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A TUTORIAL ON THE USE OF EXCEL 2010 AND EXCEL FOR MAC 2011 FOR CONDUCTING DELAY-DISCOUNTING ANALYSES

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In recent years, researchers and practitioners in the behavioral sciences have profited from a growing literature on delay discounting. The purpose of this article is to provide readers with a brief tutorial on how to use Microsoft Office Excel 2010 and Excel for Mac 2011 to analyze discounting data to yield parameters for both the hyperbolic discounting model and area under the curve. This tutorial is intended to encourage the quantitative analysis of behavior in both research and applied settings by readers with relatively little formal training in nonlinear regression.

Key words: behavioral economics, delay discounting, impulsivity, Microsoft Excel, technology

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The goal of this technical article is to present researchers with a tutorial on how to conduct both nonlinear regression and area under the curve (AUC) estimations using Microsoft Office Excel 2010 and Excel for Mac 2011 (hereafter referred to simply as Excel) to analyze delay-discounting data. Analyses of delay discounting (the process by which delayed rewards have lower subjective values than sooner rewards of the same magnitude) have become increasingly popular due to their ability to allow researchers to investigate the temporal properties of reward for socially important problems (see Critchfield & Kollins, 2001; Madden & Bickel, 2010). Specifically, this operationalization of decision making is translated easily to issues concerning impulsivity and self-control. For instance, behavior analysts have come to define a form of impulsivity as preference for a smaller sooner reward, despite a larger delayed alternative being available (see Schweitzer & Sulzer-Azaroff, 1988). This behavioral interpretation of impulsivity has led to numerous advances in clinical issues such as increasing tolerance to reinforcement delay in individuals with acquired brain injury or autism (Dixon & Cummings, 2001; Dixon & Falcomata, 2004), as well as in the general assessment of impulsivity in children with attention deficit hyperactivity disorder (ADHD; Hoerger & Mace, 2006; Neef et al., 2005), serious emotional disturbance (e.g., Neef, Mace, & Shade, 1993), and severe problem behaviors (e.g., Vollmer, Borrero, Lalli, & Daniel, 1999).

Collecting Discounting Data

The commonly used procedure for studying discounting is the administration of a series of hypothetical monetary choice trials (see Critchfield & Kollins, 2001; Madden & Johnson, 2010). Typically, hypothetical monetary choice paradigms feature a titrating series of choices between smaller sooner rewards (SSRs) and a larger later reward (LLR). The point at which an individual switches from choosing the LLR to the SSR is commonly termed *the indifference point.* This indifference point serves as an estimation of the *subjective value* of the LLR after some delay. This methodology then is replicated across numerous delay values (i.e., the delay until the receipt of the LLR) to arrive at an understanding of the individual's preference

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for reward over time (the reader is encouraged to consult Madden & Johnson, 2010, for a lengthier discussion on discounting assessment methodology). As the reader may surmise, the employment of hypothetical choice, as well as the use of verbal self-report, is a substantial deviation from the direct measurement techniques usually used in behavior-analytic studies. Nevertheless, numerous studies have demonstrated that values obtained from hypothetical choices correlate with values obtained from actual rewards (see Johnson & Bickel, 2002; Lagorio & Madden, 2005; Madden, Begotka, Raiff, & Kastern, 2003; Madden et al., 2004).

Quantifying Degree of Discounting

In the quantitative analysis of discounting, the hyperbolic model predicts that subjective values decrease as a hyperbolic decay function over time (Mazur, 1987; Myerson & Green, 1995). In the hyperbolic model (Equation 1), V represents the subjective value of an LLR amount (A) at a given delay (D):

$$V = A/(1 + kD). \qquad (1)$$

The parameter k is a free parameter that denotes the degree of discounting (or the discounting rate) observed in the data path (i.e., steepness of the curve or how fast the value drops as a function of delay). Parameter k is thus the dependent variable in quantitative studies of discounting. Higher k values translate to higher degrees of discounting or impulsivity. To determine k, the researcher must plot the subjective values against reward delays. The researcher then uses least squares nonlinear regression to fit a curve to the data points.

Describing participant patterns of discounting presents numerous analytical challenges for researchers who are unfamiliar with advanced statistics because of reliance on nonlinear regression models. Although a full understanding of how nonlinear regression works requires mastery of matrix algebra, the basic method is relatively easy to follow. First, the researcher is required to enter the numerical value of the dependent variable at each level of the independent variable (or the subjective value of the LLR or indifference point at each delay value in the case of delay discounting) into the quantitative model. Next, a best fit line (or curve) is generated according to those initial values. Specifically, a best fit line or curve is generated by estimating a free parameter (e.g., k) within the model until the vertical difference between each observed data point and the estimated point (called the *residual value*) on the line is minimized to the smallest possible value (see Figure 1). In particular, the regression process calculates the smallest grand sum of the squared residuals, which is why this process is termed *least squares* regression (for a thorough discussion on this topic, see Motulsky & Christopoulos, 2004). Through this iterative line curve-fitting process, the free parameter value (e.g., k in discounting models) is identified. Because of this iterative process, nonlinear regression is most efficiently and accurately completed with the aid of computer software. Unfortunately, nonlinear regression programs are substantially more expensive than Excel. For instance, GraphPad Prism is a program frequently cited in discounting literature due to its relative ease of use in conducting extremely precise nonlinear regression analyses. GraphPad Prism costs approximately $450 for one academic license ($300 for one student license; http://www.graphpad.com), whereas a full-version Excel 2010 costs only $140 (http://office.microsoft.com). Moreover, many agencies and institutions supply users with complimentary copies of Excel or offer the program at greatly reduced prices. Thus, the focus of the remaining technical article is on using Excel to conduct discounting analyses. Note that we restrict the scope of this paper to the hyperbolic model and AUC approaches for the sake of parsimony.[1]

Despite the advantages of describing discounting using a quantitative model, the reader should be advised that limitations exist with

[1]For a discussion on the differing quantitative models of discounting, the reader is encouraged to consult McKerchar et al. (2009) and Myerson and Green (1995).

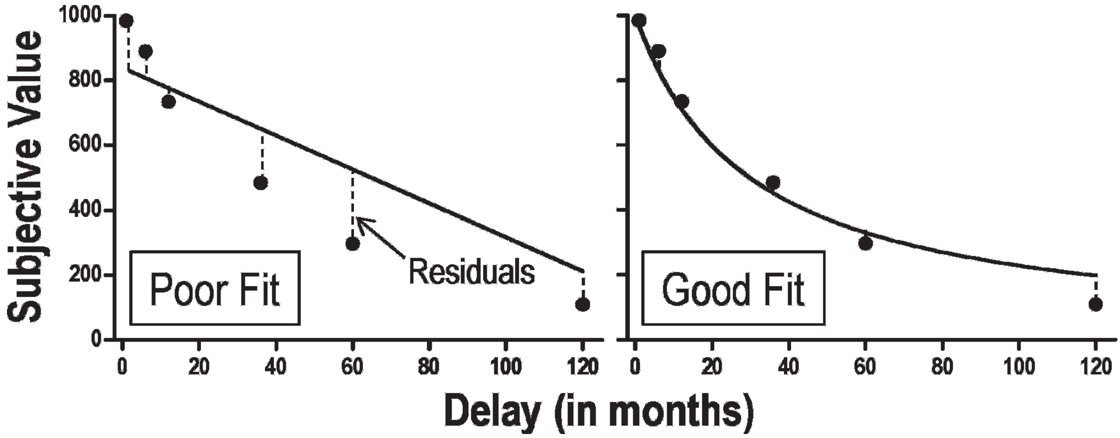

Figure 1. A depiction of how residuals are utilized in nonlinear regression.

such analyses. For example, numerous preference reversals could prohibit statistical software from fitting a line to the data. Also, using nonlinear regression merely estimates a description of the participants' decision-making tendencies. For those who wish to analyze data without necessarily conforming to the assumptions of theoretical models or using nonlinear regression, Myerson, Green, and Warusawitharana (2001) proposed that AUC may be used to estimate degrees of discounting. Using AUC may be especially advantageous in novel applications or translational research in which theories of decision making or impulsivity are not necessarily the focus of study (i.e., the researcher simply wants to use AUC as a dependent variable without theorizing models of decision making or impulsivity). To conduct AUC calculations, the analyst plots indifferent points on the *y* axis as a function of delay plotted along the *x* axis. In this technique, lines are drawn connecting data points, with vertical lines drawn from the *x* axis to each indifference point to generate a series of trapezoids. For example, in Figure 2, a series of trapezoids were generated based on hypothetical discounting data (see the case example presented below). The inset of Figure 2 depicts the trapezoid generated between delays of 270 and 520 days. A step-by-step depiction of this process applied to the trapezoid between 270 and 520 days is shown in Figure 2. The area of the trapezoid is determined by calculating the height of each side of the trapezoid (Step 1; top panel of inset), calculating the width of the trapezoid (Step 2; middle panel of inset), and multiplying the average of the two heights by the width (Step 3; bottom panel of inset). Using this technique, the analyst can then sum the areas of all the derived trapezoids to yield an AUC estimate. The equation for this analysis is

$$\text{AUC} = \sum (x_2 - x_1)\left[\frac{(y_1 + y_2)}{2}\right], \quad (2)$$

where x_1 and x_2 are successive delay value, and y_1 and y_2 are the subjective values or indifference points associated with those delays. Thus, the total AUC negatively correlates with *k* values derived from the quantitative models discussed above, such that steep discounters (i.e., relatively impulsive responders) with high *k* values will have low AUC. Finally, to calculate a total proportion of AUC, the summed AUC is divided by the total possible AUC. The total possible AUC is equal to the maximum delay (width) multiplied by the undiscounted amount (height).

Practical Utility of a Quantitative Analysis of Discounting

Notwithstanding the clinical interest in the promotion of self-control and the advantages of using discounting analyses to understand

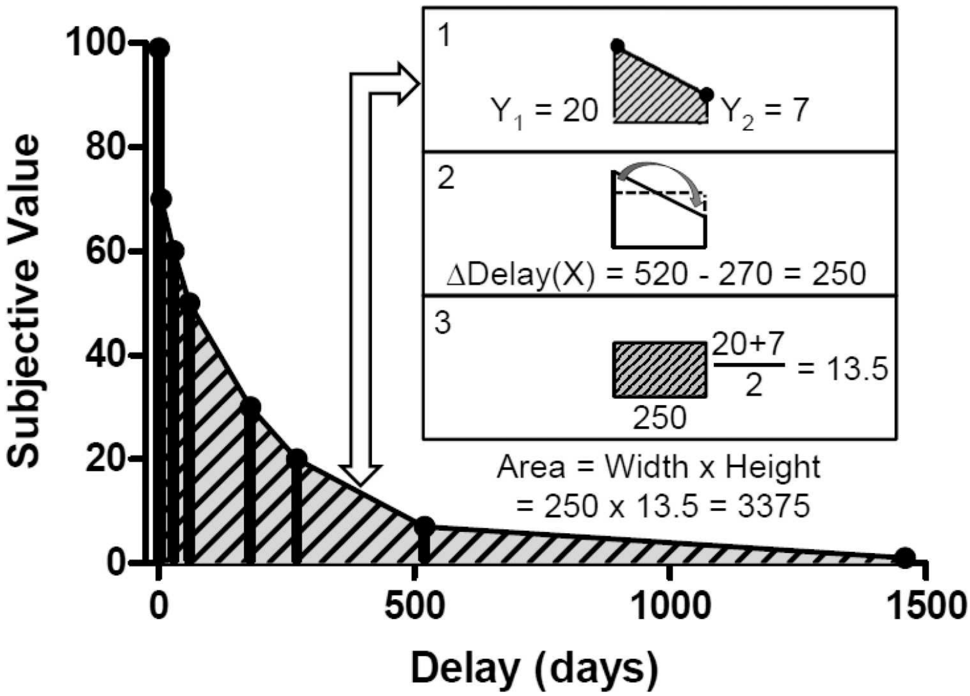

Figure 2. Graphical depiction of hypothetical discounting data from the case example. Vertical lines dropped from each data point depict delineation of trapezoids used to calculate AUC. Inset describes the process of calculating the area of each trapezoid (see text for details).

socially important behaviors (see Critchfield & Kollins, 2001), only four articles to date in *JABA* (only 0.78% of those in PsycINFO) have explicitly examined discounting using conventional quantitative methods (Dixon & Holton, 2009; Dixon, Jacobs, & Sanders, 2006; Dixon, Marley, & Jacobs, 2003; Reed & Martens, 2011). PsycINFO searches of *self-control* and *impulsivity* yielded an additional 36 relevant articles in *JABA*. Thus, although behavior analysts are interested in these topics, the majority of these studies did not employ assessments of discounting in their procedures. Which behavioral variables could account for the relatively low number of submissions using quantitative models of discounting to *JABA*? Critchfield and Reed (2009) hypothesize that applied behavior analysts may be hesitant to use such procedures because they lack formal training in such methods or view the use of equations as an overly complicated and difficult contribution to the analysis of operant behavior. Although the methods to obtain discounting parameters or estimates are indeed seemingly complex due to nonlinear regression models, they may be completed through the aid of spreadsheet applications such as Excel. The purpose of this paper is to provide a rudimentary review of how these calculations are performed, and to provide a task analysis to aid the reader in creating an Excel-based calculator for use in analyzing discounting data. The procedures we detail in this article supplement those provided by Dallery and Soto in a recent workshop at the Association for Behavior Analysis International (2010). We hope that the provision of these analytical methods will encourage researchers to conduct quantitative discounting analyses in an effort to add further breadth to this growing literature. Moreover, we hope that this article will help to ease readers' concerns that they lack the quantitative training or ability to conduct such analyses, because we present the reader with the means to analyze such data. Preparing researchers and clinicians to translate from quantitative models (e.g., in the present case, discounting) will further our field's mission to contribute to the broader behavioral sciences by achieving "innovation through synthesis" (Mace & Critchfield, 2010, p. 296). That is, modeling the discounting phenomenon and integrating these findings with those from other disciplines to address concerns of the human condition will help researchers and practitioners to improve measurement of the processes that underlie choice. Specifically, in the case of discounting, there is great potential for behavior analysts to affect diverse disciplines due to the increasing interest in discounting by behavioral, cognitive, and social psychologists (e.g., Rachlin, 1989; Waltz & Follette, 2009), as well as behavioral (e.g., Madden & Bickel, 2010) and neuroeconomists (e.g., Ayres, 2010).

A Case Example

Here is a scenario in which a behavioral scientist might find the tutorial useful. You are a researcher interested in determining whether a behavioral account of impulsivity (i.e., discounting) can predict sixth-grade students' performance on commonly used continuous performance tasks in the diagnosis of ADHD (e.g., the Gordon Diagnostic System [GDS], 1983, and the Conners Continuous Performance Test II Version 5 [CPT-II], 2004). For the discounting portion of your study, you plan to administer a child-adapted discounting procedure (e.g., Reed & Martens, 2011) to derive the discounting parameter *k,* as well as AUC. To determine the predictive validity of the discounting task for use in ADHD screenings, you will compare the derived discounting scores (*k* and AUC) with scores obtained from the GDS and the CPT-II Version 5. For the sake of this tutorial, we will focus only on how to derive the discounting parameters.

As described above, the discounting parameters are derived from the participants' series of choices between an SSR (values less than $100 that adjust following each response; see Madden & Johnson, 2010, for examples of this adjustment procedure) and an LLR (in this example, always $100) across varying lengths of delay (i.e., the delay until the receipt of the LLR). In this case, you choose the delay values (in days; adapted from Reed & Martens, 2011) of 1, 5, 30 (i.e., 1 month), 60 (i.e., 2 months), 180 (i.e., 6 months), 270 (i.e., 9 months), 520 (i.e., ≈1.5 years), and 1,460 (i.e., 4 years) days. The observed subjective values yielded by your assessment for one participant are 99, 70, 60, 50, 30, 20, 7, and 1, respectively (across delays of 1 day to 1,460 days). The remainder of this article will discuss the procedures to derive discounting scores (*k* and AUC) for this participant (and conceivably others).

TUTORIAL ON CREATING THE CALCULATOR

Creating the Workbook

1. Open a new blank workbook in Excel 2010. Label the tab for this worksheet at the bottom of the screen (currently labeled "Sheet1") "MyData" (do not include a space between the words "My" and "Data") by double-clicking on the label "Sheet1" to highlight the words, and then typing the word "MyData." Use this procedure throughout the tutorial to change the tab names.
2. Prepare the "MyData" tab to resemble Panel A in Figure 3. Cells A1 and B1 are highlighted to prompt the user to enter data under these cells in order to run the analysis described later in this tutorial.
3. Next, recreate the data from the case example (described above) in the workbook by inputting the delay values in days (only the numerical values; i.e., 1, 5, 30, 60, 180, 270, 520, 1460; do not include the word

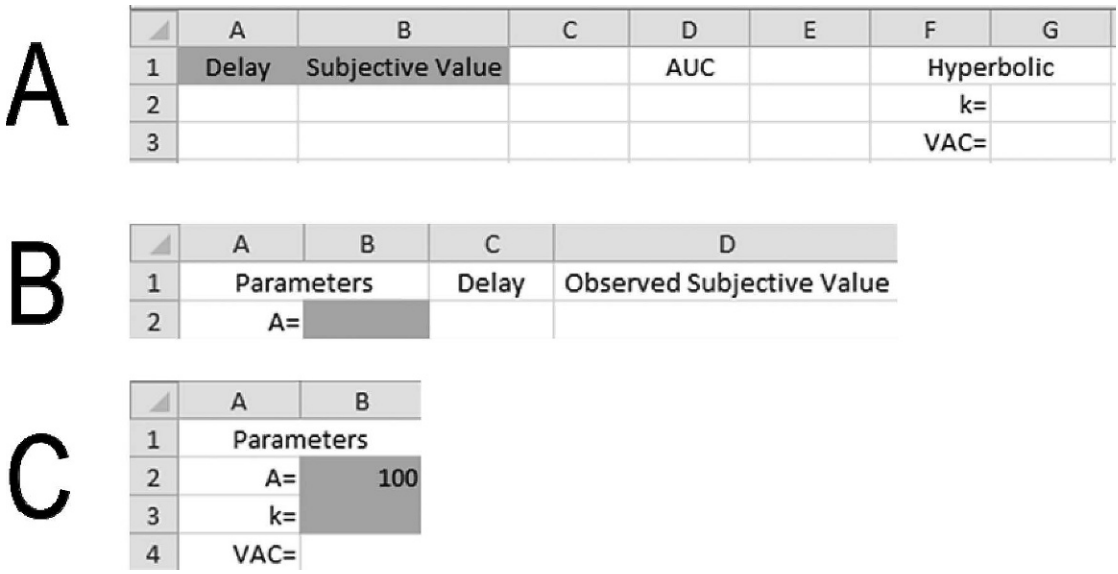

Figure 3. Screen shots depicting how (A) the "MyData" tab, (B) the "Template" tab and (C) Columns A and B of the "Hyperbolic" tab should be formatted.

"days") in Column A (Cells A2 through A9) and the subjective value of $100 at each delay in Column B (Cells B2 through B9; 99, 70, 60, 50, 30, 20, 7, and 1, respectively; do not include the $ sign). Note that these values will change depending on the researcher's experimental questions and dependent variables.[2]

4. If you have not done so already, save the workbook by clicking on the FILE tab in the upper left corner of the screen, and then select SAVE AS. Select the file location you would like to save the workbook to, and then type "Discounting Calculator" into the FILE NAME box, and then click the SAVE button.

Installing the Solver Add-In

To conduct the regression analyses, the Solver Add-In for Excel is necessary.

1. Click on the DATA tab on the Excel ribbon bar at the top of the screen. If the word "Solver" appears at the far right side of the toolbar (in the ANALYSIS section), Solver is already installed. If this is case, skip to the next section.
2. To install the Solver Add-in for Windows, click FILE and then OPTIONS to pull up the Excel options window. However, for Excel for Mac 2011, Solver may be downloaded at http://www.solver.com/mac/dwnmac2011solver.htm (instructions for installation also may be found on this website).
3. Click on ADD-INS on the left column.

[2]Often, researchers are interested in the differences in discounting between special populations and the norm (e.g., gamblers vs. nongamblers, substance abusers vs. nonsubstance abusers, etc.) or across parametric variables (e.g., age, income, etc.). In such cases, the researcher may want to fit the discounting model to an entire group's data set. A commonly used approach to model group discounting is to calculate the median subjective value of the group at each delay. The median values then may be analyzed as if they were obtained from an individual participant. For the sake of this calculator, the median values of the group may be entered into the Subjective Value column on the "MyData" tab in the initial stages of analysis. Unfortunately, designing an Excel calculator to analyze all participants simultaneously is outside of the scope of this tutorial. For large-group analyses that warrant an efficient means of analysis, we recommend the reader use GraphPad Prism 5.

4. Use the dropdown menu next to MANAGE towards the bottom middle of the table to select EXCEL ADD-INS, and then click GO.
5. Under the ADD-INS menu, check the SOLVER ADD-IN box, and click OK.
6. Click on the DATA tab on the Excel ribbon bar at the top of the screen. At the far right corner, "Solver" should now appear on the screen.
7. Save the spreadsheet.

Creating the Calculator Template

1. Open a new blank worksheet by clicking the icon to the right of the "MyData" tab (Sheet2) on the bottom of the screen. Relabel this tab "Template."
2. Prepare the "Template" tab to resemble Panel B of Figure 3.
3. Next, program Excel to read the LLR amount value from Cell B2 by clicking on Cell B2. You will notice that "B2" appears in the NAME BOX to the left of the formula bar and directly above Column A. Change the "name" of this cell to "A" by clicking the "B2" in the NAME BOX and typing "A" and pressing the ENTER key. Now, when you click on Cell B2, "A," rather than "B2," will appear in the NAME BOX.
4. Because the running example consists of an LLR of $100, type "100" in Cell B2 as the amount to be used in the calculations.
5. In Cell C2, type "=IF(ISNUMBER(MyData!A2),MyData!A2,"")" and press ENTER. The command "IF(ISNUMBER" tells Excel to predict only a subjective value if a delay value is entered into the referenced cell. Note that "" consists of open and closed double quotes ("") with no space between the two. This will be employed throughout this tutorial. The number "1" should now appear in Cell C2. Click on Cell C2, and then place the mouse cursor over the small black square in the lower right corner of Cell C2 until the cursor becomes a cross. Click and hold the left mouse button down on the small black square. Drag the cursor down to Cell C101 and then release. This process is known as "drag and drop" and will be referenced as such throughout the remainder of this tutorial. Using this command, the calculator will conduct analyses based on 100 possible delay values.
6. With all 100 cells (C2 to C101) selected, drag and drop Cells C2 through C101 to the D column by dragging to the right one column.
7. Scrolling to the top of the spreadsheet, you should now see that the delay and subjective values from the "MyData" worksheet now appear in Cells C2 through C9 and D2 through D9, respectively. This process programs the calculator to read up to 100 delay and subjective values from the "MyData" tab.
8. Create a copy of this tab by right-clicking on the newly created "Template" tab at the bottom of the screen, clicking MOVE OR COPY, selecting (MOVE TO END) under the BEFORE SHEET header, and then checking the CREATE A COPY box. You will now have a duplicate tab named "Template (2)."
9. Save the spreadsheet.

Creating the AUC Calculator

1. Click on the "Template" worksheet tab. Double-click on the tab label "Template," to select the title, and type "AUC."
2. Type "Area of Trapezoid," "Total Possible Area," and "Proportion AUC" in Cells E1, F1, and G1, respectively.
3. In Cell E2, type "=IF(ISNUMBER(C2),(C2)*((D2)/2),"")." This algorithm programs Excel to calculate the area of the trapezoid between the origin (delay value of zero) and the first delay value, for use in calculating AUC using Equation 2.

A number approximating 49.50 should now appear in Cell E2.

4. In Cell E3, type "=IF(ISNUMBER(C3),(C3-C2)*((D3+D2)/2),"")." This algorithm programs Excel to calculate the area of the trapezoid between the first and second delay values, for use in calculating AUC using Equation 2. A number approximating 338 should now appear in Cell E3.
5. Drag and drop the formula in E3 into Cells E4 through E101. This will fill all the cells with the equation, and will calculate the area of each trapezoid in the E column for each delay value entered in the C column. Data should now appear in Cells E3 through E9.
6. In Cell F2, type "=(MAX(C:C)*A)" to program Excel to determine the maximum possible AUC, if no discounting occurred. Specifically, this algorithm multiplies the maximum delay value in Column C by the LLR amount. The value "146000" should now appear in Cell F2.
7. In Cell G2, type "=IFERROR(SUM(E2:E101)/F2,"")." This command programs Excel to divide the grand sum of Column E (the areas of the trapezoids), and divides this sum by the maximum area possible to yield a proportion of AUC. A value approximating 0.122 should now appear in Cell G2.
8. Save the spreadsheet.

Creating the Hyperbolic Model Calculator

1. Click on the "Template (2)" worksheet tab. Double-click on the tab label "Template (2)," to select the title, and type "Hyperbolic."
2. Prepare Columns A and B of the "Hyperbolic" tab to resemble Panel C of Figure 3. Type "Predicted Subjective Value," "Residual Squared," "Sum of Squares Regression," "Distance," and "Sum of Squared Difference" in Cells E1, F1, G1, H1, and I1, respectively.
3. Next, program Excel to read the *k* value from Cell B3 by clicking on Cell B3. You will notice that "B3" appears in the NAME BOX to the left of the formula bar and directly above Column A. Change the "name" of this cell to "k" by clicking the "B3" in the NAME BOX, typing "k," and pressing ENTER. Now, when you click on Cell B3, "k" (rather than "B3") will appear in the NAME BOX.
4. Solver must begin the iterative process with an initial value to derive each free parameter. Using Madden and Johnson's (2010) description of a "modest" rate of discounting, enter a *k* value of .05 in Cell B3. Note that Solver will adjust this amount to best fit the data when the nonlinear regression procedure is employed in later steps of this tutorial. Thus, the derived value (i.e., following the curve fitting) may differ substantially from the initial value.
5. Next, prepare Excel to predict the subjective value of the LLR amount at the first delay value by entering the discounting equation in Cell E2. Specifically, click on Cell E2 and type "=IF(ISNUMBER(C2),A/(1+k*C2),"")." A value approximating 95.24 will now appear in Cell E2.
6. Drag and drop the formula in E2 into Cells E3 through E101. This will fill all the cells with the equation, and will predict subjective values in the E column for each delay value entered in the C column. Data should now appear in Cells E3 through E9.
7. In Cell F2, type "=IF(ISNUMBER(E2),(E2-D2)^2,"")." A value approximating 14.15 will now appear in Cell F2. This command is squaring the difference between predicted and observed subjective values. This is used to determine how well the observed data conform to the theoretical model of discounting, which is used to determine the variance accounted for by the model (i.e., VAC or R^2). Drag and drop Cell F2 into Cells F3 through F101.

Data now will appear in Cells F3 through F9.

8. In Cell G2, type "=SUM(F2:F101)." A value approximating 1721.84 now will appear in Cell G2. This command sums all the squared differences in the F column. In least squares regression (which is what will be used by Solver to determine the discounting parameters in this tutorial), the sum of squares is minimized as best as possible.

   In Cell H2, type "=IF(ISNUMBER(D2),(D2-(AVERAGE($D$2:$D$101)))^2,"")." A value approximating 3234.77 will now appear in Cell H2. Drag and drop Cell H2 into Cells H3 through H101. Data now will appear in Cells H2 through H9. This command squares the difference between the observed subjective value at each delay and the average of the observed subjective values as part of the regression analysis.
9. In Cell I2, type "=SUM(H2:H101)" to sum the squared distance scores from the F column. A value approximating 7954.88 now will appear in Cell I2.
10. Because Cell B4 will display the VAC by the hyperbolic model, change the "name" of this cell to "VAC" by clicking the "B4" in the NAME BOX, typing "VAC" and pressing ENTER. At this point, when you click on Cell B4, "VAC"(rather than "B4") will appear in the NAME BOX.
11. In Cell B4, type "=IFERROR(1-(G2/I2),"")." The "IFERROR" command programs Excel to return a value only if there are valid data in Cells G2 and I2. This command programs Excel to return the VAC by subtracting the ratio of the sum of squares from regression to the sum of squared differences from 1. A value approximating .78 now will appear in Cell B4.
12. Save the spreadsheet.

Finalizing the MyData Tab

1. Click on the "MyData" tab.
2. In Cell D2, type "=AUC!G2." This command programs Excel to extract the data displayed in Cell G2 of the "AUC" tab in Cell D2 of the "MyData" tab.
3. In Cells G2 and G3, type "=Hyperbolic!B3" and "=Hyperbolic!B4," respectively. The data from the hyperbolic calculator now will appear in Cells G2 and G3.
4. Save the spreadsheet.

Using Solver to Perform Nonlinear Regression with the Hyperbolic Model

1. Click on the "Hyperbolic" tab.
2. Click on the DATA tab on the Excel ribbon toolbar, and click on SOLVER. Use Figure 4 to complete the Solver Parameters menu. Click ADD to add a constraint stipulating that *k* must be greater than or equal to zero. In the resulting window, type "k" in the left box, select ">=" from the dropdown menu in the middle box, and type "0" in the right box. Click OK to close the window.
3. Click OPTIONS to the right of the dropdown menu featuring the text "GRG Nonlinear." Under the ALL METHODS tab, type "100000" in the ITERATIONS box under the SOLVING LIMITS header. Click OK. Note that in earlier versions of Excel, the number of iterations is constrained to just 10,000. This is still a sufficient number for the sake of these analyses.
4. The SOLVER PARAMETERS menu now should appear identical to that in Figure 4. Click SOLVE.
5. The SOLVER RESULTS box will now appear. By default, KEEP SOLVER SOLUTION will be checked. Click OK to return to the spreadsheet to view the results. You will notice that Cell B3 (the *k* value) now displays "0.01923." This is the *k* value that nonlinear regression solved for. You also will notice that the VAC in Cell B4 indicates that the hyperbolic model accounts for .9297 (92.98%) of the variance in the data.

Figure 4. Screen shot of the Solver Parameters menu window associated with Step 3 of the Using Solver to Perform Nonlinear Regression with the Hyperbolic Model procedures.

6. Clicking on the "MyData" tab at the bottom of the screen will return you to the data entry worksheet. You will notice that the hyperbolic model parameters now are updated with those obtained from the nonlinear regression.
7. Save the spreadsheet.

SUMMARY

The Microsoft Office Excel spreadsheet program has utility in various behavior-analytic activities, ranging from single-subject design graphing (Carr & Burkholder, 1998; Dixon et al., 2009) to more complicated procedures such as conducting matching analyses (Reed, 2009) and generating reinforcement schedules (Bancroft & Bourret, 2008). In this article, we have described two simple ways to perform traditional delay discounting analyses to assist readers.[3] Given the growing interest in self-

[3]This calculator was validated using the raw data and derived discounting parameters reported in Dixon et al. (2006). Specifically, we reanalyzed the data in Table 1 in Dixon et al. using our calculator, and found the same results for all participants. We then reanalyzed these data using the nonlinear regression function in GraphPad Prism 5, and yielded discounting parameters equal to those derived from our Excel calculator.

control/impulsivity assessment and treatment, as well as in the processes that underlie choice and discounting, we hope this tutorial encourages researchers to use discounting models as an additional analytic tool in self-control or decision-making research. Many interesting extensions of discounting are possible, and the field remains wide open for such innovative translation.

Understanding population differences is an important step in developing behavioral models of impulsive behaviors. A potential advantage to this approach is that quantitative models may lead to insights for more sophisticated treatments that would not otherwise be achieved (see Waltz & Follette, 2009). To date, only one study in *JABA* has investigated discounting with children (Reed & Martens, 2011); thus, more work in this area is warranted. Likewise, using the quantitative measures yielded by discounting analyses, behavior analysts can offer a scientifically valid pre- and posttreatment measure to evaluate the effects of behavioral interventions (as in Dixon & Holton, 2009). Moreover, discounting parameters such as *k* or AUC are understood by a wide range of social scientists outside behavior analysis, offering behavioral researchers a metric that has transdisciplinary utility that ultimately may increase the impact of their research. For researchers interested in other modalities of discounting, please note that only slight modifications to the current spreadsheet are necessary to perform probability discounting analyses (see Green, Myerson, & Ostaszewski, 1999; Rachlin, Raineri, & Cross, 1991).

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