Manual for Delay Discounting Task

Data Output

The data file for the delay discounting task can be found at C:\\Documents\PEBL 2.0\battery\Delay Discounting\data\participant code number

	A	B	C	D	E	F	G	H
1	subnum	trial	stim	type	resp	corr	rt	
2	10	1	Rs 2500 n	W	<rshift>	0	3114	
3	10	2	Rs 1000 nc	L	<lshift>	0	3766	
4	10	3	Rs 4500 nc	L	<lshift>	0	4463	
5	10	4	Rs 70 now	W	<rshift>	0	2111	
6	10	5	Rs 3500 n	L	<rshift>	1	1559	
7	10	6	Rs 70 now	L	<lshift>	0	2543	
8	10	7	Rs 1500 n	L	<rshift>	1	3375	
9	10	8	Rs 50 now	L	<lshift>	0	1879	
10	10	9	Rs 2500 n	L	<rshift>	1	1367	
11	10	10	Rs 3000 n	W	<rshift>	0	1384	
12	10	11	Rs 4500 nc	W	<rshift>	0	1168	
13	10	12	Rs 1000 n	L	<lshift>	0	1488	
14	10	13	Rs 3500 n	L	<lshift>	0	2303	
15	10	14	Rs 1500 n	W	<rshift>	0	1560	
16	10	15	Rs 1500 n	L	<lshift>	0	1743	
17	10	16	Rs 1500 n	W	<rshift>	0	2215	
18	10	17	Rs 80 now	W	<lshift>	1	3447	
19	10	18	Rs 1000 n	W	<rshift>	0	1551	
20	10	19	Rs 30 now	L	<rshift>	1	2334	
21	10	20	Rs 500 no	L	<rshift>	1	1671	
22	10	21	Rs 2500 n	W	<rshift>	0	1135	
23	10	22	Rs 10 now	W	<rshift>	0	1527	
24	10	23	Rs 60 now	W	<lshift>	1	2487	
25	10	24	Rs 30 now	W	<rshift>	0	2799	

Figure 1

Step 1: Data sorting

In Figure 1, a screenshot of the actual data file is given. From the columns given, only two columns need to be retained **(stim** and **resp).** The remaining columns can be removed and serve no function in the latter analysis. After removing the unrequired columns, the data file will look like Figure 2, given below.

▲	A	B	C	D	E
1	stim	resp			
2	Rs 40 now or Rs 100 in 1 week	<rshift>			
3	Rs 5000 now or Rs 5000 in 1 week	<lshift>			
4	Rs 3500 now or Rs 5000 in 1 month	<rshift>			
5	Rs 50 now or Rs 100 in 12 months	<lshift>			
6	Rs 4500 now or Rs 5000 in 3 months	<lshift>			
7	Rs 90 now or Rs 100 in 3 months	<lshift>			
8	Rs 1 now or Rs 100 in 3 months	<rshift>			
9	Rs 2500 now or Rs 5000 in 3 months	<rshift>			
10	Rs 30 now or Rs 100 in 1 month	<rshift>			
11	Rs 80 now or Rs 100 in 12 months	<lshift>			
12	Rs 2000 now or Rs 5000 in 3 months	<lshift>			
13	Rs 1500 now or Rs 5000 in 1 month	<rshift>			
14	Rs 40 now or Rs 100 in 3 months	<rshift>			
15	Rs 1 now or Rs 5000 in 12 months	<rshift>			
16	Rs 1 now or Rs 100 in 1 week	<rshift>			
17	Rs 500 now or Rs 5000 in 1 week	<lshift>			
18	Rs 30 now or Rs 100 in 12 months	<lshift>			
19	Rs 1 now or Rs 5000 in 1 month	<rshift>			
20	Rs 1 now or Rs 100 in 12 months	<rshift>			
21	Rs 50 now or Rs 100 in 1 week	<rshift>			

Figure 2

In Figure 2, only two columns have been retained, which includes the exact stimulus on screen (**stim**) and the response of the participant (**resp**). In the modified delay discounting task, there are a total of 88 trials, which has to be separated into eight blocks based on the **length of delay** and **amount of fixed delay reward**. The matrix below provides an idea

Rs 100 in 1 week	Rs 5000 in 1 week
Rs 100 in 1 month	Rs 5000 in 1 month
Rs 100 in 3 months	Rs 5000 in 3 months
Rs 1000 in 12 months	Rs 5000 in 12 months

As given in the matrix, there are a total of four delay periods (**1 week, 1 month, 3 months, 12 months**) for which two reward amounts are tested (**Rs 100, Rs 5000**). In each block, there is a total of 11 trials which represents increasing amounts of immediate reward in proportion to the fixed delayed reward. The proportions are **1%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100%** of the fixed delayed reward. The 1% and 100% immediate rewards are included as

control items in order to assess consistency of responses. When the data output file is arranged according to the matrix given above, it will look like Figure 3, given below

1	Rs 1 now or Rs 100 in 1 week	\<rshift\>	Rs 1 now or Rs 5000 in 1 week	\<rshift\>
2	Rs 10 now or Rs 100 in 1 week	\<rshift\>	Rs 500 now or Rs 5000 in 1 week	\<rshift\>
3	Rs 20 now or Rs 100 in 1 week	\<rshift\>	Rs 1000 now or Rs 5000 in 1 week	\<lshift\>
4	Rs 30 now or Rs 100 in 1 week	\<rshift\>	Rs 1500 now or Rs 5000 in 1 week	\<rshift\>
5	Rs 40 now or Rs 100 in 1 week	\<rshift\>	Rs 2000 now or Rs 5000 in 1 week	\<rshift\>
6	Rs 50 now or Rs 100 in 1 week	\<lshift\>	Rs 2500 now or Rs 5000 in 1 week	\<rshift\>
7	Rs 60 now or Rs 100 in 1 week	\<rshift\>	Rs 3000 now or Rs 5000 in 1 week	\<rshift\>
8	Rs 70 now or Rs 100 in 1 week	\<rshift\>	Rs 3500 now or Rs 5000 in 1 week	\<rshift\>
9	Rs 80 now or Rs 100 in 1 week	\<rshift\>	Rs 4000 now or Rs 5000 in 1 week	\<lshift\>
10	Rs 90 now or Rs 100 in 1 week	\<rshift\>	Rs 4500 now or Rs 5000 in 1 week	\<rshift\>
11	Rs 100 now or Rs 100 in 1 week	\<lshift\>	Rs 5000 now or Rs 5000 in 1 week	\<rshift\>
12				
13	Rs 1 now or Rs 100 in 1 month	\<rshift\>	Rs 1 now or Rs 5000 in 1 month	\<rshift\>
14	Rs 10 now or Rs 100 in 1 month	\<rshift\>	Rs 500 now or Rs 5000 in 1 month	\<rshift\>
15	Rs 20 now or Rs 100 in 1 month	\<lshift\>	Rs 1000 now or Rs 5000 in 1 month	\<rshift\>
16	Rs 30 now or Rs 100 in 1 month	\<lshift\>	Rs 1500 now or Rs 5000 in 1 month	\<lshift\>
17	Rs 40 now or Rs 100 in 1 month	\<lshift\>	Rs 2000 now or Rs 5000 in 1 month	\<rshift\>
18	Rs 50 now or Rs 100 in 1 month	\<lshift\>	Rs 2500 now or Rs 5000 in 1 month	\<rshift\>
19	Rs 60 now or Rs 100 in 1 month	\<rshift\>	Rs 3000 now or Rs 5000 in 1 month	\<rshift\>
20	Rs 70 now or Rs 100 in 1 month	\<rshift\>	Rs 3500 now or Rs 5000 in 1 month	\<lshift\>
21	Rs 80 now or Rs 100 in 1 month	\<rshift\>	Rs 4000 now or Rs 5000 in 1 month	\<lshift\>
22	Rs 90 now or Rs 100 in 1 month	\<rshift\>	Rs 4500 now or Rs 5000 in 1 month	\<lshift\>
23	Rs 100 now or Rs 100 in 1 month	\<lshift\>	Rs 5000 now or Rs 5000 in 1 month	\<lshift\>
24				
25	Rs 1 now or Rs 100 in 3 months	\<rshift\>	Rs 1 now or Rs 5000 in 3 months	\<rshift\>
26	Rs 10 now or Rs 100 in 3 months	\<lshift\>	Rs 500 now or Rs 5000 in 3 months	\<rshift\>
27	Rs 20 now or Rs 100 in 3 months	\<lshift\>	Rs 1000 now or Rs 5000 in 3 months	\<lshift\>
28	Rs 30 now or Rs 100 in 3 months	\<rshift\>	Rs 1500 now or Rs 5000 in 3 months	\<lshift\>
29	Rs 40 now or Rs 100 in 3 months	\<lshift\>	Rs 2000 now or Rs 5000 in 3 months	\<lshift\>
30	Rs 50 now or Rs 100 in 3 months	\<lshift\>	Rs 2500 now or Rs 5000 in 3 months	\<lshift\>
31	Rs 60 now or Rs 100 in 3 months	\<lshift\>	Rs 3000 now or Rs 5000 in 3 months	\<lshift\>
32	Rs 70 now or Rs 100 in 3 months	\<rshift\>	Rs 3500 now or Rs 5000 in 3 months	\<lshift\>
33	Rs 80 now or Rs 100 in 3 months	\<rshift\>	Rs 4000 now or Rs 5000 in 3 months	\<lshift\>
34	Rs 90 now or Rs 100 in 3 months	\<lshift\>	Rs 4500 now or Rs 5000 in 3 months	\<lshift\>
35	Rs 100 now or Rs 100 in 3 months	\<lshift\>	Rs 5000 now or Rs 5000 in 3 months	\<lshift\>
36				
37	Rs 1 now or Rs 100 in 12 months	\<rshift\>	Rs 1 now or Rs 5000 in 12 months	\<rshift\>
38	Rs 10 now or Rs 100 in 12 months	\<lshift\>	Rs 500 now or Rs 5000 in 12 months	\<lshift\>
39	Rs 20 now or Rs 100 in 12 months	\<rshift\>	Rs 1000 now or Rs 5000 in 12 months	\<lshift\>
40	Rs 30 now or Rs 100 in 12 months	\<lshift\>	Rs 1500 now or Rs 5000 in 12 months	\<lshift\>
41	Rs 40 now or Rs 100 in 12 months	\<rshift\>	Rs 2000 now or Rs 5000 in 12 months	\<lshift\>
42	Rs 50 now or Rs 100 in 12 months	\<lshift\>	Rs 2500 now or Rs 5000 in 12 months	\<lshift\>
43	Rs 60 now or Rs 100 in 12 months	\<lshift\>	Rs 3000 now or Rs 5000 in 12 months	\<lshift\>
44	Rs 70 now or Rs 100 in 12 months	\<lshift\>	Rs 3500 now or Rs 5000 in 12 months	\<lshift\>
45	Rs 80 now or Rs 100 in 12 months	\<lshift\>	Rs 4000 now or Rs 5000 in 12 months	\<lshift\>
46	Rs 90 now or Rs 100 in 12 months	\<lshift\>	Rs 4500 now or Rs 5000 in 12 months	\<lshift\>
47	Rs 100 now or Rs 100 in 12 months	\<lshift\>	Rs 5000 now or Rs 5000 in 12 months	\<lshift\>

Figure 3

In Figure 3, the output file has been arranged according to the amount of delayed reward and length of time. Within each block, the trials have also been arranged in an ascending order of increasing immediate reward. The final part of data sorting is to replace all the responses with 0 and 1s in order to aid analysis. All responses of **<lshift>** should be replaced by 1, and all responses of **<rshift>** should be replaced with 0s.

Step 2: Computation of indifference points/subjective value

Once the data output file has been sorted, the indifference points for each eight blocks needs to be separately computed. The indifference point refers to the smallest immediate amount which the participant is willing to take instead of the larger delayed reward. The process of computing indifference point is given in following examples.

Rs 1 now or Rs 100 in 1 month	0	Rs 1 now or Rs 5000 in 1 month	0
Rs 10 now or Rs 100 in 1 month	0	Rs 500 now or Rs 5000 in 1 month	0
Rs 20 now or Rs 100 in 1 month	0	Rs 1000 now or Rs 5000 in 1 month	0
Rs 30 now or Rs 100 in 1 month	0	Rs 1500 now or Rs 5000 in 1 month	0
Rs 40 now or Rs 100 in 1 month	1	Rs 2000 now or Rs 5000 in 1 month	0
Rs 50 now or Rs 100 in 1 month	1	Rs 2500 now or Rs 5000 in 1 month	0
Rs 60 now or Rs 100 in 1 month	1	Rs 3000 now or Rs 5000 in 1 month	0
Rs 70 now or Rs 100 in 1 month	1	Rs 3500 now or Rs 5000 in 1 month	0
Rs 80 now or Rs 100 in 1 month	1	Rs 4000 now or Rs 5000 in 1 month	1
Rs 90 now or Rs 100 in 1 month	1	Rs 4500 now or Rs 5000 in 1 month	1
Rs 100 now or Rs 100 in 1 month	1	Rs 5000 now or Rs 5000 in 1 month	1

Figure 4

In Figure 4 above, the range of responses have been given for two reward blocks at the delay of 1 month. The responses following each choice statement represent the participants' answers. Here, 0 indicates that the participant chose the delayed reward, whereas 1 indicates that the person chose the smaller immediate reward. The point at which a participant's responses switch from delayed reward to immediate reward is known as the **indifference point**.

For the Rs. 100 condition above, the participant's responses switched from 0 to 1 at '**Rs 40 now or Rs 100 in 1 month**' . To calculate the indifference point, a value must be derived which is between 30 and 40 since the shift of responses happened between 30 and 40 in the task. The most common way of doing this is to compute the geometric mean of 30 and 40. The **geometric mean** is defined as "…the nth root of the product of n numbers." In this case, the geometric mean of 30 and 40 was computed to be **34.64**.

 In the same way, for the Rs 5000 condition, the indifference point was located between 3500 and 4000, which was found to be **3741.66** after calculating the geometric mean. In both the instances, the computed amount represents the smallest amount that the participant is willing to take way right away instead of taking the full reward of Rs100 and Rs 5000 respectively after waiting for a month.

For further analysis, the indifference points need to be converted into proportions of their full rewards, i.e.

Proportion of subjective value= Indifference value/Total value

Thus,

Proportion of subjective value (Rs 100, at 1 month)= Rs 34.64/Rs 100 = 0.346

Proportion of subjective value (Rs 5000 at 1 month)= Rs 3741.6/Rs5000= 0.748

In a later section, the proportions of rewards/subjective values and proportions of delays need to be computed as the final analysis will be done using the method of **Area Under the Curve (AUC)** which requires formulating a graph representing the subjective values across delays. The proportions of rewards is represented in the y-axis, and proportions of delays in the x axis, in order to plot a line graph of change of subjective values according to delay.

Proportion of rewards (Rs 100)	Proportions of rewards (Rs 5000)	Proportion of delays
Rs 100 in 1 week (ya100)	Rs 5000 in 1 week (ya5000)	1/52= 0.019
Rs 100 in 1 month (yb100)	Rs 5000 in 1 month (yb5000)	1/12= 0.083
Rs 100 in 3 months (yc100)	Rs 5000 in 3 months (yc5000)	3/12= 0.25
Rs 1000 in 12 months (yd100)	Rs 5000 in 12 months (yd5000)	1

However, the computation of the subjective values/indifference points is not always straightforward and requires some rules of thumb for computation. The same can be demonstrated in the examples below

Rs 1 now or Rs 100 in 1 month	0	Rs 1 now or Rs 5000 in 1 month	0
Rs 10 now or Rs 100 in 1 month	0	Rs 500 now or Rs 5000 in 1 month	0
Rs 20 now or Rs 100 in 1 month	0	Rs 1000 now or Rs 5000 in 1 month	0
Rs 30 now or Rs 100 in 1 month	1	Rs 1500 now or Rs 5000 in 1 month	1
Rs 40 now or Rs 100 in 1 month	1	Rs 2000 now or Rs 5000 in 1 month	1
Rs 50 now or Rs 100 in 1 month	0	Rs 2500 now or Rs 5000 in 1 month	1
Rs 60 now or Rs 100 in 1 month	0	Rs 3000 now or Rs 5000 in 1 month	0
Rs 70 now or Rs 100 in 1 month	0	Rs 3500 now or Rs 5000 in 1 month	0
Rs 80 now or Rs 100 in 1 month	1	Rs 4000 now or Rs 5000 in 1 month	0
Rs 90 now or Rs 100 in 1 month	1	Rs 4500 now or Rs 5000 in 1 month	1
Rs 100 now or Rs 100 in 1 month	1	Rs 5000 now or Rs 5000 in 1 month	1

Figure 5.a   Figure 5.b

In the examples above (Figure 5), the set of responses on two reward blocks has been given. Contrary to the previous instance, the responses in this case are not straightforward as the transition

from 0s to 1s does not happen smoothly. (i.e, 0s and 1s are random) which makes computation of the indifference points tricky. One standard rule to get over this issue is to derive the **consistency value** for each possible indifference point.

In the example above (5.a), there are two points where the indifference point could be derived (points at which 0s change to 1s). Going by the nth trials rule, in both the 4th trial Rs 30) and 9th trial (Rs 80), the responses change from 0s to 1s. In order to calculate the consistency value for each point, the number of 1s from that point onwards should be summed along with the number of 0s upto that point and then divided by the total trials.

<u>For example</u>

> <u>At Rs 30 (4th trial):</u>
> Number of 1s following the 4th trial (including it)= 5
> Number of 0s before the 4th trial= 3
> **Consistency percentage**= [(5+3)/11] X 100= **72.7%**

> <u>At Rs. 80 (9th trial)</u>
> Number of 1s following the 9th trial (including it)= 3
> Number of 0s before the 9th trial= 6
> **Consistency percentage**= [(6+3)/11] X 100= **81.8%**

From the calculations above, it was found that the consistency score at Rs 80 was higher than that of Rs 30. Thus, the 9th trial would be used as the base for calculating the indifference point, which would be the geometric mean of Rs 80 and Rs 70. Usually, consistency percentages below 75% indicate that the set of responses are random and cannot be relied completely.

Similarly, for Figure 5.b too, there are two points where the indifference point could be derived (4th trial and 10th trial). The consistency scores can be calculated for these two points as given below:

> <u>At Rs 1500 (4th trial):</u>
> Number of 1s following the 4th trial (including it)= 5
> Number of 0s before the 4th trial= 3
> **Consistency percentage**= [(5+3)/11] X 100= **72.7%**

> <u>At Rs. 4500 (10th trial)</u>
> Number of 1s following the 9th trial (including it)= 2
> Number of 0s before the 9th trial= 6
> **Consistency percentage**= [(6+2)/11] X 100= **72.7%**

In this instance, the consistency scores for both the points were exactly equal (although quite low). The most reasonable way to take the calculations further would be to derive a subjective value/indifference point by taking a geometric mean of both the points, i.e, 4500 and 1500.

Step 3: Area Under the Curve (AUC)

The Area Under the Curve (AUC) is a relatively simple and atheoretical way to summarize the indifference points (Myerson, Green, & Warusawitharana, 2001). To calculate AUC, delays and indifference points are first normalized (i.e., expressed as a proportion of the maximum value) (**Step 2**). The area underneath the curve is then computed by summing the results of the following equation for each delay and indifference point pair: $(x2 - x1) [(y1 + y2)/2]$, where x1 and x2 are successive delays and y1 and y2 are the indifference points associated with those delays (see Myerson et al. for more detail). The AUC can range from 1 (no discounting) to 0 (maximum discounting). Larger AUCs thus represent less discounting by delay (less impulsivity, or conversely, more self-control).

Worked example: Using the methods described in the sections earlier, a hypothetical set of values is given below.

Delays (x)	Rs 100 (y)	Rs 5000 (y)
1 week (xa= 0.019)	ya(100)= 0.89	ya(5000)= 0.95
1 month (xb= 0.083)	yb(100)= 0.75	yb(5000)= 0.89
3 months (xc= 0.25)	yc(100)= 0.24	yc(5000)= 0.63
12 months (xd= 1)	yd(100)= 0.03	yd(5000)= 0.14

In order to derive the above values, the proportions of subjective values to the maximum reward were computed for both amounts (Rs 100 and Rs 5000). The delays were also expressed in terms of proportions to the maximum delay (1 year). With these values, a graph can be easily obtained, which would look something like the one given below.
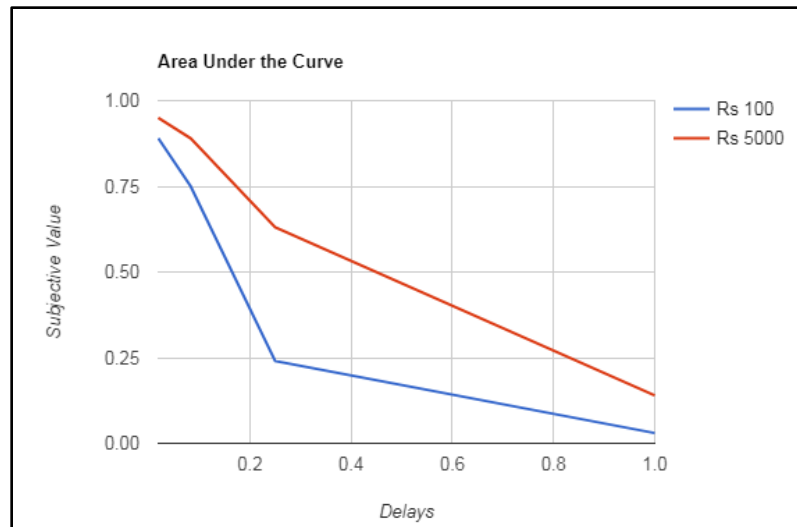

Figure 6

The graph provides a visual representation of the delay discounting effect, or the nature in which the subjective value of certain amount decreases with time. For both Rs 100, and Rs 5000, we can see that the subjective value of those amounts decreases with time. For example, at 3 months, the value of Rs 100 is equal to a mere Rs 24 to the participant. The downward sloping lines remain the most distinct aspects of the delay discounting effect.

Also, the graph depicts the second most distinct aspect of delay discounting, that is the effect of amount on delay. We can see that the subjective values for Rs 100 decreases sharply compared to Rs 5000, which indicates that people are more willing to wait for rewards, if the reward is high or worthwhile. This effect has been demonstrated across a wide range of experimental studies.

Finally, the last bit of calculation is the computation of the area under the curve, which provides a sum total of subjective value for an amount across various delays. In simple words, it is the area or space right under the graph that was just plotted for subjective immediate values for a delayed amount.

To calculate the area under the curve, we begin by normalizing the delay and subjective value for each data point. That is, the delay was expressed as a proportion of the maximum delay, and the subjective value was expressed as a proportion of the nominal amount (i.e., the subjective value divided by the actual, delayed amount). These normalized values were used as x coordinates and y coordinates, respectively, to construct a graph of the discounting data. This has been done and represented in the sections so far.
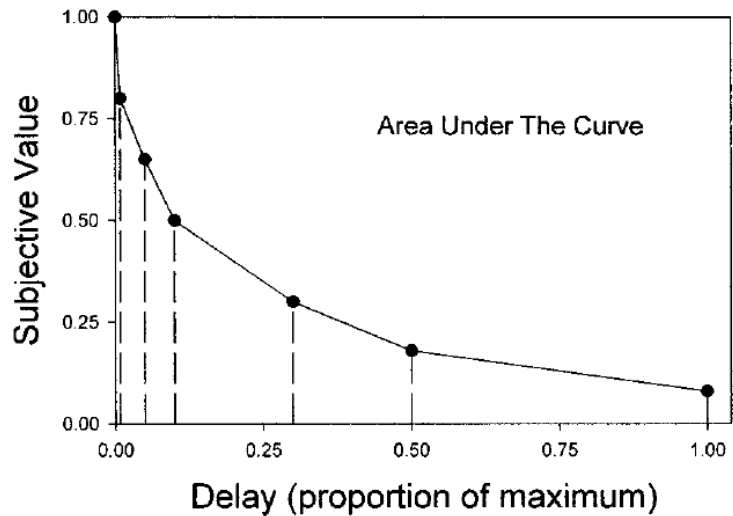

Figure 7

Vertical lines were then drawn from each data point to the x axis, subdividing the graph into a series of trapezoids (as shown in Figure 7). The area of each trapezoid is equal to

$$(x2 - x1)*[(y1 + y2)/2],$$

where $x1$ and $x2$ are successive delays, and $y1$ and $y2$ are the subjective values associated with these delays. (For the first trapezoid, the value of $x1$ and $y1$ are defined as 0.0 and 1.0.) The area under the empirical discounting function is equal to the sum of the areas of these trapezoids. The steeper the discounting (i.e., the lower the subjective value of delayed or probabilistic rewards), the smaller the area under the curve will be.

Because the x and y values are both normalized, the area under the curve can vary between 0.0 (steepest possible discounting) and 1.0 (no discounting). It is important to note that, because the area is calculated from the empirical discounting function (i.e., the actual data points) rather than from a curve fit to the data (e.g., Equation 1), the obtained area measure does not depend on any theoretical assumptions regarding the form of the discounting function. In addition to having the advantage of being theoretically neutral, the area-under-the curve measure circumvents the statistical problems created by skewed distributions.