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# Time Matters Less When Outcomes Differ: Unimodal vs. Cross-Modal Comparisons in Intertemporal Choice

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**Abstract.** Unimodal intertemporal decisions involve comparing options of the same type (e.g., apples now versus apples later), and cross-modal decisions involve comparing options of different types (e.g., a car now versus a vacation later). As we show, existing models of intertemporal choice do not allow time preference to depend on whether the comparisons to be made are unimodal or cross-modal. We test this restriction in an experiment using the *delayed compensation method*, a new extension of the standard method of eliciting intertemporal preferences that allows for assessment of time preference for nonmonetary and discrete outcomes, as well as for both cross-modal and unimodal comparisons. Participants were much more averse to delay for unimodal than cross-modal decisions. We provide two potential explanations for this effect: one drawing on multiattribute choice, the other drawing on construal-level theory.

**History:** Accepted by Yuval Rottenstreich, judgment and decision making.

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**Keywords:** intertemporal choice • decision modelling • economics: behavior and behavioral decision making • delay discounting

## Introduction

In intertemporal choices, the objects of choice are distributed over time, so decision makers face variations not only in what the outcomes are but also in when they are received. Examples include whether to go to a movie tonight or a football game tomorrow, whether to take a job in sales now or to graduate and then seek a professional career, or whether to buy a car now or wait five years and build an extension to the house.

Conflicts between the “what” and the “when” are central to empirical and theoretical accounts of time preference (for surveys, see Frederick et al. 2002, Manzini and Mariotti 2009, and Urminsky and Zauberman 2014). Such accounts usually focus on trade-offs between *quantity* and *timing*. In much of the empirical literature, the options are different quantities of money at different dates (e.g., \$100 now versus \$120 in 12 months). When the options are not sums of money, they are generally different quantities at different dates of some nonmonetary object or commodity (e.g., chocolates, the number of lives saved, grams of cocaine).<sup>1</sup>

However, many real-world choices (including the examples in our opening paragraph) do not reduce to

a trade-off between timing and the quantity of a given good. Instead, not only do the goods differ in when they occur, but also in what they are. We call such choices *cross-modal*. These can be contrasted with *unimodal* choices, where the options are the same good at different dates, even if perhaps in different quantities. We will focus on the relationship between considerations of timing and considerations of what the object to be received is by setting variations in the quantity of goods to one side and concentrating on choices between single items at different dates. Obviously, such choices may still be cross-modal or unimodal. For example, to introduce some cases from the experiment reported below, the choice between a box of chocolates today and a fountain pen in 60 days is cross-modal, whereas that between a fountain pen today and an identical pen in 60 days is unimodal. We investigate whether time preference operates in the same way (and to the same degree) in cross-modal and unimodal choices. Our motivation for this is twofold.

First, as just noted, many everyday intertemporal decisions are cross-modal, whereas empirical research on time preference has usually followed a unimodal

paradigm. Although people do face unimodal decisions in their personal finances, it remains a largely neglected question how far the lessons of unimodal research extend to those everyday decisions that are cross-modal.<sup>2</sup>

Second, the issue of whether time preference operates differently in cross-modal compared with unimodal choices marks a divide between two approaches to modelling: one *value*-based, the other *attribute*-based. The former rests on a classic view that intertemporal choices reduce to comparisons of values (typically, discounted present values), with each option having a value independent of its alternatives. On this account, it should make no fundamental difference whether the decisions through which time preference is revealed are cross-modal or unimodal. We present an experimental test of this prediction, taking as our starting point a baseline value-based model of the strength of time preference. As we will make precise below, this model predicts that overall aversion to delay is the same for cross-modal and unimodal decisions.

If this prediction were confirmed, it would be good news for those who seek to generalise findings from research on unimodal decisions. But we find instead that our participants are considerably more patient in the cross-modal than in the unimodal choices that we pose to them. Although this finding contradicts our baseline model, it is consistent with earlier research showing that the standard (unimodal) way of eliciting time preferences appears to exaggerate observed impatience relative to other elicitation procedures (e.g., Frederick 2003; Read et al. 2005, 2013). More important, greater patience in cross-modal discounting chimes well with an attribute-based approach. The finding is quite intuitive if the weight that a difference in timing carries in participants' intertemporal decision making depends on how many other differences between options there are to consider. We sketch an account of our findings in this form, as well as a further account that suggests the mental representations of options differ in unimodal and cross-modal choice.

To investigate whether revealed aversion to delay differs systematically in strength between cross-modal and unimodal decisions, we develop a way to measure it that can be applied regardless of whether the options differ in ways other than timing and quantity. This is the *delayed compensation method*.

### The Delayed Compensation Method

In the delayed compensation method (henceforth, DCM), a participant first chooses between two options that each specify a good to be received and a date of receipt. The options may differ in the good, the date, or both. As in the example introduced earlier, the options might be a box of chocolates today and a pen in 60 days, or they might be a pen today and an identical pen in 60 days. The decision maker indicates which

option she prefers and the delayed monetary compensation she requires to make her just willing to accept the dispreferred option instead of the preferred one. Regardless of the direction of the initial preference, monetary compensation is paid in a common period that comes after the later of the two options' delivery dates (hence "delayed" compensation).

The DCM has several noteworthy features. First, by capturing preference trade-offs using monetary compensation, we avoid the need for divisibility in goods. By paying that compensation at a common date (for all tasks), we avoid the need for auxiliary assumptions about the discounting of money. By having the common compensation date after the date of receipt of the later good, we ensure the compensation cannot be used to purchase either option. By using compensation for having a dispreferred option instead of a preferred one (regardless of which would be received earlier), we guarantee that the compensation is positive and so avoid any need to take money from participants and any suggestion that they "ought" to prefer earlier options. We also avoid any confound with loss aversion, such as might be introduced if we sometimes elicited willingness to accept and sometimes willingness to pay, or if we gave participants one of the options as an initial endowment. Finally, as this paper's implementation of it shows, the DCM allows strength of time preference to be assessed without varying quantities of consumption goods, thereby preventing any resulting confounds with diminishing marginal utility.

### The Fisher Diagram

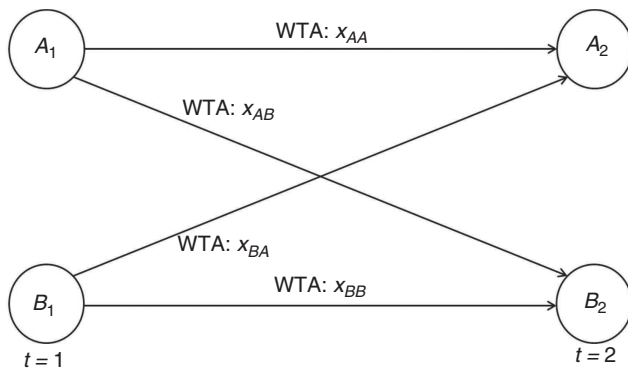
Figure 1 provides a representation of the DCM and allows us to refine the question of whether time preference differs between cross-modal and unimodal comparisons. We call the figure the *Fisher diagram*, as it is inspired by Chart 4 from Irving Fisher's *Theory of Interest* (1930).

Figure 1 shows two goods ( $A$  and  $B$ ) and two time periods ( $t = 1, 2$ ) in which a good might be received. Together, these ingredients define four options, or dated goods ( $A_1, A_2, B_1, B_2$ ), shown in circles. (As explained below, we let  $A$  be the good that is preferred when timing is not an issue. So using our earlier examples and for someone who prefers chocolates to a pen,  $A_1$  could be a box of chocolates today and  $B_2$  a pen in 60 days.)

In the Fisher diagram, the two horizontal arrows represent unimodal intertemporal comparisons; the two diagonal arrows, cross-modal ones. In our unimodal comparisons, the options differ only in the timing of receipt; in cross-modal comparisons, the options differ in the good to be received as well as the timing.<sup>3</sup>

In the DCM, the agent is faced with a choice at (or before) period  $t = 1$  between two options, which are dated goods from Figure 1. She will receive one of the

**Figure 1.** Fisher Diagram



*Notes.* The Fisher diagram shows the different goods ( $A$  and  $B$ ) at specified times ( $t = 1$  and  $t = 2$ ) and the four different comparisons between goods at different dates. For each pair of dated goods, the WTA is the monetary amount that, when given in addition to the dispreferred of the two options, will make the agent just willing to take the dispreferred instead of the preferred option. The figure shows a case where, in all four intertemporal comparisons, the  $t = 1$  option is preferred.

options at the time specified. She is required to state the monetary compensation to be received at period  $t = 3$  (i.e., some fixed time after period  $t = 2$ ) that is just sufficient to make her willing to accept her dispreferred option instead of her preferred one. In the language of economics, this is her willingness to accept (WTA).

The only assumption on preferences that the DCM requires is that the agent has preferences over the dated goods and can specify the relevant compensations. To streamline the exposition, we set out some additional *default assumptions* imposed unless otherwise stated: the agent prefers receiving any of the dated goods of Figure 1 to receiving nothing and has strict preferences between them.<sup>4</sup> There is one good—we name it  $A$ —that the agent prefers to the other good whenever both would be delivered in the same period (i.e.,  $A_1$  is preferred to  $B_1$ , and  $A_2$  is preferred to  $B_2$ ).<sup>5</sup> The agent prefers any good delivered at  $t = 1$  to the same good delivered at  $t = 2$  (i.e.,  $A_1$  is preferred to  $A_2$ , and  $B_1$  is preferred to  $B_2$ ). Given transitivity, it then follows that  $A_1$  is preferred, and  $B_2$  dispreferred, to every other option. The intuition is that  $A_1$  is the better good, with the added advantage of early delivery, whereas  $B_2$  is the worse good, with the added disadvantage of late delivery. These default assumptions do not determine preference between  $B_1$  and  $A_2$ . As  $B_1$  is the worse good but sooner, whereas  $A_2$  is the better good but later, it is possible to prefer  $B_1$  to  $A_2$  or  $A_2$  to  $B_1$ . Our analysis will cover both cases.

We start with an agent who prefers  $B_1$  to  $A_2$  and therefore prefers the earlier option in any given pair. For her, the DCM always elicits the monetary compensation just sufficient to induce acceptance of the later option instead of the earlier. We use  $x_{AA}$  to denote the compensation required to accept  $A_2$  instead of  $A_1$ ,  $x_{BB}$

denotes the compensation required to accept  $B_2$  instead of  $B_1$ ,  $x_{AB}$  denotes the compensation required to accept  $B_2$  instead of  $A_1$ , and  $x_{BA}$  denotes the compensation required to accept  $A_2$  instead of  $B_1$ . The first subscript indicates the good in the earlier and preferred option; the second subscript, the good in the later and dispreferred option. So  $x_{AB}$  and  $x_{BA}$  relate to different comparisons, as Figure 1 makes clear.

The next section sets out a baseline value-based model from which we derive precise predictions, but we end this section by giving a parallel intuitive argument. When  $B_1$  is preferred to  $A_2$  and the default assumptions hold, the agent prefers  $A_1$  to  $B_1$  to  $A_2$  to  $B_2$ . So, from a value-based perspective, we would expect the cross-modal compensation term  $x_{AB}$  to be the largest of the four,  $x_{BA}$  the smallest, and the unimodal terms intermediate. Intuitively,  $x_{AB}$  is large because it includes compensation not only for delay but *also* for taking the worse good ( $B$ ) rather than the better one ( $A$ ), and  $x_{BA}$  is small because the disadvantage of delay is partly *offset* by taking the better good ( $A$ ) rather than the worse one ( $B$ ). As  $x_{AB}$  and  $x_{BA}$  are driven in opposite directions by the difference between the better and worse goods, we compare their sum [ $x_{AB} + x_{BA}$ ] to the corresponding sum [ $x_{AA} + x_{BB}$ ] of unimodal compensations. If the difference between good  $A$  and good  $B$  has equal and opposite impacts on  $x_{AB}$  and  $x_{BA}$ , those impacts will cancel in the cross-modal sum, leaving only the influences of delay. These influences will be the same as those that drive the unimodal sum if (as a value-based perspective implies) there is no fundamental difference between attitude to delay in cross-modal and unimodal comparisons. This leads to the prediction that, when  $B_1$  is preferred to  $A_2$ , [ $x_{AB} + x_{BA}$ ] will equal [ $x_{AA} + x_{BB}$ ]. This prediction is made formally in the next section, which also provides a corresponding prediction for when  $A_2$  is preferred to  $B_1$ .

### A Baseline Model

We now present a model of the preferences the agent has at the point of decision in the DCM (at or before  $t = 1$ ) and how they determine the four WTA compensation terms. This model is premised on maximization of decision utility and encompasses all commonly cited discounting frameworks (including exponential, hyperbolic, quasi-hyperbolic, and constant sensitivity forms). We specify that decision utility depends on dated goods to be received and delayed monetary compensation, and it is additively separable in those two sources of utility. Although the DCM is a general framework, as we apply it in this paper, the agent is restricted to receive one unit of one dated good, so we define a distinct utility for the receipt of each of these goods, using  $a_1, a_2, b_1,$  and  $b_2$  as the utility terms for  $A_1, A_2, B_1,$  and  $B_2$ , respectively. These terms reflect both the nature of the good to be received and any delay



until that occurs.<sup>6</sup> Finally, we define  $v(\cdot)$  as an increasing function of monetary compensation at  $t = 3$  and set  $v(0) = 0$ .<sup>7</sup> We refer to  $v(\cdot)$  as utility of money. Unless otherwise stated, we assume that it is linear in delayed compensation. Appendix A covers the case of diminishing marginal utility of money and gives more detail on other aspects of the model.

We begin with an agent who prefers  $B_1$  to  $A_2$ , as in the previous section. The unimodal WTAs  $x_{AA}$ ,  $x_{BB}$  and the cross-modal WTAs  $x_{AB}$ ,  $x_{BA}$  (see Figure 1) are defined by the following equations:

$$a_1 = a_2 + v(x_{AA}), \quad (1.i)$$

$$b_1 = b_2 + v(x_{BB}), \quad (1.ii)$$

$$a_1 = b_2 + v(x_{AB}), \quad (1.iii)$$

$$b_1 = a_2 + v(x_{BA}). \quad (1.iv)$$

In each case, the left-hand side is the utility of the preferred option, the first term on the right-hand side is the utility of the dispreferred option, and the final term that of the compensation required to accept the dispreferred option. It follows by simple arithmetic that

$$\begin{aligned} v(x_{AA}) + v(x_{BB}) &= (a_1 - a_2) + (b_1 - b_2) \\ &= (a_1 - b_2) + (b_1 - a_2) \\ &= v(x_{AB}) + v(x_{BA}). \end{aligned} \quad (2)$$

With  $v(\cdot)$  linear, this implies that

$$x_{AA} + x_{BB} = x_{AB} + x_{BA}. \quad (3)$$

Equation (3) is the prediction stated in the previous section for an agent who prefers  $B_1$  to  $A_2$ .

Figure 1 provides the key intuitions of our baseline model. First, look at  $x_{AB}$  and  $x_{AA}$ . Each is a compensation for forgoing the early  $A_1$  in exchange for a later option: for  $B_2$  in  $x_{AB}$  and for  $A_2$  in  $x_{AA}$ . Since  $B_2$  is worse than  $A_2$ ,  $x_{AB}$  exceeds  $x_{AA}$ ; it does so by an amount determined by the difference in utility between the two delayed goods and by the utility function for money,  $v(\cdot)$ . Now, look at  $x_{BB}$  and  $x_{BA}$ . As Figure 1 shows, each is a compensation for forgoing  $B_1$ : for  $B_2$  in  $x_{BB}$  and for  $A_2$  in  $x_{BA}$ . As the agent thinks  $B_2$  is worse than  $A_2$ ,  $x_{BB}$  exceeds  $x_{BA}$  by an amount again determined by the utility difference between the delayed goods and by  $v(\cdot)$ . So, for any given  $v(\cdot)$ , the difference in utility between  $A_2$  and  $B_2$  determines both  $[x_{AB} - x_{AA}]$  and  $[x_{BB} - x_{BA}]$ . With  $v(\cdot)$  linear,  $x_{AB} - x_{AA} = x_{BB} - x_{BA}$ , which rearranges to give Equation (3).

As an example using our experimental goods, imagine Alice prefers the chocolates to the pen (so, for her, good  $A$  = chocolates) and that her function  $v(\cdot)$  has the simplest linear form  $v(x) = x$ , so the compensation terms are given directly by differences in the decision utilities of dated goods. Let those utilities be 30 and 25, respectively, for the chocolates and pen at  $t = 1$ ; let

the utilities be 24 and 20, respectively, for the chocolates and pen at  $t = 2$ . In the unimodal comparisons, Alice demands compensations of 6 (= 30 – 24) for delaying the chocolates and 5 (= 25 – 20) for delaying the pen. In the cross-modal comparisons, she demands 10 (= 30 – 20) for taking the delayed pen instead of early chocolates and 1 (= 25 – 24) for taking delayed chocolates instead of the early pen. The cross-modal compensations have the same sum as the unimodal ones: 10 + 1 = 6 + 5. Equivalently, and reflecting the argument of the previous paragraph, 10 – 6 = 5 – 1 = 4; 4 is the difference in utility between the delayed chocolates and the delayed pen.

We now adapt the analysis for an agent who prefers  $A_2$  to  $B_1$ . The terms  $x_{AA}$ ,  $x_{BB}$ , and  $x_{AB}$  are defined as before by Equations (1.i)–(1.iii). However, compensation in the DCM always accompanies the least preferred good. Therefore,  $x_{BA}$  is undefined for this agent, and compensation to achieve indifference between those two options must now accompany the dispreferred  $B_1$ . We use  $y_{BA}$  to denote this compensation, which is governed by

$$a_2 = b_1 + v(y_{BA}). \quad (1.iv')$$

By simple arithmetic, using (1.i)–(1.iii) and (1.iv'),

$$\begin{aligned} v(x_{AA}) + v(x_{BB}) &= (a_1 - a_2) + (b_1 - b_2) \\ &= (a_1 - b_2) - (a_2 - b_1) \\ &= v(x_{AB}) - v(y_{BA}). \end{aligned} \quad (2')$$

With  $v(\cdot)$  linear, this implies that, for an agent who prefers  $A_2$  to  $B_1$ ,

$$x_{AA} + x_{BB} = x_{AB} - y_{BA}. \quad (3')$$

The only difference between (3') and (3) is that  $-y_{BA}$  appears in place of  $+x_{BA}$ .<sup>8</sup>

To contrast  $-y_{BA}$  with  $+x_{BA}$ , consider the case of Bob who, like Alice, prefers the chocolates to the pen (so again, good  $A$  = chocolates) and has  $v(x) = x$ . But Bob very strongly prefers the chocolates. For him, the utilities are 50 and 25, respectively, for the chocolates and pen at  $t = 1$  and 40 and 20, respectively, for the chocolates and pen at  $t = 2$ . In the unimodal comparisons, Bob demands compensations of 10 (= 50 – 40) for delaying the chocolates and 5 (= 25 – 20) for delaying the pen. In the cross-modal comparisons, however, he demands 30 (= 50 – 20) for taking the delayed pen instead of early chocolates. But Bob likes chocolates enough to take the delayed chocolates over the earlier pen and demands 15 (= 40 – 25) for taking the earlier pen instead. The compensation of 15 is  $y_{BA}$ , and the equality in Equation (3') holds: 10 + 5 = 30 – 15.

We place both  $+x_{BA}$  and  $-y_{BA}$  and their equivalents for other pairs under the umbrella term *cost of delay*. For any pair of dated goods with different delivery dates,

this is the compensation required to accept the later good when the earlier is preferred—and the negative of the compensation required to accept the earlier good when the later is preferred. Thus, while compensation for taking a dispreferred option is always positive, cost of delay can be negative. Our null hypothesis, based on the baseline model of behaviour in the setup of Figure 1, can then be stated in the general form: *the sum of the two unimodal costs of delay equals the sum of the two cross-modal costs of delay.*<sup>9</sup>

As we have shown, this hypothesis is robust to whether the agent prefers the “better but later” good ( $A_2$ ) to the “worse but earlier” good ( $B_1$ ), or vice versa. However, it does depend on the function  $v(\cdot)$  being linear. Arguably, linearity of utility in money is a suitable assumption for the relatively small sums needed to compensate for differences between the goods used in the experiment. However, concavity of  $v(\cdot)$  is an obvious alternative specification, which, as we show in Appendix A, does matter: with  $v(\cdot)$  concave, the model predicts the sum of costs of delay will be greater for cross-modal comparisons than for unimodal ones.

The restrictions we derive from our baseline model are not specific to the traditional Samuelsonian discounted utility model (Samuelson 1937) but apply equally to a whole family of models from economics and psychology. The model makes *no* assumptions about whether there is a single discount function, separate discounting for goods and money, and/or good-specific discount functions.<sup>10</sup> The gaps between periods  $t = 1, 2$ , and 3 can be of any calendar duration; given their durations, any decreasing discount function is allowed.

## Experiment

We have conducted a series of studies comparing unimodal and cross-modal intertemporal choices, using variations of the DCM. Here, we present only the “flagship” study. Its results are representative of all of the studies.<sup>11</sup>

The study was programmed in Qualtrics and conducted online in August 2014 using the Amazon Mechanical Turk online labour market. After the tasks described below, participants answered follow-up questions and provided basic demographic information, summarised in Table 1.

## Design and Method

The design was an implementation of the DCM. The goods were a good-quality fountain pen by Lamy and a box of 36 luxury chocolates by Godiva. They were selected because they could be sourced from Amazon.com, and because their prices were similar (about \$30 each on Amazon at the time). We ordered the items for participants either “today” or “in 60 days” as appropriate, to be delivered (free) to the participant’s

**Table 1.** Demographics ( $n = 300$ )

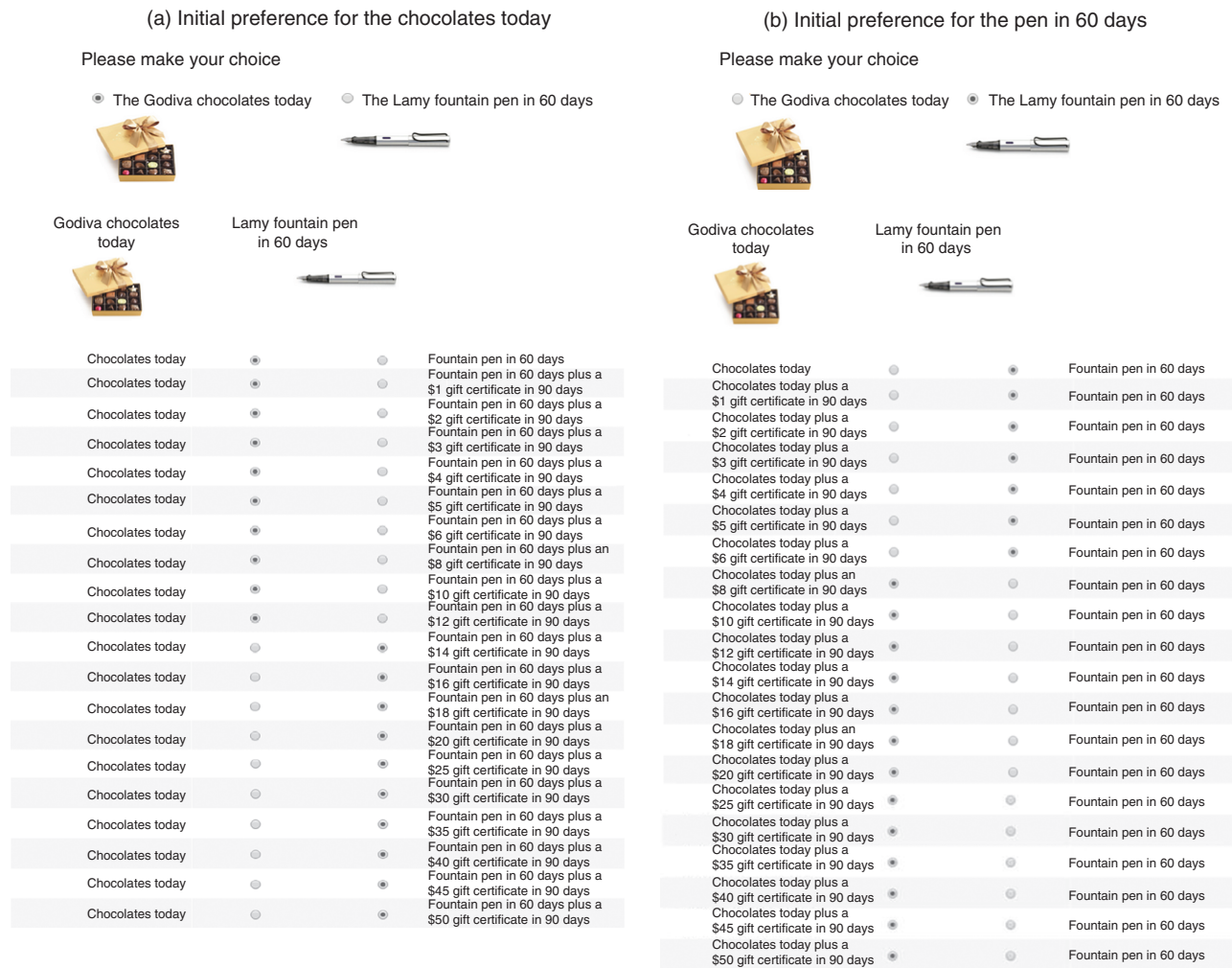
Variable	Percentage or value
Female (%)	43.00
Age at last birthday (in years) (s.d.)	30.81 (9.06)
Education	
Low education (%)	11.67
Medium education (%)	34.00
High education (%)	54.33
Married (%)	31.67
Has children (%)	31.33
Employed full or part time (%)	72.33

*Notes.* Low education is defined not having begun university. Medium education is being currently at university. High education is having completed university.

address. Thus, the four dated goods were a pen today, a pen in 60 days, a box of chocolates today, and a box of chocolates in 60 days. The experiment elicited the compensation needed to induce the participant to accept the dispreferred one out of a pair of options, each of which was one of these dated goods. Compensation was in the form of Amazon.com gift certificates, delivered in 90 days, which could be used by the participant effectively as money at that time.

There were four choice conditions: two based on unimodal choices (chocolates today or in 60 days; a pen today or in 60 days) and two based on cross-modal choices (chocolates today or a pen in 60 days; a pen today or chocolates in 60 days). Each participant was assigned to one condition. Before starting the task, participants were shown pictures and brief descriptions of the goods. They then made a single choice between the options. Depending on what they chose, they were then assigned to a choice list following the logic depicted in Figures 2(a) and 2(b). The first row in the choice list repeated the initial choice, and in subsequent rows, the dispreferred option was supplemented with compensating money amounts to be delivered in 90 days. The second row combined compensation of \$1 in 90 days with the item they did not originally choose. This compensation increased down the choice list in \$1 increments to \$6, then in \$2 increments to \$20, and \$5 increments up to a maximum of \$50. We chose this maximum because it comfortably exceeded the Amazon.com price of each item.

The decisions of two hypothetical individuals are illustrated in Figure 2. For the purposes of analysis, we measure the indifference point as the midpoint between the highest amount that would not induce the participant to switch and the lowest amount that would. So in Figure 2(a), compensation for taking the pen later over the chocolates is \$13, or the midpoint between the \$12 turned down and the \$14 accepted. The individual in Figure 2(b) prefers the pen later over the chocolates today and requires an estimated \$7

**Figure 2.** (Color online) Example Choice Lists

*Notes.* The figure shows how either initial choice (between chocolates today and a pen in 60 days) would be followed by a choice list in which participants would indicate their WTA to take the option they did not initially choose instead of their initially preferred option. Each participant would see the choices from either (a) or (b).

(midpoint between \$6 and \$8) to take the chocolates today.<sup>12</sup>

To test for convergent validity of our unimodal measures, we elicited two conventional measures of time discounting after participants had completed the DCM. One measure consisted of choices between smaller-sooner and larger-later amounts of money, selected from Kirby et al. (1999). The other was a matching task adapted from Van den Bergh et al. (2008). The participants stated the delayed sum they regarded as just as good as \$15 now, where the delays were one week and one month, and time preference was measured using the area-under-the-curve method (Myerson et al. 2001). Since these tasks are unimodal, we should expect responses to them to correlate with those to the unimodal tasks of the DCM.

In total, 324 U.S. residents completed the survey. We excluded 24 who had opted out of receipt of goods, and hence the incentivisation, by not providing an email

address.<sup>13</sup> Every participant was given a five-digit ID number. We randomly selected 37 of these numbers to identify participants to receive one of their choices for real, i.e., the option they had chosen in one initial choice or one row of a choice list. This choice would either be a good or a good plus monetary compensation in the form of an Amazon.com gift voucher. All participants were informed that one in nine of them would receive a choice for real and that the list of all chosen ID numbers would be emailed to everybody, followed by emails to the chosen participants indicating what they would receive and when. The gift vouchers sent out as monetary compensation were worth \$20.21 on average.

## Results

**Initial Choices.** We first consider the initial choices between goods unaccompanied by monetary compensation. For unimodal choices, the great majority chose



the earlier option: 84% (65/77) for chocolates and 84% (62/74) for the pen. For cross-modal choices, the proportion choosing the earlier option was much lower: 61% (48/79) chose chocolates now over a pen later, and 51% (36/70) chose a pen now over chocolates later. Because these proportions are lower ( $p < 0.001$ ) for cross-modal than unimodal, cross-modal choices are at least partly determined by preferences over goods. Because they sum to more than 100% (albeit not significantly;  $p = 0.124$ ), choices also seem at least partly determined by time. Time, however, is not decisive, since 43% (65/149) of participants facing a cross-modal choice chose the delayed option.

**Cost of Delay.** Our main question is whether the impact of time is the same when making cross-modal and unimodal choices. This is measured by cost of delay.

The baseline model predicts that, for each individual, the sum (or, equivalently, the average) of that individual's two cross-modal costs of delay equals the sum (respectively, average) of their two unimodal costs of delay. In our design, each participant reveals the cost of delay for one pair of options. Random assignment to groups then implies that, if the baseline model is correct, we should find the average cost of delay across the participants completing cross-modal tasks equal to average cost of delay across the participants completing unimodal cases. But that is not at all what we observe.

Figure 3 shows the cost of delay for each pair of options, averaged across participants making the choice between those options. Each cross-modal column in the figure is markedly shorter than each unimodal column, indicating that average observed cost of delay is lower for cross-modal than unimodal comparisons. More precisely, the mean values for cost of delay in each of the comparisons are as follows:

Unimodal—chocolates: cost of delay = \$5.31,

Unimodal—pens: cost of delay = \$3.91,

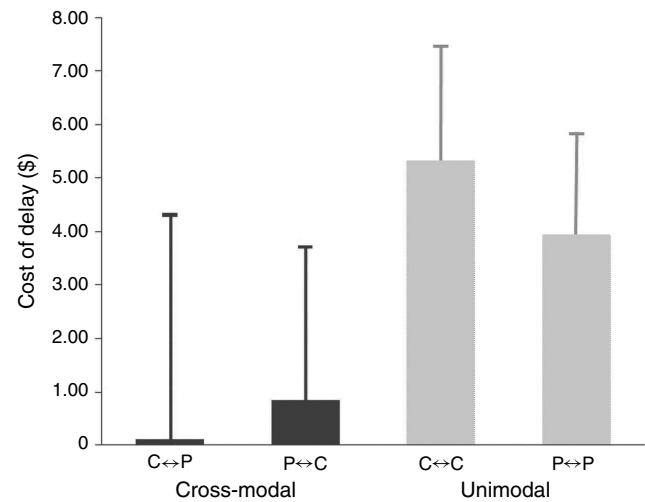
Chocolates now, pens later: cost of delay = \$0.12,

Pens now, chocolates later: cost of delay = \$0.86.

Aggregating across chocolates and pens, the mean cost of delay is much lower for cross-modal comparisons (\$0.46) than for unimodal ones (\$4.63), and the difference is statistically significant ( $p = 0.006$ ).

The difference between unimodal and cross-modal cost of delay was confirmed with two analyses. The first was an ordinary least squares (OLS) regression that pooled responses from all questions but, as indicated in Endnote 12, excluded participants who did not switch. As a further check on robustness, we conducted a Tobit regression (Amemiya 1973), which allowed us to include these individuals. We did this by assigning them a WTA of \$52.50, as if they would have switched

**Figure 3.** The Average Cost of Delay for Each Intertemporal Comparison Across Participants Who Made That Comparison



*Notes.* For each comparison, a participant's cost of delay is obtained from his or her WTA for taking the dispreferred option instead of the preferred one. Cost of delay is given by WTA itself when the sooner option is preferred and by minus WTA (hence, negative) when the later option is preferred. Dark bars are for cross-modal comparisons and light bars for unimodal ones. The upper 95% confidence interval is shown. "C" stands for the box of chocolates and "P" for the pen. For each column, the first letter denotes the good in the earlier option and the second letter the good in the later option.

had there been one more increment in the choice list. The Tobit takes into account the truncation of data at  $\pm\$52.50$ . The results for both analyses are presented in Table 2, with and without demographic controls. In all four regressions, the coefficient on the cross-modal dummy is significant and negative, confirming the earlier analysis.

**Correlations with Conventional Measures of Time Preference.** To test whether the unimodal comparisons of our DCM capture the same kind of time preference as conventional measures, we correlated unimodal costs of delay to the standard time preference measures, separately for the pen and the chocolates. This analysis, reported in Table 3, suggests that the conventional time preference measures typically correlate in the expected direction with the unimodal cost of delay, especially for the two choice-based conventional measures (where  $p < 0.01$  and  $p < 0.05$ , respectively). The correlation between the conventional measures and the cross-modal costs of delay are not significant at the 95% confidence level.

**Non-Preference-Based Influences.** So far we have tested whether responses to the DCM reflect preferences that are aligned with the baseline model, and our results suggest they do not. In the Discussion, we will consider preference-based alternatives to the baseline model, but here, we investigate the possibility that



**Table 2.** Influence of Cross-Modality on Cost of Delay

Cost of delay (\$)	OLS excl. no-switch Model (1)	Tobit incl. no-switch Model (2)	OLS excl. no-switch Model (3)	Tobit incl. no-switch Model (4)
<i>Cross-modal</i> (dummy, 1 = yes)	-4.17*** (1.49)	-5.52*** (1.67)	-4.09*** (1.57)	-5.43*** (1.75)
<i>Female</i> (dummy, 1 = yes)			-2.25 (1.53)	0.19 (1.77)
<i>Age at last birthday</i> (years)			-0.04 (0.11)	-0.12 (0.12)
<i>Low education</i> (dummy, 1 = yes)			-0.41 (2.64)	-0.19 (2.65)
<i>High education</i> (dummy, 1 = yes)			-2.35 (1.76)	-0.60 (2.30)
<i>Married</i> (dummy, 1 = yes)			0.08 (2.19)	-0.60 (2.30)
<i>Has children</i> (dummy, 1 = yes)			0.76 (2.34)	2.46 (2.52)
<i>Employed full or part time</i> (dummy, 1 = yes)			-1.30 (1.83)	-2.38 (2.18)
<i>Constant</i>	4.63*** (0.73)	6.36*** (1.05)	8.88*** (3.05)	11.30*** (3.24)
<i>n</i>	292	298	292	298
<i>R</i> <sup>2</sup>	0.026		0.044	
Pseudo- <i>R</i> <sup>2</sup>		0.004		0.006
Sigma (Tobit)		14.58 (1.00)		14.48 (0.99)

Notes. The terms “incl. no-switch” and “excl. no-switch” denote regressions including and excluding data from respondents who never switched, respectively. Where these data are included, Tobit regression allows for the truncation of the data. Robust standard errors are reported in parentheses.

\* $p < 0.10$ ; \*\* $p < 0.05$ ; \*\*\* $p < 0.01$ .

responses to the DCM may reflect influences other than preferences.

For “choice lists” similar to those used in this study, people sometimes switch near the middle of the scale or, less frequently, at other focal points (Andersen et al. 2006). To see how such scale effects might contribute to our results, consider an extreme case in which every participant demands the same compensation (say, \$10), regardless of her preference and of which choice she faced. Suppose that, in a given choice, the proportion  $f$  of participants prefer the earlier option over the

later one. For these participants, the cost of delay is calculated as their raw WTA. But for the proportion  $1 - f$  of participants who prefer the later option, the cost of delay is the negative of their raw WTA. Thus, if all raw WTAs are driven by a scale effect to \$10, the average cost of delay in a given choice is driven to the dollar sum  $10f - 10(1 - f) = 10(2f - 1)$ . When we compare two choice tasks, this scale effect will drive the average cost of delay for the task with the lower  $f$  below that for the task with the higher  $f$ . As cross-modal tasks may pit preferences over type of good against those over timing, we would expect  $f$  to be systematically lower in cross-modal tasks than in unimodal tasks. Indeed, that is what we find. So a strong enough scale effect would tend to draw average cost of delay for a cross-modal comparison below that for a unimodal comparison. Evidently, this argument does not require the specific value of \$10 as the one to which scale effects draw raw WTA responses. But besides  $f$  taking different values for cross-modal and unimodal cases, the argument does crucially depend on scale effects drawing raw WTA responses toward specific values, regardless of the options.

We address this possibility in two ways: first, by looking directly for evidence that raw WTAs are independent of the choice faced, and second, by excluding

**Table 3.** Correlations Between Cost of Delay and the Conventional Time Preference Measures

DCM comparison (sooner good–later good)	Conventional task	Correlation	Significance ( $p$ -value)
Choc–choc	Choice	0.3025	0.0083
	Matching	-0.1953	0.0931
Pen–pen	Choice	0.2574	0.0314
	Matching	-0.0409	0.7368
Choc–pen	Choice	0.1563	0.1717
	Matching	0.0363	0.7526
Pen–choc	Choice	0.1067	0.3828
	Matching	-0.2037	0.0932

from our analysis the most obvious candidate for a salient fixed value to which scale effects might draw responses.

First, we provide evidence of significant differences between raw WTA responses across the four choices. The means for the cross-modal cases are \$14.28 (chocolates now, pen later) and \$9.22 (pen now, chocolates later). These are significantly different from one another ( $p = 0.0043$ ). The unimodal means are closer in value, at \$8.00 (chocolates now and later) and \$6.10 (pen now and later), and they do not differ significantly at the 95% confidence level ( $p = 0.0723$ ). Crucially, equality between the mean unimodal raw WTA and mean cross-modal raw WTA can be rejected at the 99% confidence level. These points suggest that the distributions of raw responses are different between tasks, reflecting sensitivity to the options and to strength of preference between them.

Second, we drop the most likely candidate for a scale effect-driven response. Since 23% of the sample switches at the \$10 row, we repeated the OLS and Tobit regressions of cost of delay on cross-modality and demographics but remove from the sample participants that switch in this row. Table 4 reports the results of these regressions, showing that despite the smaller sample size, the cross-modal effect persists. The effect

size is similar to that in Table 2, and the effect is significant at the 90% confidence level (at least) in all cases.

## Discussion

So far we have made three contributions: we presented a new preference measurement instrument, crystallised the implications of standard (value-based) theories for the relationship between unimodal and cross-modal intertemporal comparisons, and provided empirical findings at odds with the predictions of those theories. We now discuss how the DCM relates to standard methods, explain how our baseline model is characteristic of value-based modelling approaches, and then take the first steps toward a view of preference that can explain our empirical finding.

**Measurement Instrument.** We have already stated the main distinctive advantages of the DCM. But although the DCM departs from more traditional methods, such as eliciting an indifference point between smaller sooner and larger later sums of money, both the DCM and the traditional methods share the same core idea, which is that agents require compensation to accept the delay of an outcome, and this compensation provides a measure of time preference.

**Table 4.** Influence of Cross-Modality on Cost of Delay, Excluding Those Who Switched for \$10

Cost of delay (\$)	OLS excl. no-switch Model (1)	Tobit incl. no-switch Model (2)	OLS excl. no-switch Model (3)	Tobit incl. no-switch Model (4)
<i>Cross-modal</i> (dummy, 1 = yes)	-3.90* (1.86)	-5.69*** (2.14)	-3.89* (2.03)	-5.42** (2.27)
<i>Female</i> (dummy, 1 = yes)			2.33 (1.91)	1.02 (2.26)
<i>Age at last birthday</i> (years)			-0.03 (0.14)	-0.15 (0.16)
<i>Low education</i> (dummy, 1 = yes)			-0.46 (3.33)	0.02 (3.32)
<i>High education</i> (dummy, 1 = yes)			-3.07 (2.25)	-0.09 (2.62)
<i>Married</i> (dummy, 1 = yes)			-0.28 (2.94)	-1.19 (3.08)
<i>Has children</i> (dummy, 1 = yes)			0.27 (3.22)	3.43 (3.50)
<i>Employed full or part time</i> (dummy, 1 = yes)			-0.29 (2.28)	-1.78 (2.74)
<i>Constant</i>	3.94*** (0.89)	6.24*** (1.50)	7.78** (3.89)	10.74*** (4.10)
<i>n</i>	223	229	223	229
<i>R</i> <sup>2</sup>	0.019		0.037	
Pseudo- <i>R</i> <sup>2</sup>		0.004		0.005
Sigma (Tobit)		16.18 (0.77)	—	16.08 (1.17)

*Notes.* The terms “incl. no-switch” and “excl. no-switch” denote regressions including and excluding data from respondents who never switched, respectively. Where these data are included, Tobit regression allows for the truncation of the data. Robust standard errors are reported in parentheses.

\* $p < 0.10$ ; \*\* $p < 0.05$ ; \*\*\* $p < 0.01$ .

It is evident the DCM works on this principle, but it might be less clear how the more traditional methods do. Here, we demonstrate the commonality by showing how each task of the DCM can be reduced to the canonical task in two steps. In the first step, abolish the distinction between  $t = 3$  and  $t = 2$ , so that compensation is received at the same time as the later good. In the second step, make both the earlier and later good be the same fixed amount of money rather than discrete consumer goods. The good and the compensation are then in the same divisible units; the task elicits the adjustment to an initial sum of money that the participant requires to delay its receipt from  $t = 1$  to  $t = 2$ . For example, a participant who is indifferent between \$100 today and \$120 in six months is revealing she will demand \$20 compensation in six months to accept \$100 in six months instead of \$100 today.

The DCM is more general than the canonical task in that it achieves divisibility of compensation without requiring divisibility of goods. This permits the goods to be discrete and different from one another, so allowing for cross-modal comparisons and many other possibilities, while leaving unaffected the core underlying idea about compensation as a measure of preference.

**The Value-Based Modelling Approach.** Earlier we used a baseline model to derive the hypothesis that the sum of cross-modal costs of delay equals the sum of unimodal costs of delay in the setup summarized by the Fisher diagram (see Figure 1). A key assumption for this hypothesis was linearity of utility for the relevant money amounts. Linear utility is a standard assumption for small money amounts, but concavity is an obvious alternative and has been proposed even for small amounts (e.g., Andersen et al. 2008, Andreoni and Sprenger 2012, Galanter 1962, Kahneman and Tversky 1979). In Appendix A, we show that assuming concavity does change the prediction of the baseline model. But this does not redeem the baseline model, because the change is in the opposite direction of what we observe.

As argued above, the baseline model is quite general when considered within the class of value-based accounts of intertemporal comparison. Nevertheless, it relies on the fundamental principle of the value-based approach, that the utility of a given dated good is *independent of its comparators*. To see this, recall the argument that follows Equation (3) showing why, for an agent who prefers  $B_1$  to  $A_2$  and has  $v(\cdot)$  linear,  $[x_{AB} - x_{AA}]$  equals  $[x_{BB} - x_{BA}]$ . The argument is that each square-bracketed term is given by the difference in utility between the delayed goods  $B_2$  and  $A_2$ . It rests on an implicit assumption that it does not matter to that difference whether these delayed goods are received instead of  $A_1$  (as they are for  $x_{AB}$  and  $x_{AA}$ ) or instead of  $B_1$  (as they are for  $x_{BB}$  and  $x_{BA}$ ). As this assumption is just an application of the fundamental principle, it

will typically carry over into other value-based models. In view of this, we now explore explanations of our findings that depart from the value-based approach.

**Explaining the Cross-Modal Effect.** We provide two potential explanations for the discrepancy between cross-modal and unimodal choice that assume, respectively, that the weights put on option features and the interpretation of those options vary with what they are compared with. In the first explanation, which draws on insights from multiattribute choice (Houston and Sherman 1995), the weight put on each attribute of an option is inversely related to how many attributes differ between those options. The second explanation draws on construal-level theory (Trope and Liberman 2003) and proposes that the mental representation of options depends on what they are compared to.

The first explanation treats the delay in intertemporal choices as only one attribute among many.<sup>14</sup> All attributes, including delay, receive a decision weight that is directly related to their general importance and inversely related to the number of attributes that differ between options.<sup>15</sup> To illustrate the idea in an atemporal context, consider the value a consumer might place on the “color” attribute when valuing two used cars. Suppose this consumer will pay \$100 more for a blue car than a red one when the cars differ only in color. Now suppose the cars differ in multiple attributes, such as model, engine size, mileage, age, and the upholstery on the seats. As these differences proliferate, the impact of color will likely decline until it plays little if any role in that consumer’s valuation of the cars. In general, as options become less similar in other respects, the weight on any differentiating attribute will decrease.<sup>16</sup>

We now briefly outline a model based on this intuition, which is elaborated and generalised in Appendix B. Consider a stylised attribute specification of our four experimental options. Because the goods are either identical (in the unimodal comparisons) or very different (in the cross-modal), we capture the nature of the options as two elements in a vector, corresponding to the presence or absence of a particular good. The vector has an additional element for the timing of the good. If chocolates are the preferred good, a box of chocolates available now can be denoted as  $A_1 = (\alpha, 0, \pi)$ , where the first element is nonzero because the box of chocolates is present, and  $\alpha$  denotes the atemporal value of the chocolates. The second element is zero because the pen is absent (if present, we denote it as  $\beta$ ), and the third is  $\pi$  because the good is available now. Options are compared by first taking the difference between two option vectors and then the (possibly weighted) sum of the elements of the resulting difference vector. This corresponds to the cognitive process of comparing options and computing their differences on each attribute. As an illustration, take two options—the chocolates now,  $A_1 = (\alpha, 0, \pi)$ , and

**Table 5.** Multiattribute Accounts of Cross-Modal and Unimodal Choices

Mode	Options	Attributes	Difference	Equal weight model		Unequal weight model	
				Aggregate difference	Sum	Aggregate weighted difference	Sum
Unimodal	$A_1$	$(\alpha, 0, \pi)$	$[0, 0, \pi]$	$\pi$	$2\pi$	$\pi$	$2\pi$
	$A_2$	$(\alpha, 0, 0)$					
	$B_1$	$(0, \beta, \pi)$	$[0, 0, \pi]$	$\pi$			
	$B_2$	$(0, \beta, 0)$					
Cross-modal	$A_1$	$(\alpha, 0, \pi)$	$[\alpha, -\beta, \pi]$	$\pi + (\alpha - \beta)$	$2\pi$	$(\pi + (\alpha - \beta))/3$	$(\frac{2}{3})\pi$
	$B_2$	$(0, \beta, 0)$					
	$B_1$	$(0, \beta, \pi)$	$[-\alpha, \beta, \pi]$	$\pi - (\alpha - \beta)$		$(\pi - (\alpha - \beta))/3$	
	$A_2$	$(\alpha, 0, 0)$					

the pen later,  $B_2 = (0, \beta, 0)$ —and compute the difference between them on each attribute,  $A_1 - B_2 = [\alpha, -\beta, \pi]$ . *Provided each attribute is weighted equally*, and using an additive specification, the strength of preference will follow the sum of these differences: the unweighted sum of the three elements is  $\alpha - \beta + \pi$ . The relative sizes of  $\alpha, \beta$ , and  $\pi$  are then enough to determine both the choice between  $A_1$  and  $B_2$  and the compensation required to take the less preferred of the two. (As  $A$  denotes the preferred good,  $\alpha > \beta$ , and preference is for  $A_1$ , given any  $\pi > 0$ . The compensation depends on all three terms.) This specification has an affinity with the baseline model in that combined strength of preference for both unimodal and cross-modal choices are the same as shown by the “Equal weight model” columns of Table 5.

Suppose, however, our decision maker has limited attention and, as attribute differences proliferate, finds she has to spread that attention more thinly. The model detailed in Appendix B is based on the idea that a fixed quantity of attention is allocated over attributes that differ. Although the model is more general, a simple instance is shown in the “Unequal weight model” column of Table 5. In this instance, for the unimodal case, delay is the only attribute that differs, and so it receives a weight of one; in the cross-modal case, all three attributes vary, not only delay, and so each receives a weight of one-third. This leads the combined strength of preference (the final column of Table 5) to be lower for cross-modal choices.

An additional and related explanation is that whether a choice is cross-modal or unimodal influences the mental representation or *construal* of choice options. This extends the idea that the objects of choice are not defined by their physical properties but in their interpretation by the agent (e.g., Nisbett and Ross 1991), a notion that has received a substantial boost in the form of construal-level theory (Liberman and Trope 1998). To illustrate the idea, again imagine choosing between two cars, where car A is available now and car B later. When comparing the cars, we are likely to

define them in terms of features such as “color” and “leather seats.” Now imagine choosing between car A now and a vacation next year. We will certainly think of the two options differently—perhaps defining them in terms of their different purposes such as “transportation” and “relaxation.” It would not be surprising if these different construals led to differences in the value placed on car A. Likewise, when choosing between chocolates now and later, our construal may be based on considerations such as the tastiness of the chocolates or how they melt in the mouth. This concrete representation can promote a preference for earlier receipt of the good (Chen and He 2011). By contrast, when making cross-modal choices we may care less about when the good is received, because we construe the options in terms of their more abstract and functional characteristics (perhaps improving a relationship, or writing a novel); see, e.g., Kim et al. (2013), Liberman and Trope (1998), and Liberman et al. (2002).

A study by Malkoc et al. (2010, Experiments 1A and 1B) also suggests that similarity between options, which is central to our distinction between cross-modal and unimodal choices, can influence patience, and does so by changing the way options are construed. Malkoc et al. did not elicit cross-modal and unimodal intertemporal choices, but rather elicited intertemporal choices after first having their participants make what we would call a “relatively unimodal” comparison (a feature-by-feature comparison of two very similar digital cameras) and a “relatively cross-modal” comparison (between one of the digital cameras and a film camera with which it shared none of the specified features). After making the comparison, participants indicated how eager they were to receive a digital camera by indicating their WTA to agree to a 3- and 10-day delay in the delivery of that camera. Malkoc et al. found that participants were more sensitive to the delay when the initial comparison was (in our terminology) unimodal rather than cross-modal and also that that participants were generally more patient (although not significantly so) when a cross-modal evaluation had



preceded their choice. Malkoc et al. also observed that their participants construed the choice options more abstractly in their cross-modal-like comparison case, and that this difference in construal mediated the differences in patience in the two conditions.

The notion of “relative” cross-modality, hinted at in the above paragraph, brings in a broader issue. In our design the unimodal choices were between identical objects and the cross-modal choices between radically different objects. But there are many intermediate possibilities, such as choosing between a rescued cat from the animal shelter today or a pedigree cat from a litter yet to be born. Our experiment tested extreme cases, with delay the only attribute that varied between options in unimodal comparisons. As we have shown, such comparisons are likely to accentuate the importance of time. A similar mechanism could be at work in canonical measures of time preference used in the previous literature. These measures vary two attributes (quantity and timing), which is fewer than the number that would vary in many cross-modal decisions of everyday life. While there is much to learn about the role of time in complex decisions, our findings suggest that time does not have an absolute or predefined importance in decision making.

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### Appendix A. Further Analysis of the Baseline Model

In this appendix, we flesh out some details of the baseline model and extend it to cover the case where utility of money is nonlinear. We assume the agent’s decisions, taken at or before the start of  $t = 1$ , maximise the following objective function, each component of which is a subutility function that is finitely valued and strictly increasing in all arguments:

$$U = u(A_1, A_2, B_1, B_2) + v(\cdot). \quad (\text{A.1})$$

This functional form imposes additive separability between dated goods and money, with utility from the former denoted by  $u(\cdot)$  and from the latter by  $v(\cdot)$ . We impose that each dated good takes either the value 1 (indicating the agent receives it) or the value 0. Without further loss of generality, define the notation used in the main text as follows:  $u(1, 0, 0, 0) \equiv a_1$ ;  $u(0, 1, 0, 0) \equiv a_2$ ;  $u(0, 0, 1, 0) \equiv b_1$ ;  $u(0, 0, 0, 1) \equiv b_2$ . We normalise  $u(0, 0, 0, 0)$  to zero.

Following the default assumptions of the main text, we ignore indifference between dated goods and impose that  $A_1 > B_1$ ,  $A_2 > B_2$ ,  $A_1 > A_2$ , and  $B_1 > B_2$ , with  $>$  denoting strict preference. This leaves open the preference over  $B_1$  and

$A_2$  where considerations of preference over timing and preference over types of good can conflict. For brevity, in this appendix, we use the term “order TP” (for timing-based preference) for the case where  $B_1 > A_2$  and “order GP” (for good-based preference) for the case where  $A_2 > B_1$ .

The terms  $x_{AA}$ ,  $x_{BB}$ , and  $x_{AB}$  are given by Equations (1.i)–(1.iii) in the main text. For order TP,  $x_{BA}$  is given by Equation (1.iv); for order GP,  $y_{BA}$  is given by Equation (1.iv’). The calculations in the main text demonstrate that, regardless of the functional form of  $v(\cdot)$ , Equation (2) holds under order TP and Equation (2’) under order GP. When  $v(\cdot)$  is linear, Equations (2) and (2’) imply Equations (3) and (3’), respectively, which establish the null hypothesis of the baseline model. However, linearity of  $v(\cdot)$  is crucial for the transition from Equation (2) (respectively, (2’)) to Equation (3) (respectively, (3’)). The main task of this appendix is to show how the argument would be affected if  $v(\cdot)$  is strictly concave.

Take order TP first. It follows from its definition and the default assumptions that  $\infty > a_1 > b_1 > a_2 > b_2 > 0$ . These inequalities along with Equations (1.i)–(1.iv) imply that  $\infty > v(x_{AB}) = a_1 - b_2 > a_1 - a_2 = v(x_{AA}) > 0$  and  $\infty > v(x_{BB}) = b_1 - b_2 > b_1 - a_2 = v(x_{BA}) > 0$ , whereas Equation (2) yields  $v(x_{AB}) - v(x_{AA}) = v(x_{BB}) - v(x_{BA})$ . Since  $v(\cdot)$  is strictly increasing, these points imply that  $v(x_{AB}) - v(x_{AA})$  and  $v(x_{BB}) - v(x_{BA})$  are equal increments to  $v(\cdot)$  induced by increases in its argument, in one case from  $x_{AA}$  to  $x_{AB}$  and in the other case from  $x_{BA}$  to  $x_{BB}$ . From Equations (1.iii) and (1.ii),  $v(x_{AB}) = a_1 - b_2 > b_1 - b_2 = v(x_{BB})$ . Consequently, with  $v(\cdot)$  strictly concave,  $x_{AB} - x_{AA} > x_{BB} - x_{BA}$ . Rearranging yields  $x_{AB} + x_{BA} > x_{AA} + x_{BB}$ . This inequality replaces Equation (3) when  $v(\cdot)$  is concave and preference order TP applies.

Now consider order GP, with which (together with the default assumptions) implies  $\infty > a_1 > a_2 > b_1 > b_2 > 0$  (NB:  $a_2$  and  $b_1$  are flipped relative to order TP). As a first step, define the sum of money  $z$  such that  $v(z) = a_1 - b_1$  and recall that  $v(0) = 0$ . From these points and Equations (1.ii)–(1.iii),  $v(x_{AB}) - v(z) = b_1 - b_2 = v(x_{BB}) - v(0)$ . Since  $v(\cdot)$  is increasing and  $b_1 - b_2 > 0$ , each of the terms  $v(x_{AB}) - v(z)$  and  $v(x_{BB}) - v(0)$  is an increment to  $v(\cdot)$  induced by an increase in its argument, in one case from  $z$  to  $x_{AB}$  and in the other case from 0 to  $x_{BB}$ ; the two increments are equal since, as just noted,  $v(x_{AB}) - v(z) = v(x_{BB}) - v(0)$ . Equations (1.ii)–(1.iii) also imply  $v(x_{AB}) = a_1 - b_2 > b_1 - b_2 = v(x_{BB})$ . Combining these conclusions, strict concavity of  $v(\cdot)$  implies

$$x_{AB} - z > x_{BB} - 0. \quad (\text{A.2})$$

Now, using Equations (1.i) and (1.iv’),  $v(z) - v(x_{AA}) = a_2 - b_1 = v(y_{BA}) - v(0)$ . Since  $v(\cdot)$  is increasing and  $a_2 - b_1 > 0$ , each of the terms  $v(z) - v(x_{AA})$  and  $v(y_{BA}) - v(0)$  is an increment to  $v(\cdot)$  induced by an increase in its argument, in one case from  $x_{AA}$  to  $z$  and in the other case from 0 to  $y_{BA}$ . Moreover, as just noted,  $v(z) - v(x_{AA}) = v(y_{BA}) - v(0)$ . Since  $v(z) = a_1 - b_1 > a_2 - b_1 = v(y_{BA})$ ,  $v(z) > v(y_{BA})$ . Combining these conclusions, strict concavity of  $v(\cdot)$  implies

$$z - x_{AA} > y_{BA} - 0. \quad (\text{A.3})$$

From (A.2) and (A.3),  $[x_{AB} - z] + [z - x_{AA}] > x_{BB} + y_{BA}$ . Rearranging yields  $x_{AB} - y_{BA} > x_{AA} + x_{BB}$ . This inequality replaces Equation (3’) when  $v(\cdot)$  is concave and preference order GP applies.

These arguments and those of the main text establish the following summarising result, which encapsulates all features of the baseline model needed for the paper.

**Proposition 1.** *In the baseline model,*

- (i)  $x_{AB} + x_{BA} \geq x_{AA} + x_{BB}$  for preference order TP;
- (ii)  $x_{AB} - y_{BA} \geq x_{AA} + x_{BB}$  for preference order GP; and
- (iii) in both (i) and (ii), the weak inequality holds as an equality when  $v(\cdot)$  is linear and as a strict inequality when  $v(\cdot)$  is strictly concave.

This result shows that, provided each participant displays either preference order TP or preference order GP, concavity of  $v(\cdot)$  cannot rationalise failure of the null hypothesis of the baseline model unless that failure takes the form that the combined cross-modal cost of delay exceeds the combined unimodal cost of delay. The opposite could, of course, be explained by convexity of  $v(\cdot)$ , but that would be a very unusual assumption since we are only concerned with  $v(\cdot)$  in the domain of monetary gains.<sup>17</sup>

### Appendix B. A Weighted Multiattribute Intertemporal Choice Model

Here, we provide a more general and formal account of the weighted multiattribute intertemporal choice model sketched in the main paper and illustrated in Table 5, and we extend the argument to include explicit reference to monetary compensation. The model draws on ideas from a range of earlier researchers and has some formal properties in common with the model of Köszegi and Szeidl (2013). The model is specifically developed in the context of our experimental setup, and we do not claim greater generality for it.

The two goods and the two time periods are as in Figure 1, yielding the same four dated goods. But now, as depicted in Table 5, let there be three attributes on which a dated good can be evaluated: attribute 1 takes the value  $\alpha$  if the good to be received is of type  $A$  and 0 otherwise, attribute 2 takes the value  $\beta$  if the good is of type  $B$  and 0 otherwise, and attribute 3 takes the value  $\pi$  if the good will be received in  $t = 1$  and 0 if it will be received in  $t = 2$ . We impose  $\alpha, \beta,$  and  $\pi > 0$ .<sup>18</sup>

For brevity, we address only the case where, in any comparison between dated goods, the agent prefers the one with a sooner delivery date, denoted by  $S$ , over the one with the later delivery date, denoted by  $L$ . As in the main text, we use  $x$  to denote WTA for taking the dispreferred option instead of the preferred one. The WTA is determined by the difference between the sums of weighted attributes for each option:

$$\sum_{r \in \mathfrak{X}} w_r [S_r - L_r] = v(x), \quad (\text{B.1})$$

where  $v(\cdot)$  is an increasing function defined on money;  $\mathfrak{X}$  is the set of attributes, with typical element  $r$ . The terms  $S_r$  and  $L_r$  are, respectively, the values of  $S$  and  $L$  for attribute  $r$ ; and  $w_r$  is the weight put on attribute  $r$  when comparing  $S$  and  $L$ . Note that money is treated separately from other attributes to make its role as a measure of the “cost” of exchanges of dated goods clear. This makes the analysis simpler and comparable in this respect to the baseline model, without altering the key mechanism that we model. It does differ formally, however, from previous attribute-based choice models of time preference where money is treated similar to other attributes (e.g., Scholten and Read 2010).

The weight put on each attribute is a function of the absolute difference between the two options on that attribute and the sum of those absolute differences for all attributes where the two options differ. That is, for any attribute  $r \in \mathfrak{X}$ ,

$$w_r = g(|S_r - L_r|) / \sum_{r' \in \mathfrak{X}'} g(D_{r'}), \quad (\text{B.2})$$

where  $\mathfrak{X}'$  is the subset of  $\mathfrak{X}$  containing those attributes where  $S$  and  $L$  take different values,  $D_{r'}$  is the maximum (in absolute value) difference in values possible on attribute  $r' \in \mathfrak{X}'$ , and  $g(\cdot)$  is an increasing function with  $g(0) = 0$ . The formulation (B.2) imposes no restrictions on the relative sizes of  $g(\alpha)$ ,  $g(\beta)$ , and  $g(\pi)$ , leaving the decision maker free to regard any attribute as “intrinsically” more important than any other. However, an attribute for which  $S$  and  $L$  take the same value has no bearing on the choice between them. Instead, a total decision weight of unity is spread across those attributes where  $S$  and  $L$  differ in proportions determined by their intrinsic importance. (This generalises the case considered in Table 5.)

In the value-vector form,  $A_1 = (\alpha, 0, \pi)$ ,  $A_2 = (\alpha, 0, 0)$ ,  $B_1 = (0, \beta, \pi)$ , and  $B_2 = (0, \beta, 0)$ . As in the main text, we let good  $A$  be the preferred good. To ensure this and that, in every intertemporal comparison, the earlier option is preferred to the later one, it suffices to impose  $\pi g(\pi) > \alpha g(\alpha) - \beta g(\beta) > 0$ . Then,  $x_{AA}$  and  $x_{BB}$  are defined implicitly by

$$[\pi g(\pi) / g(\pi)] = v(x_{AA}), \quad (\text{B.3})$$

$$[\pi g(\pi) / g(\pi)] = v(x_{BB}), \quad (\text{B.4})$$

i.e., by  $\pi = v(x_{AA}) = v(x_{BB})$ . It is an immediate implication that  $x_{AA} = x_{BB}$ . Note, however, that this implication would be relaxed had we allowed different delay attributes for different goods.

For brevity, we denote the sum  $g(\alpha) + g(\beta) + g(\pi)$  as  $\Omega$ . Then  $x_{AB}$  satisfies

$$[\pi g(\pi) + (\alpha g(\alpha) - \beta g(\beta))] / \Omega = v(x_{AB}). \quad (\text{B.5})$$

Similarly,  $x_{BA}$  satisfies

$$[\pi g(\pi) - (\alpha g(\alpha) - \beta g(\beta))] / \Omega = v(x_{BA}). \quad (\text{B.6})$$

We now work out the implications of these implicit definitions for the relationship between cross-modal and unimodal WTAs. First, suppose  $v(x) = x$ . Then,

$$x_{AA} + x_{BB} = 2\pi \quad (\text{B.7})$$

and

$$x_{AB} + x_{BA} = [2\pi g(\pi) / \Omega]. \quad (\text{B.8})$$

Thus,  $x_{AA} + x_{BB} > x_{AB} + x_{BA}$ , because the ratio  $g(\pi) / \Omega$ , which we will call the *cross-modal deflator*, is less than unity. By a trivial extension of the argument,  $x_{AA} + x_{BB} > x_{AB} + x_{BA}$  is guaranteed for any linear  $v(\cdot)$ .

Now, suppose  $v(\cdot)$  is concave. From Equations (B.3) and (B.4),  $v(x_{AA})$  and  $v(x_{BB})$  each takes the value  $\pi$ . Relative to this, the value of  $v(x_{BA})$  in (B.6) is deflated in two ways. First,  $\pi$  is deflated by the cross-modal deflator  $g(\pi) / \Omega$ ; then the result is further reduced by subtracting  $(\alpha g(\alpha) - \beta g(\beta)) / \Omega (> 0)$  from it. Since  $v(\cdot)$  is increasing, it follows that each of  $x_{AA}$  and  $x_{BB}$  exceeds  $x_{BA}$ . By contrast, relative to  $v(x_{AA})$  and  $v(x_{BB})$ , the

value of  $v(x_{AB})$  is reduced by the corresponding operation of the cross-modal deflator but then increased by the addition of  $(\alpha g(\alpha) - \beta g(\beta))/\Omega$  to the result. Consequently, the average of  $v(x_{AB})$  and  $v(x_{BA})$  is constant at  $[\pi g(\pi)/\Omega]$ , which is unambiguously below the average of  $v(x_{AA})$  and  $v(x_{BB})$ . However, ceteris paribus, a rise in  $(\alpha g(\alpha) - \beta g(\beta))/\Omega$  will increase the deviations of  $v(x_{AB})$  and  $v(x_{BA})$  from  $\pi g(\pi)/\Omega$  and so increase  $(x_{AB} + x_{BA})/2$ , if  $v(\cdot)$  is concave. Taken far enough, this effect may be able to raise  $(x_{AB} + x_{BA})$  over  $(x_{AA} + x_{BB})$ . However, for that to happen, the effect would have to outweigh the downward impact of the cross-modal deflator on  $(x_{AB} + x_{BA})$ .

Intuitively,  $(x_{AA} + x_{BB})$  reflects twice the cost of delay when that cost is at its maximum in the sense that all attention is paid to delay. By contrast,  $(x_{AB} + x_{BA})$  reflects twice the cost of delay when the decision maker is partly distracted from delay by other matters. Those other matters tend to drive  $x_{AB}$  up because it must compensate for a worse type of good rather than a better one, whereas they tend to drive  $x_{BA}$  down for the converse reason. Although exchange-of-type-of-good considerations have an impact on the cross-modal WTA terms, those impacts cancel out when the cross-modal WTAs are summed, if  $v(\cdot)$  is linear. They need not cancel out if  $v(\cdot)$  is nonlinear, but nevertheless, they go in opposite directions in the two cross-modal cases. In many cases, the combined impact of exchange-of-good-considerations on  $(x_{AB} + x_{BA})$  is likely to be of second-order importance, especially if  $v(\cdot)$  is only mildly nonlinear. By contrast, the downward effect of the cross-modal deflator on the relative impact of delay considerations on  $(x_{AB} + x_{BA})$  compared with  $(x_{AA} + x_{BB})$  is a first-order matter.

## Endnotes

<sup>1</sup> Examples include Chapman (1996), Frederick (2006), Hardisty and Weber (2009), Kim et al. (2013), McClure et al. (2007), Reuben et al. (2010), and Ubfal (2016).

<sup>2</sup> Bickel et al. (2011) study what they call cross-commodity discounting for choices between money and cocaine. Their methods and goals are significantly different from ours.

<sup>3</sup> For the reasons given in the introduction, in this paper's application of the DCM, we specify that  $A_1$  and  $A_2$  are identical objects received at different dates (and likewise,  $B_1$  and  $B_2$ ). However, in a more general form, the DCM would allow them to differ by quantity and quality as well as by timing; for example,  $A_1$  could be a box of 10 chocolates and  $A_2$  a box of 15;  $B_1$  could be a ballpoint pen and  $B_2$  a fountain pen, in each case delivered at the relevant date.

<sup>4</sup> Allowing indifference between dated goods would just proliferate uninteresting cases.

<sup>5</sup> In our experiment, the two goods are a box of chocolates and a fountain pen. We allow either of them to take the role of the preferred good  $A$  for a given participant. Thus, all that is ruled out here is the possibility that the participant prefers one of the goods, if delivered at  $t = 1$ , and the other, if delivered at  $t = 2$ . Although not logically impossible, we do not see this as an important case. (A separate study that tested directly for this possibility using the same goods found its incidence to be negligible.)

<sup>6</sup> It is significant that we model impacts on decision utility (viewed from the moment of decision) of the prospect of receiving a good of a given type at a given date, making no assumption about when the good is consumed except that it does not precede receipt. Thus, we avoid problems that arise for some intertemporal decision experiments if capital markets and/or storage allow consumption to be rescheduled across time relative to income when the analysis

assumes consumption and income to be simultaneous (for discussion, see, e.g., Cubitt and Read 2007, Frederick et al. 2002).

<sup>7</sup> This is a simple way to capture that if (contrary to our default assumptions) the agent were indifferent between two options, no compensation would be required to persuade her to take one rather than the other. As monetary compensation to take a dispreferred option is always positive, we define  $v(\cdot)$  only on the nonnegative interval. So we require no assumptions about utility of money in the domain of monetary losses. As monetary compensation is at  $t = 3$ , the function  $v(\cdot)$  embeds any discounting of money in that period as viewed from the moment of decision. The framework is neutral about when the money is spent (or on what, provided only that this does not interact with utility from goods received in the earlier periods in a way that would affect the relationship between cross-modal and unimodal comparisons).

<sup>8</sup> Some readers may be tempted to think that  $x_{BA} = -y_{BA}$  (e.g., if they combine Equations (3) and (3')). This is not correct. For any agent with a strict preference between  $B_1$  and  $A_2$ , only one of  $x_{BA}$  and  $y_{BA}$  is defined, and only one of Equations (3) and (3') holds.

<sup>9</sup> This formulation is for the case employed here in which there are two types of good. With  $k > 2$  types of goods, the corresponding, more general hypothesis is that the average of the cross-modal costs of delay equals the average of the unimodal costs of delay, an amendment needed because, in general, there are  $k - 1$  times as many cross-modal as unimodal comparisons.

<sup>10</sup> To see this, note that there is nothing in the model that forces the ratio  $(a_2/a_1)$  to equal  $(b_2/b_1)$  or that ties those ratios to any property of the function  $v(\cdot)$ . Moreover, as the analysis above only deals with situations such as those in our implementation of the DCM in which the agent receives one unit of one dated good, it puts no restrictions on how the agent views combinations of dated goods, multiple units of a given good, or losses of either goods or money. The main restriction that it does impose is additive separability of decision utility between goods and money, but, as the goods and money are received in different periods, that restriction would be implied by any model in which the agent maximises an objective function that is additively separable between time periods.

<sup>11</sup> Three related experiments used methods similar to the experiment reported here and produced results that replicate the findings reported in this paper. A further experiment used an alternative methodology, and its results support the interpretation presented in this paper. Details are available from the authors.

<sup>12</sup> More than 96% of respondents made a single switch in the choice list. Of those who did not, three switched more than once (for these, we coded cost of delay as the midpoint between the first and last switch) and six (2%) did not switch even for \$50. We excluded these six individuals from our analysis of cost of delay because when asked for to provide open-ended values of WTA (without incentives), their responses either contradicted earlier responses or seemed too extreme to be credible. Two further respondents gave a different answer in the first row of the response table than they gave in the preliminary pairwise choice, which we interpreted as indicating indifference (cost of delay = 0).

<sup>13</sup> We confirmed our conclusions by replicating the analysis on the set of all respondents (and dealing with those who did not switch in different ways).

<sup>14</sup> Attribute-based approaches have previously been successfully applied to discounting decisions involving money (e.g., Dai and Busemeyer 2014, Ericson et al. 2015, Leland 2002, Rubinstein 2003, Read et al. 2013, Scholten and Read 2010).

<sup>15</sup> A more radical view would be that delay is entirely unimportant to participants unless it is highlighted to them. One rationale, suggested to us by a reviewer, is that people are used to making choices between goods (for example, choosing between chocolates and pens) but less used to choosing when they would be received.



<sup>16</sup>Many similar models make related predictions in a wide range of (usually atemporal) contexts. These include Tversky's (1969) model of intransitivity, regret theory (Bell 1982, Loomes and Sugden 1982, 1987), the cancellation and focus model (Houston and Sherman 1995, Houston et al. 1989), the salience theory (Bordalo et al. 2012, 2013), and the theory of focusing (including applications to intertemporal choice; Kőszegi and Szeidl 2013).

<sup>17</sup>It is also possible to reverse the inequalities if, contrary to order TP and to order GP, the agent regards *A* as a better good than *B* when both are delivered in period 1 but *B* as better than *A* when both are delivered in period 2. Although this is logically possible, we do not think it likely for the goods and time periods of our experiment.

<sup>18</sup>In a more complete model, the elements in the vector will consist of attributes that characterize various features of the options and not just their presence or absence, and options might be partially overlapping on those attributes. Adding such elements would not alter the logic of the argument we make but require more cumbersome notation, so we set them aside.

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