–42.
- Lawyer, S. R., Schoepflin, F., Green, R., & Lenks, C. (2011). Discounting of hypothetical and potentially real outcomes in nicotine-dependent and non-dependent samples. *Experimental and Clinical Psychopharmacology, 19*, 263–274.
- Lawyer, S. R., Williams, S. A., Prihodova, T., Rollins, J. D., & Lester, A. C. (2010). Probability and delay discounting of hypothetical sexual outcomes. *Behavioural Processes, 84*, 687–692.
- Madden, G. J., Begotka, A. M., Raiff, B. R., & Kastern, L. L. (2003). Delay discounting of real and hypothetical rewards. *Experimental and Clinical Psychopharmacology, 11*, 139–145.
- Mazur, J. E. (1987). An adjusting procedure for studying delayed reinforcement. In M. L. Commons, J. E. Mazur, J. A. Nevin, & H. Rachlin (Eds.), *Quantitative analysis of behavior* (The effect of delay and of intervening events on reinforcement value, Vol. 5, pp. 55–73). Hillsdale, NJ: Erlbaum.
- McKerchar, T. L., Green, L., & Myerson, J. (2010). On the scaling interpretation of exponents in hyperboloid models of delay and probability discounting. *Behavioural Processes, 84*, 440–444.
- McKerchar, T. L., Green, L., Myerson, J., Pickford, S., Hill, J. C., & Stout, S. C. (2009). A comparison of four models of delay discounting in humans. *Behavioural Processes, 81*, 256–259.
- Myerson, J., & Green, L. (1995). Discounting of delayed rewards: Models of individual choice. *Journal of Experimental Analysis of Behavior, 64*, 263–276.
- Myerson, J., Green, L., & Warusawitharana, M. (2001). Area under the curve as a measure of discounting. *Journal of the Experimental Analysis of Behavior, 76*, 235–243. doi:10.1901/jeab.2001.76-235
- O'Donoghue, T., & Rabin, M. (2001). Risky behavior among youths: Some issues from behavioral economics. In J. Gruber (Ed.), *Risky behavior among youths: An economic analysis* (pp. 29–67). Chicago, IL: University of Chicago Press.
- Odum, A. L., & Rainaud, C. P. (2003). Discounting of delayed hypothetical money, alcohol, and food. *Behavioural Processes, 64*, 305–313.
- Petry, N. M. (2001a). Delay discounting of money and alcohol in actively using alcoholics, currently abstinent alcoholics, and controls. *Psychopharmacology, 154*, 243–250.
- Petry, N. M. (2001b). Pathological gamblers, with and without substance abuse disorders, discount delayed rewards at high rates. *Journal of Abnormal Psychology, 110*, 482–487.
- Rachlin, H. (2006). Notes on discounting. *Journal of the Experimental Analysis of Behavior, 85*, 425–435.
- Rachlin, H., & Green, L. (1972). Commitment, choice, and self-control. *Journal of the Experimental Analysis of Behavior, 17*, 15–22.
- Rachlin, H., & Jones, B. A. (2008). Social discounting and delay discounting. *Journal of Behavioral Decision Making, 21*, 29–43.
- Raineri, A., & Rachlin, H. (1993). The effect of temporal constraints on the value of money and other commodities. *Journal of Behavioral Decision Making, 6*, 77–94. doi:10.1002/bdm.3960060202
- Rasmussen, E. B., Lawyer, S. R., & Reilly, W. (2010). Percent body fat is related to delay and probability discounting for food in humans. *Behavioural Processes, 83*, 23–30.
- Stevens, S. S. (1957). On the psychophysical law. *Psychological Review, 64*, 153–181. doi:10.1037/h0046162
- Taylor, S., Arantes, J., & Grace, R. C. (2009). Temporal discounting for monetary and close relationship outcomes. *Personal Relationships, 16*, 385–400.
- Vuchinich, R. E., & Simpson, C. A. (1998). Hyperbolic temporal discounting in social drinkers and problem drinkers. *Experimental and Clinical Psychopharmacology, 6*, 292–305.