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The short of it: Abbreviating the temporal discounting procedure

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Abstract

A typical temporal discounting procedure determines the present, subjective value (indifference point) of a delayed outcome at 5 – 8 different delays to that outcome. These indifference points are used to determine a single index of discounting called a discounting rate. One concern that remains in the collection of this data is the high number of trials or choices, resulting in participant fatigue or other factors that may affect the validity of the data. In this report, we propose an abbreviated alternative to the more comprehensive and time-consuming discounting procedure. Specifically, we propose that fewer indifference points can be used to determine statistically equivalent discount rates with no loss in data sensitivity. We reanalyzed temporal discounting data obtained with 7 indifference points, and estimated discount rates from all combinations of 2, 3, and 4 of the 7 indifference points. Results indicate that valid and sensitive discounting indices can be obtained with fewer indifference points, and the most appropriate sets of indifference points are highlighted. The proposed abbreviated procedure is likely to be particularly useful when time constraints or participant fatigue is a concern, as well as in repeated-measures contexts.

Author keywords

temporal discounting; discounting procedure; abbreviated procedure; discount rates

The number of human temporal discounting studies has grown substantially over the last decade, resulting in important advancements in the understanding of intertemporal choice. Studies incorporating temporal discounting procedures and insights have extended our understanding of areas such as social dilemmas (Harris & Madden, 2002; Yi, Johnson, & Bickel, 2005) and altruism (Rachlin, 2002). Gender differences have been explored with temporal discounting procedures (Kirby & Markovic, 1996; Wilson & Daly, 2004), as have developmental issues (Green, Fry, & Myerson, 1994; Olson, Hooper, Collins, & Luciana, 2007). Additionally, we are expanding insights into the neurobiology of decision-making (McClure Laibson, Lowenstein, & Cohen, 2004; Kable & Glimcher, 2007) and substance

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abuse using the temporal discounting paradigms. Temporal discounting plays a prominent role in recent theories of substance abuse (Bechara, 2005; Bickel, Miller, Yi, Kowal, Lindquist, Pitcock, 2007; Redish, Jensen, & Johnson, 2008), and may be predictive of drug relapse (Dallery & Raiff, 2007; Krishnan-Sarin, Reynolds, Duhig, et al., 2007; Yoon, Higgins, Sugarbaker, Thomas, & Badger, 2007).

Given the expansion of temporal discounting research, it is becoming increasingly important that the employed methods and procedures are capable of fulfilling the needs of future research. One of the currently popular paradigms asks participants to choose between binary choice alternatives where the outcome of one alternative occurs immediately and the outcome of the other occurs following some delay. The sequence of choices can vary depending on the specific algorithm of choice presentation, but ultimately, these choices are used to determine the present subjective value (called an indifference point) of a specific outcome at a specific delay. Depending on the procedure, the number of trials or choices to produce 1 indifference point has been fixed on as little as 6 (the decreasing adjustment procedure of Du, Green, & Myerson, 2002), as many as 30 or more (sequential presentation of Reynolds, Karraker, Horn, & Richards, 2003), or highly variable depending on the participant's consistency (the double-limit procedure of Baker, Johnson, & Bickel, 2003).

This process is repeated with the same outcome at different delays to produce multiple indifference points, and these indifference points are used to estimate a single index or parameter estimate of discounting called a discounting rate. Given that the number of indifference points determined from a participant is frequently 5 (de Wit, Enggasser, & Richards, 2002; Ohmura, Takahashi, & Kitamura, 2005; Reynolds, Karraker, Horn, & Richards, 2003), 6 (Mitchell, 1999; 2004), 7 (Coffey, Gudleski, Saladin, & Brady, 2003; Dixon, Marley, & Jacobs, 2003; Heyman & Gibb, 2006) or 8 (Green, Fry, & Myerson, 1994; Harris & Madden, 2002), the number of trials or choice pairs multiplies very quickly. For example, the decreasing adjustment procedure of Du et al. (2002) coupled with 7 indifference points requires 42 trials to obtain one discount rate at each magnitude, commodity, valence (gains/losses), etc. To obtain indifference points for 2 magnitudes of 2 commodities at 2 valences, 336 trials would be required. And with a large number of trials comes concerns about data validity resulting from participant fatigue, boredom, etc.

To reduce the number of choice pairs to determine a temporal discount rate, Kirby and colleagues (Kirby & Markovic, 1996; Kirby, Petry, & Bickel, 1999) developed and implemented an abbreviated procedure called a Monetary Choice Questionnaire (MCQ). This 27-item binary choice questionnaire is substantially shorter than the indifference point procedure (noted above), and with a fixed set of questions, can be conducted via paper and pencil or computerized assessment method. Thus, the MCQ is particularly useful when a limited amount of time and resources are available to collect temporal discounting data.

However, MCQ does have some disadvantages. Rather than calculating a discount rate based on numerous indifference points, the MCQ assigns a pre-determined discount rate based on the distribution of choices; no indifference points are calculated. Thus one potential weakness of the MCQ is that the absence of indifference points precludes data analysis at a molecular level (analysis of probability discounting procedures indicates that

overall discount rates may overlook important differences observed with indifference points; Yi, Chase, & Bickel, 2007). More importantly, only 9 different discount rates per magnitude condition are possible using the MCQ (with some exception), creating effectively an ordinal scale of measurement rather than the interval/ratio scale of other assessment methods. There exists the possibility that the discount rate obtained via MCQ is less able to detect between- and within-subject differences than the discount rate obtained via the indifference point method. Though the MCQ has been able to detect magnitude effects (Kirby & Markovic, 1996) and population differences (Kirby et al., 1999), the assessment may fail to detect differences when effects sizes are small. In fact, Epstein, Richards, Saad, Paluch, Roemmich, and Lerman (2003) compared discount rates using both the indifference point method and MCQ, finding that the two procedures are not interchangeable: a 1-unit change in discount rate observed with the indifference point method was associated with .60 to .66-unit change with the MCQ. Assuming no differences in variability across the MCQ and indifference point method (no measures of variability are reported in Epstein et al., but visual inspection suggests that they are highly similar), the MCQ method will result in lower power than when using the indifference point method since effects sizes for MCQ are about 1/3 less than that for the indifference point method. Defining *sensitivity* for the purposes of this paper as a proportional change in one assessment as a function of another (the term *sensitivity* in diagnostic testing is used to describe the probability that a test correctly detects the presence of a disease), the MCQ does appear less sensitive than the indifference point method.

This report proposes that an abbreviated version of the indifference point method is appropriate for obtaining temporal discounting data. The focus of this analysis was to determine if an abbreviated number of indifference points could be utilized in temporal discounting procedures that would produce equivalent and equally sensitive discounting rates as those estimated with a full set of 7 indifference points. Upon determining all combinations, or abbreviated sets, comprised of 4, 3, and 2 indifference points (more than 4 indifference points would not result in a substantial reduction in the number of trials), discounting rates were estimated for each abbreviated set. Abbreviated sets with significantly different mean discounting rates compared to the full set were discarded, as were those abbreviated sets that were not statistically equivalent to the full set. Lastly, sensitivity of the remaining abbreviated sets, compared to the full set, was examined.

Method

Data

All data used in this analysis were obtained from participants enrolled in one of four studies at the University of Arkansas for Medical Sciences, and no criteria were applied to determine inclusion/exclusion in these analyses. Portions of the data from one of these studies have previously been published (Bickel, Yi, Gatchalian, & Kowal, 2008). A final dataset consisting of discounting data for 266 participants (161 female) with a mean age of 39.3 years (± 1.6 years) and mean education of 14.0 years (± 0.3 years) was used in the analysis. Computerized assessments of the discounting of \$100 and \$1000 future hypothetical money gains were used to determine indifference points. In both discounting

conditions, indifference points were estimated at each of 7 delays (1 day, 1 week, 1 month, 6 months, 1 year, 5 years, 25 years) using either the double-limit or decreasing adjustment algorithm. Resulting indifference points between these two procedures have been shown to potentially differ (Kowal et al., 2007); however, this potential difference does not confound our analyses as all tests are within-subject and simply utilize different combinations of the same indifference points to estimate discounting parameters.

Procedure

Creating Abbreviated Sets—Abbreviated sets of indifference points were formed by obtaining all possible combinations of size p (2, 3, or 4) indifference points from the full set of 7. Level of abbreviation is denoted with $7Cp$, read “seven choose p .” Accordingly, there were 35 sets in the $7C4$ and $7C3$ grouping, and 21 sets in the $7C2$ grouping.

Natural log transformed discounting parameters ($\ln[k]$) were estimated using a variation of Mazur’s (1987) hyperbolic equation (Equation 1) at \$100 and \$1000 outcomes using all 7 indifference points to establish baselines for subsequent analysis.

$$Y = A / (1 + \exp^{\ln(k) X}) \quad (1)$$

Y is the theoretical subjective value of A , A = amount (\$100, \$1000), X = delay (in days), and $\ln(k)$ is our log transformed discounting parameter. Note that $\exp[\ln(k)] = k$, and the estimated $\ln(k)$ is equivalent to taking the log transformation of Mazur’s estimated k . Log transforming of the k parameter normalized the typically skewed distribution and allowed for parametric analysis to be conducted. This function was then used to estimate $\ln(k)$ for each subject/amount/set of indifference points across the 4 groupings (i.e. $7C4$, $7C3$, and $7C2$) resulting in 45,864 estimates to compare to the full set.

Finding Difference Between Full and Abbreviated Sets—In order to initially assess which abbreviated sets of indifference points may ultimately result in statistical equivalence to measures from the full set and discard those that are statistically different, a null hypothesis statistical test was employed in the form of paired t tests to identify those abbreviated sets where the estimated mean average was statistically different (at $p < .05$) from the mean average of the $\ln(k)_F$ parameter as estimated with the full set, at either the \$100 or \$1000 amount. If the mean of an abbreviated set was determined to be statistically different at either the \$100 or \$1000 level, that abbreviated set was discarded and not included in the remaining analyses. Exclusion based on statistical difference at either magnitude ensures the usefulness of the sets across magnitudes rather than just one.

Finding Equivalence between Full and Abbreviated Sets—Having excluded the abbreviated sets that were statistically different from the full set, an equivalence test determined statistical equivalence between the remaining abbreviated sets and full set. Equivalence testing is often used in clinical trials to show indistinguishable outcomes between distinguishable treatments and has been covered in both clinical and statistical literature for a number of years (see Blackwelder, 1982; Detsky & Sackett, 1986; Hauck & Anderson, 1984; Frick, 1995; Haidar et al., 2008; Metzler, 1991; Selwyn & Hall, 1984;

Westlake, 1976). Some popular and appropriate statistical methods for determining equivalence include two one-sided t tests (Rogers, Howard, & Vessey, 1993; Schuirmann, 1987), the use of descriptive confidence intervals (Dunnett & Gent, 1977), and the use of inferential confidence intervals (ICI; Tryon, 2001; Tryon & Lewis, 2008). The ICI method as described by Tryon (2001) was utilized to establish statistical equivalence between the discounting parameters estimated with the full sets and those estimated with abbreviated sets. This method of statistical testing has been shown to be “algebraically equivalent with D.J. Schuirmann’s (1987) use of 2 one-sided t tests”, and “provides an intuitive graphic method for inferring statistical difference as well as equivalence” (Tryon & Lewis, 2008, p. 272).

In order to meet a statistical level of equivalence, Tryon posits that the inferential confidence intervals (ICI) about the means of the parameters being tested must have a range (upper confidence interval of the greater mean parameter minus the lower confidence interval of the lower mean parameter; R_g) that is less than an a priori range of inconsequence (), and that the ICI’s of the compared means must overlap. Tryon (2001) presents a factor (E) used for the reduction of the critical t -value (denoted $t_{(1-\alpha)100\%}$ with the degrees of freedom suppressed) in comparing two dependent means, expressed using the following:

$$t_x = t_{95} \frac{\sqrt{S_{Y_1}^2 + S_{Y_2}^2 - 2r_{12}S_{Y_1}S_{Y_2}}}{S_{Y_1} + S_{Y_2}} = E t_{95} \quad (2)$$

where S_{Y_1} and S_{Y_2} are the standard errors of the means for groupings 1 and 2, r_{12} is the correlation between Y_1 and Y_2 , and E , the reduction factor, is the ratio of the standard error of the difference to the sum of the standard errors of the two grouping means. The reduction factor is then used to construct the ICI about the sample means so that overlap satisfies the overlapping of the ICIs criterion of equivalence.

Agreement and Sensitivity—Estimates derived from abbreviated sets that were shown to be equivalent were then analyzed for agreement using the Bland-Altman analysis. Sufficient agreement between measurements obtained through different equipment, techniques, analysis, etc., is often sought in measurement comparisons to justify adaptation of a new procedure. Correlation analyses are often used but are inappropriate for assessing agreement. In this work, the Bland-Altman pairwise comparison (Bland & Altman, 1986, 1999) uses the within-subject difference between the full and abbreviated estimates, as well as the average of the two to assess three indicators of agreement. The first measure of agreement is the mean difference (or bias) between discounting measures, ideally 0. The second measure of agreement is the variability in the differences, used for constructing intervals (e.g., mean difference ± 2 standard deviations of the differences) in which most of the observed differences should lie (e.g., about 95%). The third and final indicator of agreement assesses the relationship between the difference of the two estimates and the magnitude of their average. Epstein et al. (2003) used the Bland-Altman analysis to examine the level of agreement between discounting parameters obtained using the MCQ and indifference point method. Results from both the linear regression and Bland-Altman

analysis are then utilized to recommend specific sets of indifference points for abbreviating the standard discounting procedure.

Results

Table 1 shows point estimates and summary statistics of $\ln(k)_F$ measures derived from Equation 1 using the full set of all 7 indifference points. All full model estimates were used in subsequent analysis and not subjected to any exclusionary criteria. Discounting rates for all abbreviated groupings/sets ($\ln(k)_A$) were estimated at both the \$100 and \$1000 levels. Paired t test identified 26 abbreviated sets that produced mean discounting rates that were not statistically different from $\ln(k)_F$ for either \$100 or \$1000 magnitude conditions: 11 sets from the 7C4 grouping, 11 sets from the 7C3 grouping, and 4 sets from the 7C2 grouping (Table 2). The specific delays associated with each set are indicated in the 4 columns to the far right. The sets not listed here had mean discount rates that were significantly different from the full set, and were not considered further.

Equivalence testing using inferential confidence intervals (ICI) was carried out on each remaining set by amount and grouping. For the purpose of graphical display of the results, we follow Tryon's (2001) recommendation and establish a mean E (reduction factor) for the purpose of creating ICI's for all sets within each grouping/amount comparison (Figure 1). The left and right panels represent the \$100 and \$1000 amount conditions, respectively. The top, middle, and bottom panels represent the 3 groupings of sets (7C2, 7C3, and 7C4). For an abbreviated set to be determined as equivalent to the full set, two criteria must be met. First, the ICI of that set must have an equivalence range (R_g) less than that of the range of inconsequence (). Here we established as an a priori range of inconsequence the 95% confidence interval surrounding the mean of $\ln(k)_F$ at both the \$100 (UCI -5.826, LCI -6.518) and \$1000 magnitudes (UCI -6.258, LCI -6.923). R_g is the difference of the lower inferential confidence boundary of the lower mean point estimate and the upper boundary of the higher mean point estimate. Given that the ICI of the Full set lies completely within in each plot, $R_g <$ if the ICI of the abbreviated set also lies completely within . This is the case for each abbreviated set in each panel, and thus all sets pass the first criterion. For example, all 4 sets from the 7C2 groupings fulfill the first equivalence criterion for \$100 (top left panel of Figure 1): R_g calculations for each set fall well within the range of inconsequence, where $= 0.689$ and $R = 0.219, 0.173, 0.241$ and 0.295 for Sets 11, 14, 15 and 19 respectively.

The second criterion holds that there must be an overlap of the ICI's of the two measures being evaluated (i.e., The ICI's of the full and abbreviated estimate must overlap). For the 7C2 groupings, only sets 11, 14 and 15 fulfill the second equivalence criterion of confidence interval overlap, while set 19 violates this criterion in the \$100 condition. Given that both equivalence criterion were met for sets 11, 14 and 15, we can appropriately report equivalence with an associated probability value of $p < .05$ because we used an initial critical t value of 1.96 that was reduced by mean $E = 0.222$ in the construction of the ICI (Tryon, 2001). Of the 7C3 and 7C4, all passed the first and second criteria of equivalence except for set 5 of the 7C3 groupings, which failed the second criterion of overlap at both the \$100 and \$1000 conditions. Abbreviated sets that were not determined to be equivalent at both

magnitude conditions were excluded from the final phase of examination (sets 19 of 7C2 and 5 of 7C3).

Levels of agreement using the Bland-Altman analysis (with discounting estimates for \$100 and \$1000 combined for each set) are established by 1) the bias (or mean difference) of the estimates from an abbreviated and full set, 2) the amount of variability within the difference scores, and 3) the correlation between the difference scores and the magnitude of the average of the two log estimates. The third level of agreement is not useful here as a measure, and is therefore not reported. Table 3 shows the results of this analysis (Bias, variability of the difference scores) and linear regression (y-intercept, slope) for three abbreviated sets from each grouping.

A high level of overall agreement of discount rates is indicated by low bias measures; i.e., there is very small mean difference between discount rates obtained from the full and abbreviated sets. Overall agreement is also indicated by low variability of difference scores (SD): i.e., mean differences between discount rates from full and abbreviated sets are relatively consistent (in size, not direction). The regression plots for each set in Table 3 illustrate the association between the respective parameters and provide us with information regarding the location(s) on the discounting continuum where the full and abbreviated estimates may differ (Figure 2). Additionally, the slope of the regression line indicates the relative sensitivity (relative to the full set) of the discount rates obtained from the abbreviated sets. A slope equal to 1 indicates that the abbreviated set is equally sensitive to the full set, while a slope less (greater) than 1 indicates that the abbreviated set is less (more) sensitive than the full set. For example, we can see from visual inspection that the differences between the two estimates are minimal at the lower levels of discounting in the regression plot for 7C2 Set 11, but that these unsystematic differences are larger at the higher levels of discounting. Furthermore, the slope of the regression is close to 1, suggesting that a 1-unit change in discount rate with the full set is accompanied by a 1 unit-change in discount rate with the abbreviated set (i.e., that the abbreviated set is equally sensitive as the full set). With the exception of set 15 from the 7C4 grouping, abbreviated sets have slopes that are less than 1. This suggests that a 1-unit change in discount rate with the full set is associated with less than a 1-unit change with the abbreviated sets, i.e., less sensitivity, but that the loss in sensitivity is very minimal.

The three abbreviated sets from each grouping of Table 3 are the best of the remaining sets, defined as the best overall ranking on the 4 criteria: specifically, low bias, low SD, y-intercept closest to 0, and slope closest to 1. Of the 3 remaining abbreviated sets with 2 delays, set 11 was best, ranking first in y-intercept (-0.076) and slope (0.982). Visual comparison (Figure 2, top panels) also reveals that the variability is relatively small and unsystematic across the entire range of values for set 11. Of the 10 remaining abbreviated sets with 3 delays, set 24 was best, ranking first in bias (-0.005), y-intercept (0.019) and slope (1.002), and second in SD (0.786). Visual comparison (Figure 2, middle panels) reveals that the variability is unsystematic across the entire range of values for set 24. Of the 11 remaining abbreviated sets with 4 delays, set 25 was best, ranking first in bias (-0.004), intercept (0.97) and slope (0.984), and third in SD (0.688). Visual comparison in Figure 2 (bottom panels) reveals that the variability is unsystematic across the entire range of values for set 25.

To examine the reliability of the results, we randomly divided the full sample into two separate subsamples and repeated the entire set of analyses on both subsamples. With one minor exception, all observations were confirmed in both subsamples. The exception occurred for abbreviated set 21 from the 7C3 grouping where one of the two subsamples was determined to be significantly different from the full set only at the \$100 magnitude ($p=.04$). This abbreviated set was not amongst the preferred sets based on equivalence and Bland-Altman analyses (Table 3 and Figure 2), and is therefore not explored further.

Discussion

This paper reports on the equivalence and sensitivity of temporal discounting indices calculated with abbreviated sets of indifference points, compared to those calculated using a full set of 7 indifference points. Discount rates were calculated for each possible set of 4, 3, and 2 indifference points and compared to the discount rates for the full set; those with statistically different discount rates were rejected. Equivalence testing was then conducted to determine the sets that were statistically equivalent to the full set, and Bland-Altman analysis conducted on the remaining abbreviated sets to examine their sensitivity compared to the full set.

Though all of the sets listed on Table 2 result in discounting parameter estimates statistically equivalent to the full set, the Bland-Altman analysis allowed for a ranking of candidate sets. Within each grouping (7C2, 7C3, 7C4), we propose a preferred set based on a combination of 4 criteria: (1) bias, (2) variability of difference scores, and (3) regression y-intercept closest to 0, and (4) slope closest to 1. Of the 21 abbreviated sets with 2 indifference points, 3 provided discounting parameter estimates that are statistically equivalent to that obtained with the full set of 7 delays, with 11 (delays: 1 week, 25 years) being the best overall. Of the 35 abbreviated sets with 3 indifference points, 10 provided discounting that were equivalent to the full set. Of those 10 equivalent sets, set 24 (delays: 1 week, 1 year, 25 years), was best overall. Of the 35 abbreviated sets with 4 indifference points, 11 provided discounting that were equivalent to the full set, with set 25 (delays: 1 week, 1 month, 1 year, 25 years) being best overall.

Given the systematic and comprehensive set of analyses conducted with the data from abbreviated sets, future research can be reasonably confident that the use of these abbreviated sets will result in discounting parameter estimates that are equivalent to using the full set with 7 delays, with no loss in sensitivity. While one may continue to employ a more comprehensive set of delays in studies of temporal discounting, the present analyses offer a quantifiably justified procedure that is unbiased, equivalent, and sensitive. Such abbreviated procedures are likely to be of value when the length of a procedure with a comprehensive set of delays is difficult to complete. Whether the population has short attention spans or is particularly subject to fatigue, an abridged procedure employing one of the proposed abbreviated sets of delays is likely to result in data alleviated from concerns about attention or fatigue. The abbreviated procedures are also likely to be useful when the experimenter has a limited amount of time to collect assessments.

The primary limitation of the reported analyses is due to the specifics of the full set of indifference points. The full set of delays were: 1 day, 1 week, 1 month, 6 months, 1 year, 5 years, 25 years – and the discounting parameter estimates for the full set for \$100 and \$1000 hypothetical money outcomes using the hyperbolic model of discounting is the basis of the present analyses. Discount parameters would have been different had the specific delays differed for the full set, if different outcomes had been used, or data were fit to a different discounting model. As such, the results of the equivalence tests and Bland-Altman analysis would also possibly have differed. However, we do know that the delays and magnitudes used in the present analysis effectively differentiate populations, and there is functionally no loss of sensitivity in using the proposed abbreviated sets. In other words, the abbreviated sets provide discounting parameters that are as valid as the full set, which is also valid. Even if these limitations prevent adoption of proposed abbreviated sets, the present analyses provide a blueprint on how to determine appropriate abbreviated sets for any full set of delays in discounting procedures.

A related limitation is that while we propose abbreviated sets, data collection occurred with the full set of delays. Thus, given the potential non-independence of responses (preferences at 1 delay may affect preferences at a different delay), there is no guarantee that the use of the proposed abbreviated sets results in equivalent data. Additionally, use of fewer indifference points to determine a discount rate increases the influence of any single aberrant point and thus may increase random variability. We have collected data using a 7C3 abbreviated set as part of another study, and the results from 34 normal control participants indicates no loss in the ability to detect the ubiquitous magnitude effect in the delay discounting of hypothetical \$50 and \$10,000 rewards ($p < .0001$, $\eta^2 = .79$), providing supporting evidence that data collected with an abbreviated set is not adversely affected (i.e., ability to detect expected differences are maintained) and no indication that error variability is increased. However, the principal concern regarding the non-independence of data is a bigger question about the non-independence of any set of assessments, and not specific to the present report. Thus, we do not address this further.

In conclusion, the present analyses reveal the possibility of assessing temporal discounting using an abbreviated procedure that results in discounting parameter estimates identical with a more comprehensive procedure, with no overall loss of sensitivity. Generally speaking, use of the abbreviated sets listed in Table 3 is a viable option in future studies of temporal discounting, particularly when participant fatigue or limited session durations make the collection of more indifference points problematic.

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Figure 1.

Range of inconsequence (Δ) and Inferential Confidence Intervals (ICI) for the full set (F) and abbreviated sets that were determined to be not significantly different than the full set. The top, middle, and bottom panels represent sets from groupings 7C2, 7C3, and 7C4, respectively for \$100 and \$1000 condition comparisons.

Figure 2.

Regression plots of log-transformed discount rates from the Full (x-axis) and Abbreviated (y-axis) analysis. Dashed lines represent the slope of the regression, with the solid lines indicating a slope of 1. The top, middle, and bottom panels represent sets from groupings 7C2, 7C3, and 7C4, respectively.

Table 1
Summary measures of log-transformed discounting parameters for \$100 and \$1000 future hypothetical money

Amount	Mean $\ln(k)_F$	Std Err	Lower 95% CI	Upper 95% CI	Min	Max
\$100	-6.172	.176	-6.518	-5.826	-12.806	3.603
\$1000	-6.591	.169	-6.923	-6.258	-12.806	2.670

Table 2

Discounting estimates that are not statistically different from baseline discounting parameter ($\ln(k)_F$) at both \$100 and \$1000 amount conditions, using paired t tests.

Grouping/Set	\$100 $\ln(k)_F = -6.172$			\$1000 $\ln(k)_F = -6.591$			Delays					
	t	p		t	p		1d	1 wk	1 mo	6 mo	1 yr	5 yr
7C2/11	-0.057	0.68	0.50	-0.018	-0.22	0.83		✓				✓
7C2/14	-0.025	0.36	0.72	-0.030	-0.47	0.64			✓			✓
7C2/15	0.085	1.26	0.21	0.124	1.72	0.09			✓			✓
7C2/19	0.157	1.89	0.06	-0.017	-0.22	0.83					✓	✓
7C3/5	-0.134	-1.61	0.11	-0.143	-1.77	0.08	✓	✓				✓
7C3/9	-0.068	-1.01	0.31	-0.080	-1.16	0.25	✓		✓			✓
7C3/12	0.019	0.29	0.77	-0.085	-1.25	0.21	✓			✓		✓
7C3/19	-0.013	-0.19	0.85	0.067	0.96	0.34		✓	✓			✓
7C3/21	-0.097	-1.86	0.06	-0.065	-1.26	0.21		✓		✓		✓
7C3/24	-0.021	-0.44	0.66	0.012	0.24	0.81		✓		✓		✓
7C3/25	-0.015	-0.25	0.80	-5.2E-5	-0.01	0.99		✓			✓	✓
7C3/27	-0.038	-0.74	0.46	-0.029	-0.51	0.61			✓			✓
7C3/29	-0.091	-1.70	0.09	-0.048	-0.86	0.39			✓		✓	✓
7C3/30	0.069	1.60	0.11	0.096	1.94	0.05			✓		✓	✓
7C3/32	0.093	1.35	0.18	-0.005	-0.07	0.95				✓	✓	✓
7C4/4	-0.072	-1.09	0.28	-0.038	-0.58	0.56	✓	✓				✓
7C4/7	0.034	0.66	0.51	0.025	0.50	0.62	✓	✓		✓		✓
7C4/10	-0.097	-1.62	0.11	-0.085	-1.46	0.14	✓	✓			✓	✓
7C4/13	0.026	0.56	0.58	-0.013	-0.28	0.78	✓		✓			✓
7C4/15	-0.063	-1.52	0.13	-0.078	-1.87	0.06	✓		✓		✓	✓
7C4/16	-0.038	-0.82	0.42	-0.077	-1.53	0.13	✓		✓		✓	✓
7C4/19	0.040	0.72	0.47	-0.088	-1.46	0.14	✓			✓		✓
7C4/25	-0.041	-1.02	0.31	0.032	0.72	0.47		✓			✓	✓
7C4/26	0.004	0.09	0.93	0.056	1.08	0.28		✓	✓		✓	✓
7C4/30	0.003	0.06	0.95	0.022	0.53	0.59		✓		✓	✓	✓

Grouping/Set	\$100 ln(k) _F =-6.172		\$1000 ln(k) _F =-6.591		Delays					
	t	p	t	p	1d	1 wk	1 mo	6 mo	1 yr	5 yr
7C4/31	-0.075	-1.46	0.14	-0.057	-1.02	0.31	✓	✓	✓	✓

= ln(k)_F - Grouping/Set mean ln(k).

Table 3

Discounting estimates that are statistically the same as baseline discounting parameter ($\ln(k)_F$) at both \$100 and \$1000 amount conditions.

Grouping/Set \$100 & \$1000	Bias	SD	Abr-Full (intercept)	Abr-Full (slope)	Delays					
					1 d	1 wk	1 mo	6 mo	1 yr	5 yr
7C2/11	-0.038	1.353	-0.076	0.982	✓	✓				✓
7C2/15	0.104	1.138	-0.444	0.947			✓			✓
7C2/14	-0.028	1.110	-0.981	0.842			✓			✓
7C3/24	-0.004	0.786	0.019	1.002	✓	✓			✓	✓
7C3/25	-0.007	0.981	-0.055	0.990	✓	✓			✓	✓
7C3/19	0.026	1.116	-0.181	0.975	✓	✓	✓			✓
7C4/25	-0.004	0.688	-0.097	0.984	✓	✓	✓		✓	✓
7C4/30	0.012	0.687	-0.143	0.979	✓	✓			✓	✓
7C4/26	0.029	0.791	-0.187	.975	✓	✓	✓		✓	✓