What Causes Delay Discounting?

by

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**Chapter 1**

**Introduction and Background**

**1.1 Overview**

If someone is offered the choice between receiving $10 today and $15 today, she will inevitably choose the $15. However, if the same person chooses between receiving $10 today and $15 in a month, she very well may choose the $10. If she does, she has displayed delay discounting – the devaluing of future outcomes relative to present outcomes. The chief aim of this dissertation project was to contribute to answering the question: What are the psychological drivers of delay discounting behavior? That is, why do people devalue future outcomes in the way that they do? Despite its apparent importance, little research has focused on elucidating the causes of delay discounting behavior. Most studies to date have been concerned with *describing* the phenomenon rather than *explaining* it. Thus, the explanatory question was ripe for investigation. The empirical research presented here consists of a suite of studies that tested a small number of – at times disparate – accounts for delay discounting.

**1.2 Domain of study**

Delay discounting likely has vast and varied influence on human (and non-human) behavior. For the purposes of focus and tractability, I circumscribed a portion of the phenomenon as the object of this research.

First, study was restricted to decisions where one available reward is *clearly* better than the other. The value of some kinds of rewards depends upon an individual's tastes and preferences. However, it is uncontroversial to assert that receiving $20 is better than receiving $10.

Second, the focus was on *human* decision making. The fact that non-human animals exhibit delay discounting indicates that it is a fundamental process. But evidence suggests that the discounting process in humans is unique in critical ways, both because of differences in the effects of the magnitude of reward (Green, Myerson, Hold, Slevin, & Estle, 2004; Richards, Mitchell, de Wit, & Seiden, 1997), and because of the involvement of the prefrontal cortex in human discounting behavior (McClure, Laibson, Loewenstein, & Cohen, 2004).

Third, as the ultimate interest is in natural human behavior, contexts such as business or policy decision making where formal tools are used to make discounting-relevant decisions were excluded.

Fourth, study concentrated on decisions where the decider is the intended beneficiary. Decisions made for others, including future generations (e.g., Chapman, 2001; Frederick, 2006), were excluded.

Finally, I focused on decisions involving positive amounts of money. While work exists on monetary losses and non-monetary outcomes, the bulk of

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the existing literature concerns monetary rewards.  Concentrating on this domain

allowed the investigation to remain manageably straightforward, and allowed me

to build upon the ideas and discoveries of previous scholars.  There is reason to

expect that insights from this simple context will generalize to other, more typical

day-to-day decisions, or, at minimum, provide a framework for investigating these

more complex decisions.

So, given all these restrictions, the ultimate question of interest was: Why

do humans often choose to receive a smaller amount of money that can be

received sooner over a larger amount of money that can be received later?

## 1.3 Significance of delay discounting

The choice between a smaller, sooner reward (henceforth "SS") and a

larger, later reward (henceforth "LL") is likely implicated in many domains beyond

obvious areas such as credit card use and the failure to save for retirement.

While delay discounting is often studied using more straightforward monetary

decisions, the focal construct of delay discounting is thought to be wide-reaching

in its impacts: Smoking and other drug use, dieting, procrastination, and other

self-control failures have all been posed to be, at heart, delay discounting issues.

In these domains, a person arguably chooses between a SS (e.g., the pleasure

of cigarettes now) and a LL (e.g., good health later in life).  The features of

monetary delay discounting decisions map onto self-control struggles in

remarkable ways (Ainslie, 1992), and people with self-control problems devalue

future monetary rewards faster than other people (discussed in section 2.8).

Thus, the relationship of delay discounting behavior to self-control behavior is the first reason for the phenomenon's significance.

The second reason is its apparent non-normative or maladaptive nature. Why would anyone choose a smaller reward over a larger reward, even if he must wait some time to receive the larger reward? After all, the immediate and distant future are equally parts of one's life. It seems both rational and adaptive to seek to maximize the quality of one's life as a whole. While some reasons for discounting may be rational (such as economic reasons, discussed in section 2.1, and uncertainty about the future, discussed in section 2.2), discounting beyond this appears irrational and harmful to the person. If delay discounting is in fact maladaptive, how has such a behavior been preserved through the course of an evolutionary process that tends to select for adaptive behaviors? As will be shown in the subsequent literature review, some proposed explanations for the phenomenon paint the behavior as normatively justifiable, while others do not. But the apparent maladaptiveness of delay discounting has drawn philosophers, economists, and scientists to its study for centuries. If delay discounting is harmful, understanding the mechanisms that underlie it has an important practical consequence: This knowledge can be used to inform remedial actions.

**1.4 Delay discounting fundamentals**

Before examining the existing literature for hypothesized causes of delay discounting, in this section I briefly outline some terminology, methodology, phenomena, and concepts essential to the study of delay discounting.

*1.4.1 Definition of delay discounting*

Delay discounting refers to the devaluing of an outcome because of its location in the future. Other researchers have defined delay discounting as giving future consequences less weight relative to more immediate consequences (e.g., Frederick, 2006).  In a more operationalized sense, delay discounting can be construed as the tendency to choose a smaller, sooner reward over a larger, later reward.  Other terms for the same concept include "temporal discounting," "intertemporal discounting,"  and "time preference" (though this last term often has a more nuanced meaning, cf. Frederick, Loewenstein, & O'Donoghue, 2003).

*1.4.2 Characterizing delay discounting*

Researchers are often interested in the *extent* to which a person discounts future rewards.  In order to capture this, they will often elicit from a person the *present subjective value* of various future rewards – the magnitude of a SS such that the person is indifferent between the SS and a particular LL (this is also referred to as an *indifference point*).  If someone equally prefers to receive $60 today or $100 in a year, his indifference point for $100 in a year is $60.  Further, this person is said to discount *more* than someone whose indifference point in the same situation is $80.

Information of this sort is used to quantitatively characterize the extent to which a person discounts.  The way this is done depends upon the mathematical function used to describe the way future rewards are devalued over time – the

*delay discounting function*.  Initially, an exponential function was introduced by

Samuelson (1937).  Samuelson did not intend his formulation to be either

normative or descriptive, and indicated this explicitly.  Rather, he presented it as

a simplifying assumption in the context of a larger theoretical demonstration

about the measurement of utility.  However, over the coming decades, other

economists used his model in ways that assumed it was normatively and/or

descriptively valid (Frederick et al., 2003).  The reasons for this are unclear –

perhaps it was adopted because of the expression's similarities to other familiar

economic concepts, perhaps because of its simplicity.  But, for a long period of

time, an exponential formulation of the following format was preferred:

$$V = Ae^{-kD} \qquad\qquad (1)$$

where *A* is the magnitude of a delayed reward, *V* is the current subjective value

of that reward, *D* is the delay to the delivery of the reward, and *k* is a free

parameter.  The *k* parameter, often called the discount rate, varies with the

steepness of an individual's discounting, with higher *k* values indicating that

delayed rewards lose their value more quickly than smaller *k* values (Green &

Myerson, 1996).  Note that the exponential discounting function is analogous to

the formula for continuous compounding interest, which is usually expressed as:

$$P = Ce^{rt} \qquad\qquad (2)$$

where *P* is the future value of *C*, the initial deposit, *r* is the annual interest rate,

and *t* is the time in years (Manura, 2005).  But, while compounding interest adds

value to the original amount as the delay increases, the exponential discounting

function removes value from the delayed reward as the delay increases.

As an example, a person with an annual discount rate of 10% would view a $100 reward as being worth $90.48 if it is delayed for one year, worth $81.87 if it is delayed for two years, worth $74.08 if it is delayed for three years, and so on. Figure 1 illustrates the exponential discount function for this situation.
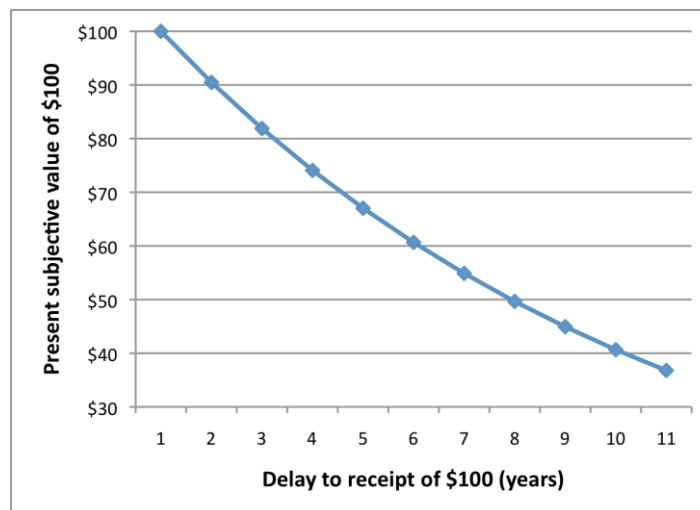


*Figure 1: Exponential discount function for a delayed reward of $100, with a discounting rate of 10% annually.*

A key feature of an exponential discounting function is that the delay discount rate remains constant over time. The same discount rate applies to a choice between outcomes available today versus next week as well as to a choice between outcomes available a year from today versus a year and a week from today. But, as researchers eventually discovered, this is not apparently true of actual discounting behavior. By the 1990s, a great deal of empirical work (e.g., many of the contributions to the volume edited by Loewenstein & Elster, 1992) showed that a hyperbolic function provided a better fit to people's discounting behavior than an exponential function. A hyperbolic function captures, with a single parameter, the apparent phenomenon that a person's

discount rate typically decreases as the delay to the reward increases (e.g.,

Johnson & Bickel, 2002; Kirby, 1997), while an exponential function could not do

this without continuously changing k values.  The hyperbolic discount function is

typically expressed as:

$$V = \frac{A}{1+kD} \tag{3}$$

where *A*, *V*, and *D* have the same meaning as in the exponential equation.  The *k*

variable remains a free parameter, but is no longer considered a "rate".

Hyperbolic functions are so named because they are of the form y = 1/x, which

describes a hyperbola.  Figure 2 compares the exponential and hyperbolic

discount functions with the same *k* value.  Note the deceleration of the devaluing

of the reward over time: The line representing the hyperbolic function becomes

notably less steep as the delay increases, resembling half of a hyperbola.
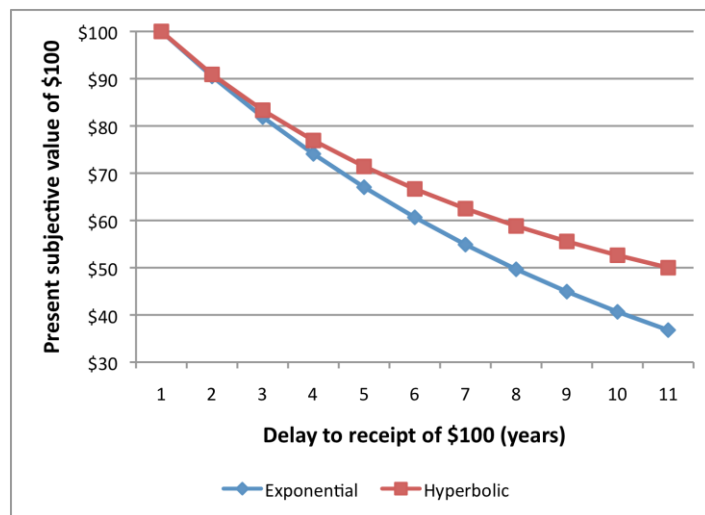


*Figure 2: Exponential and hyperbolic discount functions for a delayed reward of*

*$100, with k = 0.10.*

Indeed, much of the early empirical work on delay discounting (e.g., many of the contributions to the volume edited by Loewenstein & Elster, 1992) was concerned with establishing that a hyperbolic function was a better description of people's discounting tendencies than the exponential function that was previously assumed by economists.  One key feature of a hyperbolic function is that it allows for *dynamic inconsistency* – a preference reversal that occurs simply because one's relation in time to the available outcomes has changed (Ainslie & Haslam, 1992).  For example, one may prefer to receive $15 in a year and a week over $10 in a year, but prefer $10 today over $15 in a week.  The available outcomes are the same in both cases, simply shifted by a year.  Ainslie (1992) and other psychologists argue that this mathematical form captures a profound aspect of self-control struggles: constantly resolving to remain strong in the face of temptations that will occur in the *future*, while constantly succumbing to *present* temptations.

While the hyperbolic function is widely regarded as a sufficient description of delay discounting behavior, some researchers have proposed that a quasi-hyperbolic function better describes human behavior (e.g., McClure et al., 2004):

$$V = \beta \delta^{D} A \qquad\qquad (3)$$

where $0 < \beta \leq 1$, $\delta \leq 1$, and *V, A,* and *D* are the same as in the exponential and hyperbolic equations.  When there is no delay ($D = 0$), $\beta$ and $\delta$ are assumed to equal 1 so that V = A.  When a delay is introduced, $\beta$ and $\delta$ take on non-unity values, decreasing the present subjective value of the delayed reward.  The $\beta$ parameter is the same for all positive delays, and is meant to capture the special

value placed on immediate rewards relative to later rewards. The $\delta$ parameter raised to the power of *D* further discounts future rewards to an extent that depends upon the delay. So, for a case where $\beta = 0.8$ and $\delta = 0.9$, the following discounting curve emerges:
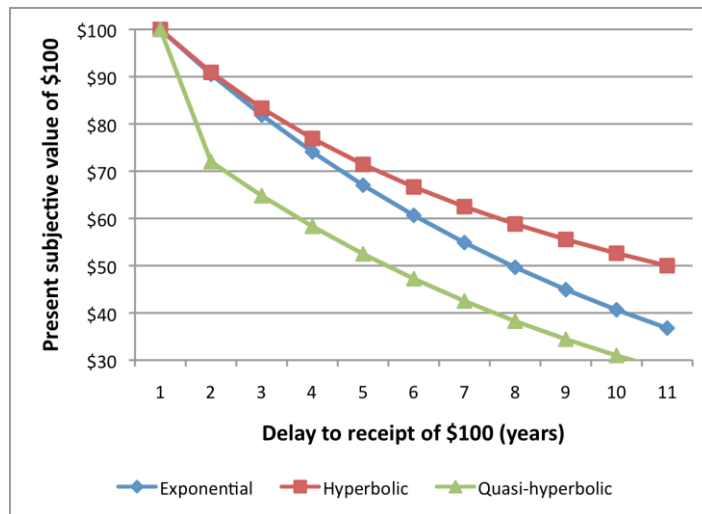


*Figure 3: Figure 2 with a quasi-hyperbolic discounting curve added, $\beta = 0.8$ and $\delta = 0.9$.*

Note the steep decrease in present subjective value as the delay increases from 0 to 1. A key difference between the quasi-hyperbolic and hyperbolic functions is that the former makes this sharp distinction between "now" and "not-now", while the latter does not. McClure and colleagues (McClure et al., 2004; McClure, Ericson, Laibson, Loewenstein, & Cohen, 2007) provided evidence that the quasi-hyperbolic function maps onto neural activation during discounting tasks in striking ways (to be discussed in section 2.8).

*1.4.3 Typical research methods*

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A small number of methods are used to study the nature of people's delay discounting behavior (reviewed by Frederick et al., 2003). Typically, paper-and-pencil or computer-presented questionnaires are administered, and they are nearly always one of two types: fill-in-the-blank, or binary forced choice. In fill-in-the-blank measures, the participant is given two reward options: in one option, the magnitude of and delay to the reward are specified by the experimenter. In the other option, one value (either the magnitude or delay of the second reward, but typically the former) is missing. The participant is asked to fill in the blank in such a way that he would be indifferent between the two options (used by, e.g., Chapman, 1996; Thaler, 1981). Here is an example of such an item:

*What number would make this statement true for you?*

*"I would equally prefer $10 today or $___ in one month."*

This method requires only a single question to determine the person's exponential discounting rate for a particular delay, and only a handful of questions to determine his hyperbolic *k* parameter. For example, if a person responded "$8" to the question above, his exponential discounting rate (*k*) is .22 (monthly). Repeating the above question with varying delays provides a number of (*V, A, D*) triplets that can be used to determine the best-fitting *k* in the hyperbolic discounting equation.

However, this fill-in-the-blank method is often apparently confusing to participants and can lead to inconsistent or nonsensical responses (G. Chapman, personal communication, November 30, 2008). Frederick et al. (2003) also report concerns with this method: Participants often seem to be applying a simple rule

(e.g., "multiply the SS by 2 or 10") in determining their response, though it seems unlikely that their actual preferences rely on such rules.

Because of these problems, the favored method in most studies is to use a series of binary forced choices between various SS and LL rewards, though there are myriad ways to do this. One common way is to hold some LL constant, while increasing or decreasing the SS incrementally, as in Table 1 (used by, e.g., Johnson & Bickel, 2002; Madden, Petry, Badger, & Bickel, 1997). For each pair of SS and LL rewards, the participant's task is to choose the one they prefer. The indifference point can be inferred by observing when the participant switches from choosing the SS to choosing the LL (when the SS is decreasing) or vice versa (when the SS is increasing). So, for example, if, when choosing between the alternatives in Table 1, a participant initially chooses the SS, and continues to do so until the SS is decreased to $85.00, we can infer that his indifference point for $100 in six months is somewhere between $92.00 and $85.00, and that therefore, his exponential discounting rate is somewhere between 0.027 and 0.014 (monthly).

However, using binary forced choices is not ideal for all circumstances. Because of the number of questions required to determine the relevant parameters, this method may not be appropriate for situations where time is a constraint (e.g., when one wants to test the effects of a priming manipulation that is expected to influence decisions for only a short period of time).

| Pair # | SS | LL |
|---|---|---|
| 1 | $100 now | $100 in six months |
| 2 | $99.00 now | $100 in six months |
| 3 | $96.00 now | $100 in six months |
| 4 | $92.00 now | $100 in six months |
| 5 | $85.00 now | $100 in six months |
| 6 | $80.00 now | $100 in six months |
| … | … | $100 in six months |
| 24 | $2.00 now | $100 in six months |
| 25 | $1.00 now | $100 in six months |
| 26 | $0.50 now | $100 in six months |
| 27 | $0.10 now | $100 in six months |

*Table 1: SS and LL components used in a common binary forced choice procedure.*

Another method, constructed by Kirby and colleagues (Kirby, Petry, & Bickel, 1999), uses a smaller set of pre-specified questions. Rather than determining an indifference point directly, Kirby's method uses the participant's responses to mathematically triangulate in on his discounting rate. Other variations on the use of binary forced choice exist (e.g., computer programs that adjust the questions asked based upon the participant's previous responses), but they rely on the same underlying principles.

More recently, Li (2008) used some novel methods to assess discounting preferences. In one study, participants were asked how happy they would be

with receiving $100 after various delays, making ratings on a 100-point scale from 0 = "not happy at all" to 100 = "very happy."  This method provides an analogue of the discounting curve with a small number of easily-understood questions.  However, this method has not yet been widely adopted.  Ultimately, the best method of assessing delay discounting will depend upon the context and its relevant constraints.

*1.4.4 Hypothetical versus real rewards*

The vast majority of research on human delay discounting involves asking participants to make decisions about hypothetical rewards.  The reasons for this are apparent: It is cheaper and easier than providing participants with real rewards.  Eliciting a person's delay discounting parameter and/or function often requires a large number of decisions (usually on the order of 27 to several hundred); the cost of actually paying out each of the rewards involved in these decisions would be prohibitive.  Additionally, the decisions participants make involve, by design, delays.  The logistical issues with the administration of delayed rewards are significant.

The widespread use of hypothetical rewards naturally raises a question: Are such decisions representative of people's behavior when it comes to *real* rewards?  In other domains of decision making, such as response to risk, behavior indeed differs when real versus hypothetical rewards are used (reviewed by Madden, Begotka, Raiff, & Kastern, 2003).  Kirby (1997) compared the discount rates obtained from studies using hypothetical rewards to studies

where one or all participants had one of their choices honored at random with real money ("potentially real" rewards).  He concluded that hypothetical rewards are discounted less than potentially real rewards, possibly because they "lack the motivational properties of real rewards" (p. 67), though he does not speculate why motivational properties should lead to more discounting.  However, Kirby also acknowledged that the comparison was confounded by the reward amounts used in the different studies, so his results may simply be a manifestation of the *magnitude effect*: the well-established finding that rewards of larger magnitude are discounted less steeply than rewards of smaller magnitude, all else equal (e.g., Green, Fry, & Myerson, 1994; Kirby & Marakovic, 1996).  The magnitude effect captures a situation where a person might, for example, prefer $10 today over $15 next week, but prefer $150 next week over $100 today.

Since the Kirby review, several studies have endeavored to directly compare discounting of real and hypothetical rewards.  Madden and colleagues (2003, 2004) used potentially real rewards, while Lagorio and Madden (2005) and Johnson and Bickel (2002) used all-real rewards (where every choice by every participant was honored with real money).  All of the studies reported in these papers failed to find significant differences in delay discounting between real and hypothetical conditions, with two exceptions.  One (of 6) of Johnson and Bickel's (2002) participants discounted hypothetical rewards more than real rewards.  Additionally, Madden et al. (2004) found that the hyperbolic function fit data from hypothetical rewards significantly better than data from real rewards.

A few other papers purport to bear on the issue as well, but they are problematic. Lane, Cherek, Pietras, and Tcheremissine (2003) used a procedure where the delay entailed in the LL was the time until the monetary amount was added to a running total on the participant's computer screen – not the time until the participant actually received the reward. The rewards were not actually delivered until the end of the session. A review by Navarick (2004) argued that hypothetical rewards are discounted less than real rewards because of a lack of a reinforcement process, but the author based this on a comparison of different kinds of rewards (i.e., real video clip rewards versus hypothetical money rewards). Kirby and Marakovic (1995) also contended that discount rates were lower for hypothetical rewards. However, they drew this conclusion from a comparison of two studies that used different methodologies. In the study using real rewards, present subjective values were inferred via an auction procedure, while in the study using hypothetical rewards, participants were simply asked to specify the present subjective value. Finally, Coller and Williams (1999) found effects of real versus hypothetical rewards, but their results were confounded with demographic variables such as income. This is problematic because it is known that income is a reliable predictor of discount rates, with lower incomes being associated with higher discount rates (e.g., Green, Myerson, Lichtman, Rosen, & Fry, 1996; Hausman, 1979; and Kirby et al., 2002).

Taking all of this research into account, the sensible conclusion seems to be that for most purposes, using hypothetical rewards is sufficiently representative of behavior with real rewards, in terms of both qualitative and

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quantitative properties of the phenomenon.  However, the single participant in

Johnson and Bickel's (2002) study whose discount rate was affected by reward

type indicates that this may not be universal.


*1.4.5 Delay discounting versus delay of gratification*

Before beginning the review of proposed causes for delay discounting in

the next section, it appears prudent to make explicit the differences between

delay discounting, and a popular area of study in developmental psychology,

"delay of gratification."  It is tempting to take results from the latter area as

indicative of processes in the former area, but this is not necessarily appropriate.

Mischel's classic "delay of gratification" paradigm (e.g., Mischel, Ebbesen,

& Zeiss, 1972; Mischel, Shoda, & Rodriguez, 1989) looks very similar to the

delay discounting paradigm. In Mischel's research, preschool-aged children were

asked to wait alone in a room until their experimenter returned. They were

informed that if they waited for the experimenter to return on her own, they would

receive a larger reward (e.g., two cookies), but if they summoned her back early,

they would receive a smaller reward (e.g., one cookie).  Mischel and colleagues

investigated many variables that caused or correlated with longer waiting times.

Many of the features of delay of gratification studies and delay discounting

studies are very similar, including the use of SS and LL rewards.  However, there

are important distinctions to be made.  Delay discounting research is concerned

with how people *make* choices, while delay of gratification research is concerned

with how people *sustain* choices.  In delay discounting studies, the participant is

not required to make a continuous exertion of self-control, since the choice she makes is binding; there is no opportunity to switch from the LL to the SS during the delay period.

Reynolds and Schiffbauer (2005) detail some empirical differences between delay discounting and delay of gratification. The first difference is the developmental onset. Delay-dependent discounting is not seen until 9 or 10 years of age, while sensitivity to delay time was observed in Mischel's preschool delay of gratification studies. Additionally, serotonin (5HT) lesions in rats impaired delay of gratification behavior but not discounting behavior. So, while the two paradigms may be similar enough for delay of gratification findings to inform delay discounting explanations to some extent, they are sufficiently different to require sincere caution when doing so.

**Chapter 2**

**Potential Explanations for Delay Discounting**

In this chapter, I review the literature to date for answers to the question, "Why does delay discounting occur in humans?" A few characteristics of this review are of note: First, it is not assumed that a single factor is responsible for the phenomenon or that all hypotheses are mutually exclusive – there could quite plausibly be multiple contributors.

Second, the preparation of this review has revealed the surprising fact that the "why" question has received limited attention from researchers. Most theorizing and experimentation on delay discounting has tended to focus on demonstrating the phenomenon in different contexts (e.g., among drug users, documenting differences in discounting for health versus monetary rewards, etc.) or on how to best describe discounting behavior mathematically (e.g., with an exponential, hyperbolic, or quasi-hyperbolic function). Though these results may supply some clues about the underlying mechanisms of delay discounting, the lack of direct investigation into causation is striking. Thus, the present review draws from such papers only insofar as they inform the question of causation.

Third, a large portion of the hypothesizing regarding the causes of delay discounting comes from 19th century economists, not modern-day psychologists. While the economists' proposals are thought-provoking, the unfortunate

consequence of contemporary psychologists' neglect of these ideas is that they have not been subject to empirical testing or even rigorous theoretical specification. Thus, some proposals that will be presented in this review lack both supporting and detracting evidence. Finally, I aim, in this review, to be exhaustive in terms of explanations proposed for delay discounting.

## 2.1 Economic reasons

It seems appropriate to first examine whether there are any normatively acceptable reasons to devalue future outcomes, and whether such reasons can account for any or all of the delay discounting behavior observed. Most of the normative reasons for discounting that have been proposed are economic in nature, and fall into three categories: anticipated increase in wealth, possibility of intertemporal arbitrage, and possibility of inflation.

### 2.1.1 Anticipated increase in wealth

It has been suggested that in at least some situations, a person may choose the SS because she believes her wealth will increase over time in such a way that the SS taken at the earlier time will provide greater utility than the LL taken at the later time (Frederick et al., 2003). Consider a college senior asked to pick between receiving $50 immediately or $200 in a year. If the student presently makes $5000 a year, but anticipates that his income in a year will be $35,000, it seems that the student may rationally select the SS on the grounds that gaining $50 when one makes $5000 a year would lead to a greater increase

in utility or happiness than gaining $200 when one makes $35,000 a year.  To my

knowledge, no studies have tested this as an explanation for delay discounting

behavior.

*2.1.2 Intertemporal arbitrage*

Another proposal is that people may choose the SS over the LL because

they think that intertemporal arbitrage is possible (Frederick et al., 2003).  That is,

a person may believe that by choosing the SS and investing it properly, she

could end up with more money than the LL by the time she could have received

the LL.  Economists (e.g., Fuchs, 1982) have proposed that one should have a

discount rate equal to the market interest rate because of such opportunities.

Only one empirical paper apparently bears directly on this issue.  In studies by

Kawashima (2006), participants made decisions about spending and saving

money in simulated economies.  It was shown that the interest rate of the

simulated economy affected participants' delay discounting rates in the

appropriate direction.

*2.1.3 Inflation.*  A third economic reason why people may devalue future

rewards is that they anticipate inflation in the relevant economy.    Inflation entails

that a unit of currency becomes less valuable over time; thus, it seems

reasonable, given an anticipation of inflation, to choose the SS if one believes

that the smaller amount consumed at an earlier time would be worth more (i.e.,

could be traded for more goods/services) than the larger reward consumed at a

later time.  A few studies support this notion: First, Ostaszewski, Green, and

Myerson (1998) showed that at a time when inflation was extremely high in Poland but not in the U.S., people tended to discount much more when rewards were expressed in terms of Polish zlotys than in terms of U.S. dollars. Second, in the simulated-economy studies by Kawashima (2006), the inflation rate affected participants' delay discounting rates in the appropriate direction. Finally, Takahashi, Masataka, Malaivijitnond, and Wongsiri (2008) showed that an unstable currency (the Thai bhat) was discounted more than rice, even though the discount rate for food is typically higher than the discount rater for money (e.g., Odum, Baumann, & Rimington, 2006).

These three economic explanations appear to be reasonable proposals, and almost certainly explain the bulk of discounting behavior in formal business contexts. However, it is unclear to what extent these factors drive the intertemporal decision making of laypeople in day-to-day life. While the studies reported above imply that economic reasons may contribute to some delay discounting behavior, other research makes it apparent that they do not account for all of it.

First, delay discounting behavior occurs when the available rewards are separated by minutes or days (e.g., McClure et al., 2007). In such situations, these economic factors are not likely in play in a normative way – anticipated increases in wealth, opportunities for intertemporal arbitrage, and anticipated inflation should be moot when dealing with such short spans of time.

Second, these economic reasons make sense only for tradable rewards (e.g., money, drugs), but discounting behavior is seen for non-tradable rewards

(small quantities of juice or water that the participant must consume immediately upon administration, as used by McClure et al., 2007). Such non-tradable rewards may be subject to concerns about diminishing marginal utility, but concerns of inflation or intertemporal arbitrage would be irrelevant (e.g., one cannot invest a small quantity of juice that must be consumed immediately).

Third, observed discounting rates are generally much higher than would be justified by economic reasons (Frederick et al., 2003). Even in Kawashima's (2006) highly controlled simulated economies, changes in discounting rates prompted by changes in inflation and interest rates, although in the appropriate directions, were too extreme to be economically justifiable. One delay discounting experiment demonstrated discounting rates as high as one billion percent annually (Ainslie & Haslam, 1992) – a rate far greater than one justified by economic reasons. Thus, it is clear that a phenomenon of interest still remains when economic factors are unlikely contributors.

It is possible, however, that overgeneralization or misapplication of economic principles could explain irrational delay discounting behavior. For example, perhaps people discount non-tradable rewards because they mindlessly overgeneralize principles that apply to tradable rewards. Such ideas have not yet been tested.

## 2.2 Uncertainty about the future

Another proposed cause for delay discounting also conceives of discounting behavior as potentially normatively defensible. The hypothesis is that

discounting occurs because of uncertainty about the future. That is, people are *less certain* of receiving rewards in the (relatively) distant future than the immediate future, and thus devalue rewards accordingly. The uncertainty hypothesis essentially proposes that delay discounting is, at heart, *probability discounting*, the devaluing of outcomes as they become less probable. Probability discounting does not appear to itself require explanation, since it is evidently quite sensible. The uncertainty hypothesis was first proposed by the economist Rae (1834), who observed, "When engaged in safe occupations and living in healthy countries, men are much more apt to be frugal, than in unhealthy, or hazardous occupations, and in climates pernicious to human life" (p. 57).

This uncertainty about the future could manifest itself in different ways: people may not believe the LL will be delivered, for example, or they may not be certain they will even be alive to receive it. Further, it is not necessary that this uncertainty be conscious. Some researchers (Critchfiled & Atteberry, 2003; Kacelnik, 2003) propose that humans evolved in an environment where future rewards were often no longer available when delivery was anticipated. In an environment like this, a mechanism (specifically, discounting the value of future rewards) may have evolved to cope with this fact. Such an evolved mechanism may affect a person's behavior on a non-conscious level despite the person's conscious beliefs, even in an environment (e.g., a laboratory) where future rewards are relatively certain. As Kacelnik (2003) puts it, "...although animals in the laboratory ought not to discount at all, if they do so it is because they respond

to the ghost of uncertainty in their environment of evolutionary adaptation" (p. 119).  The evolutionary sensibility of this hypothesis adds to its appeal.  (Little empirical evidence, though, is available to support this evolutionary account.  The only relevant study seems to be Critchfield & Atteberry's, 2003, demonstration that people with higher discounting rates fare better in a simulated group foraging task.)

Beyond theoretical appeal, a variety of empirical support for the uncertainty hypothesis is available.  First, the same functional form (hyperbolic) appears to provide the best fit for both delay discounting and probability discounting data (Green & Myerson, 2004; Rachlin, Raineri, & Cross, 1991).  That is, the same type of mathematical function is used to describe the way people devalue outcomes as time to delivery increases or probability of delivery decreases.  While this obviously does not prove that the two types of discounting are the same process, it is tantalizing support for that notion.

Second, people report feeling less certain that they will receive more delayed rewards when they are explicitly asked to make such judgments: In studies by Patak and Reynolds (2007) and Reynolds, Patak, and Shroff (2007), participants were asked to report how certain they were of receiving rewards after various delays.  The reported certainty decreased as the delay to reward increased.  However, these results must be interpreted with caution, as demand effects may have been a factor in participants' responses.  That is, participants may have assumed, upon being asked to repeatedly rate how certain they felt of

receiving a reward after increasing delays, that their ratings of certainty "ought" to change with the length of the delay.

Third, some researchers propose that delay and probability are interchangeable when it comes to decision making, and take this to imply that delay discounting arises from the more fundamental and normatively understandable probability discounting (however, a minority of researchers, e.g., Rachlin et al., 1991, believe that the converse is true: that probability discounting arises from the more fundamental delay discounting. But since the aim of this dissertation is to understand the causes of delay discounting, arguments taking delay discounting as fundamental will not be explored in depth). Rachlin et al. (1991) examined the ways in which people discounted based upon delay or probability and determined a constant of proportionality that would allow one to convert delays into "equivalent" probabilities or vice versa. That is, knowing the constant of proportionality would allow one to find the probability $x$ such that a person would be indifferent between receiving $1000 for sure in five years and receiving $1000 immediately with probability $x$ (in Rachlin et al.'s study, x was 50%). Yi, Piedad, and Bickel (2006) found this constant of proportionality to be an accurate predictor of choices and argued that delay and probability can effectively be combined into a single metric for decision making purposes.

Along these lines, Prelec and Loewenstein (1991) pointed out that delay discounting and probability discounting processes demonstrate analogous anomalies: the immediacy and certainty effects, respectively. The *immediacy effect* describes the extra significance deciders attach to immediate outcomes:

The difference between now and one day from now carries decidedly more psychological weight than the difference between two days from now and three days from now.  A parallel effect, the *certainty effect*, occurs in probability discounting: The difference between 100% probability and 90% probability is subjectively weighted more heavily than the difference between 90% and 80% (cf. prospect theory, e.g., Tversky & Kahneman, 1981).  Keren and Roelofsma (1995) and Weber and Chapman (2005) expanded this idea by demonstrating that adding explicit uncertainty to the SS can reduce or eliminate the immediacy effect, and adding delay to probabilistic outcomes can reduce or eliminate the certainty effect.  This work provides further evidence for the idea that delay and uncertainty can be substituted for one another.  Finally, Todorov, Goren, and Trope (2007) showed that decreasing the probability of an event causes people to think of the event in more abstract terms in the same way that increasing the temporal distance to the event does (this idea will be expanded upon in section 2.4).

Despite this wealth of supporting evidence, there is also compelling evidence against the uncertainty hypothesis.  First, and most detrimental, is the observation that increasing the amounts of the rewards between which a person is choosing has *opposite* effects on delay discounting and probability discounting (Du, Green, & Myerson, 2002; Green & Myerson, 2004; Holt, Green, & Myerson, 2003; Yi et al., 2006).  Increasing the magnitude of the rewards decreases the discounting rate based upon delay, but increases the discounting rate based upon probability.  At present, there are no proposed accounts for why this occurs.

This appears to be a major obstacle to the theory that delay discounting and probability discounting arise from the same underlying mechanism.

Second, if delay discounting and probability discounting are ultimately the same process, one expects that the two discounting rates would be highly correlated within individuals. However, while some sources report some degree of correlation between the two rates (e.g., Richards, Zhang, Mitchell, & de Wit, 1999), other studies that have examined the question report no significant correlation between individuals' delay and probability discounting rates (e.g., Ohmura, Takahashi, Kitamura, & Wehr, 2006; Olson, Hooper, Collins, & Luciana, 2007).

One might also suppose that, if the uncertainty hypothesis holds, probability and delay discounting would be associated within certain groups: that if people in a certain group discount delayed rewards relative to another group, they would also discount probabilistic rewards more. However, a cross-cultural study performed by Du et al. (2002) showed among Chinese and Japanese graduate students, the Chinese showed higher delay discounting, but the Japanese showed higher probability discounting. Similarly, Holt et al. (2003) demonstrated that college students who gamble had lower probability discounting rates than college students who do not gamble, but the two groups had comparable delay discounting rates. Finally, Olson et al. (2007) showed that older adolescents show less delay discounting than younger adolescents, but no difference in probability discounting was observed. It must be noted, however, that these sorts of comparisons between groups should be taken only as a

suggestive – *not* conclusive – blow against the uncertainty hypothesis.  A

difference between groups on one discounting rate but not the other could be

due to group differences in how much uncertainty is associated with various

delays.  For example, it could plausibly be the case that younger people feel that

uncertainty increases dramatically with delay, while older people think that

uncertainty increases only slightly with delay.  If this were true, the groups could

agree on how probability alone should affect value (i.e., they have identical

probability discounting rates), but still have very different delay discounting rates.

Overall, the case for the uncertainty hypothesis is mixed, with

compelling evidence on both sides.  It is clear that further investigation is

required to construct a coherent account that accommodates all the relevant

evidence.


**2.3 Pain of abstinence**

A third proposed account for delay discounting behavior, in contrast with

some other accounts, does not assume that the future outcome is valued less

because of its temporal location.  Instead, the theory, first suggested by the

economists Rae (1834) and Senior (1936), proposes that it is painful to deny the

receipt of good things, and people choose the smaller, sooner reward to avoid or

end this pain.  According Loewenstein's (1992) analysis of Senior's ideas, Senior

viewed interest as "compensation to the holder of capital for enduring the pain of

abstaining from consumption, which he viewed as 'among the most painful

exertions of human will'" (p. 8).

Unfortunately, though, there is no empirical work that directly tests this hypothesis in the delay discounting domain. There is, however, some peripheral evidence that may bear on these ideas. The first type of evidence involves viewing delay discounting choices as requiring self-control; discussion of this work will be reserved for section 2.8. The second type of evidence is found in work on delay of gratification. Loewenstein (1992) proposes that some of Mischel's work (e.g., Mischel, 1974) provides support for the "pain of abstinence" hypothesis. Mischel and colleagues found that teaching their preschool-age participants to engage in distracting thoughts during the waiting period increased the chances that the participants would wait for the larger reward. Loewenstein takes this to mean that the distracting thoughts decrease the pain of waiting, thereby allowing the child to wait for the larger reward. The validity of this interpretation, though, is not clear. Distraction may do more than alleviate pain, including causing the child to forget that there is a choice to be made. This would cause her to "choose" to wait for the larger reward by default (Yates & Revelle, 1979).

Further results from delay of gratification research could be taken as support for the pain of abstinence hypothesis: when the physical rewards were present in front of the child during the waiting period, wait times were significantly shorter than when the rewards were not present (Mischel & Ebbesen, 1970; Yates & Revelle,1979). Having the rewards present would arguably increase the pain of waiting. However, as discussed in section 1.4.5, the "delay of gratification" paradigm differs from typical "delay discounting" decision paradigms

in major ways.  In delay discounting situations, the "pain of waiting" would occur in a period during which the decision could not be reversed.  So, if pain of waiting is driving people to choose the SS, it must be the *anticipated* pain of waiting.  But, it is unclear how accurate such anticipations would be (e.g., mothers incorrectly predicted that encouraging their child to think about the LL during the waiting period would *increase* the child's waiting time; Hom & Knight, 1996).

One obstacle this hypothesis faces is that it is unclear when and why waiting for a larger reward is aversive rather than pleasurable.  Sometimes, anticipation of future rewards is pleasurable, and in at least some decision situations, people *choose* to delay a pleasurable event (e.g., a kiss from a favorite movie star), presumably to allow time for pleasant anticipation (Loewenstein, 1987).   In other situations, though, awaiting future rewards is clearly aversive.  Some researchers have made headway in addressing this issue.  Lovallo and Kahneman (2000) demonstrated that people are more willing to delay the resolution of attractive versus unattractive gambles.  Hoch and Loewenstein (1991) proposed that pain of waiting occurs when the decider has adapted to having the LL before they possess it.  So, if I plan on buying a new laptop, at first my reference point is at "not having new laptop," so I am waiting for a gain (getting the laptop).  But, if I adapt to the state of having the laptop before I get it, such that my reference point is at "having a new laptop," I am instead experiencing a loss while waiting for the laptop.

Additionally, they detailed factors that they believe can exacerbate the pain of waiting, such as physical or temporal proximity to the LL or social

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comparison, but these have not yet received empirical attention.  However, a richer answer to the question of when and why waiting for a reward is painful would be required for the "pain of waiting" theory to be a viable account of delay discounting.

## 2.4 Differences in construal (Construal Level Theory)

A third proposed cause of delay discounting is suggested by proponents of Construal Level Theory (CLT) (e.g., Trope & Liberman, 2003).  Ultimately, the idea is that people conceive of the SS in relatively concrete terms, while they conceive of the LL in relatively abstract terms.  If this concrete construal of the SS is more appealing than the abstract construal of the LL, the SS is chosen.

Some background on CLT is necessary:  CLT does not deal specifically with delay discounting, rather, it concerns the way people think about events in the near and far future.  The core of CLT is that people think of events in the far future in relatively abstract, high-level, simple terms, whereas they think of imminent events in relatively concrete, low-level, complex terms.  CLT's proponents propose that these differences in construal are a generalized heuristic that arises because there are differences in what people usually know about events in the near or far future (Trope & Liberman, 2003).  One typically only knows central, high-level information about events in the distant future, and the concrete details only emerge when the event becomes imminent.  Thus, experiences may build an association between construal level and temporal

distance, and this association may be overgeneralized to situations where one has the same sort of information about near- and far- future events.

In a typical CLT study, Liberman and Trope (1998) found that when people imagine the event "locking the door," they tend to describe it in a high-level manner as "securing the house" if the imagined event is occurring in the distant future, but prefer to describe it in a low-level manner as "putting a key in a lock and turning it" if the imagined event is occurring in the immediate future. Trope, Liberman, and colleagues have provided a wealth of experimental evidence to support CLT (e.g., Liberman, Sagristano, & Trope, 2002; Liberman & Trope, 1998; Trope & Liberman, 2000; Trope, Liberman, & Wakslak, 2007).

While no studies have directly tied CLT to delay discounting behavior, proponents of CLT argue that CLT may be a viable explanation for the phenomenon. Delay discounting behavior could occur, they argue, in situations where the lower-level construal of the SS is more positive/desirable than the higher-level construal of the LL. It is plausible that lower-level construals of rewards are more appealing than higher-level construals, since lower-level construals entail more emotional and motivational qualities (Trope & Liberman, 2003). For example, a lower-level construal of food might entail the food's taste, smell, and texture, while a higher-level construal might entail its nutritional value. This could also be the case for money, with a lower-level construal entailing exactly how the money might be used.

They further propose that CLT could explain the magnitude effect, contending that people naturally think about large rewards (e.g., $10,000) in

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more high-level, abstract ways than small rewards (e.g., $10), because larger

rewards are typically associated with more essential, high-level, and distant

goals.  So, choosing among large rewards elicits less concrete thinking about the

LL and hence less discounting (Trope & Liberman, 2003).

Unfortunately, though, no CLT studies have involved asking participants to

choose between a SS and LL.  CLT studies typically involve asking people to

choose between qualitatively different options for which ultimate relative value is

difficult to assess (e.g., a difficult but interesting assignment versus an easy but

boring assignment).  CLT studies also typically involve choices among options

that would be experienced at the same point of time – that is, people choose

among options to be experienced in the near future, *or* people choose among

options to be experienced in the distant future.  CLT studies have *not* asked

people to make decisions between near-future experiences pitted against far-

future experiences, the core of standard delay discounting decision problems.

So, while the ideas of CLT have been borne out by a good deal of

experimental data, its usefulness as an explanation for classic delay discounting

behavior is unclear.  What would high-level and low-level construals of money

be, for example?  Despite the lack of direct evidence bearing on CLT's

applicability to delay discounting, this appears to be fertile ground for future

investigation.

## 2.5 Optimism

Another account of delay discounting apparently is discussed in only a single paper (Berndsen & van der Pligt, 2001). The authors argue that "one reason why decision makers prefer immediate gains is because they are optimistic that these gains will be followed by additional gains in the future" (p. 173). The authors based this theory upon previous work which suggested that people often believe that future losses can be avoided, and extended these results to propose a sort of broad optimism that includes believing that early gains will be followed by additional gains.

For an example, consider a scenario used in their Study 1: The participant is asked to choose between a (hypothetical) SS bonus and a LL bonus at his job. According to the optimism hypothesis, the person may be inclined to choose the SS because he believes that the small bonus could be followed by further bonuses (in the time period before the LL would have been received), or that he could take the SS bonus, switch jobs, and be offered new bonuses at his new job. The authors manipulated optimism in this scenario by telling participants in the "low optimism" condition that no bonuses would follow, and that they were under a contract that would not allow them to change jobs for a long period of time. Participants in this condition showed an increased preference for the LL relative to control participants who were not given this additional information. Unfortunately, though, the optimism manipulation was confounded with a certainty manipulation. Participants in the low optimism condition were also assured that the LL would, in fact, be received (i.e., that the company they work for is financially sound, and that they themselves are in excellent health).

According to the uncertainty hypothesis, information like this would also increase

preference for the LL. So, while the optimism hypothesis is novel and somewhat

plausible, it has not yet been adequately tested.[1]


## 2.6 Intrapersonal empathy gap

Nineteenth century economist Böhm-Bawerk proposed that delay

discounting arises from a failure to adequately imagine future needs or wants.

That is, discounting occurs because of a failure to empathize with one's future

self. This lack of intrapersonal empathy may stem from something akin to

Tversky and Kahneman's (e.g., 1973) "availability" (Loewenstein, 1992). Böhm-

Bawerk (1888) phrased it like this:

> It may be that we possess inadequate power to imagine and to abstract, or that
>
> we are not willing to put forth the necessary effort, but in any event we limn a
>
> more or less incomplete picture of our future wants and especially of the remotely
>
> distant ones. (p. 269)

The term "intrapersonal empathy gap" is borrowed from the affective

forecasting literature. Scholars in this literature have proposed that people

incorrectly predict their own future emotions because of a failure to empathize

with their future selves, again, due to something like differences in availability.

Certain manipulations that encourage a person to think carefully about her future

life (e.g., asking people to predict how they would spend their time on a particular

day in the future, as implemented by Wilson, Wheatley, Meyers, Gilbert, &

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[1] A study, not reported in this dissertation, was performed that de-confounded the uncertainty and optimism factors in the study by Berndsen & van der Pligt, 2001. We found that manipulating optimism-related but not uncertainty-related information did not change discounting behavior relative to a control group.

Axsom, 2000) have been successful in bridging this intrapersonal empathy gap, decreasing affective forecasting errors.  It would be informative to see if similar manipulations could also decrease delay discounting behavior.

Some results consistent with the intrapersonal empathy gap hypothesis are available: Adams and Nettle (2009) showed that people who report habitually thinking about the future (per the Zimbardo Time Perspective Inventory, Zimbardo & Boyd, 1999) or regularly considering future consequences (per the Consideration of Future Consequences scale, Strathman, Gleicher, Boninger, & Edwards, 1994) discount less than other people.  Another provocative clue comes from analogous phenomena found in delay discounting and affective forecasting work: Gilbert, Gill, and Wilson (2002) showed that working memory load increased affective forecasting errors, while Hinson et al. (2003) showed that working memory load increased delay discounting.  This suggests that similar mechanisms may underlie the two phenomena.

## 2.7 Other theories

For the sake of being historically exhaustive, two further theories are discussed here, though they have received little attention in the literature and are likely regarded as too theoretically vague for serious empirical study.

### 2.7.1 Present utility

One proposed explanation for the phenomenon that does not rely on the devaluation of future outcomes was proposed by the economist Jevons (1871),

who suggested that people do not consider future utility at all when making intertemporal decisions. Rather, they consider only present utility. If the utility from *anticipating* the LL outweighs the utility from *obtaining* the SS, the decider will choose the LL. Otherwise, he will choose the SS. It is apparent that this hypothesis is a vast departure from other theories of delay discounting, which typically posit that future utility is a consideration.

This theory lacks both supporting and detracting data, and is arguably rather unclearly specified. How could it be determined whether someone is considering future utility or anticipation? How is "anticipation" defined? Further, as previously noted, it is unclear when waiting for future rewards is pleasurable rather than painful.

*2.7.2 Future self as other*

It has been argued that discounting (beyond what can be justified because of accurate beliefs about economic factors or uncertainty) is irrational because the present and future are equally parts of one's life, and failing to choose the larger reward (even if it will be received later in time) would reduce the quality of one's life as a whole (Frederick, 2003). But, as Frederick (2003) comments:

> The belief that a person should weight all utility the same, regardless of its temporal position, implicitly assumes that all parts of one's future are equally parts of oneself; that there is a single, enduring, irreducible entity to whom all future utility can be ascribed. (p. 90)

One unusual proposed explanation for discounting behavior suggests that there is not a single, enduring "self," and thus discounting the outcomes for one's

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future self is as sensible as discounting the outcomes for another person entirely (Parfit, 1971, 1984).  Consider the view of the philosopher Parfit (1984): "My concern for my future may correspond to the degree of connectedness between me now and myself in the future…since connectedness is nearly always weaker over long periods, I can rationally care less about my further future" (p. 313).

Frederick (2003) reports an experiment designed to test this idea.  If Parfit's hypothesis is correct, he argues, one would expect that a person who imagines her future self to be very different (in terms of "personality, temperament, likes and dislikes, beliefs, values, ambitions, goals, ideals, etc.," p. 95) from her present self would have a higher discount rates than a person who supposes that her present and future selves would be highly connected.  No correlation was found between anticipated future similarity and discount rates.  Thus, according to Frederick's operationalization of Parfit's ideas, the "future self as other" account of delay discounting behavior does not stand up to empirical examination.

## 2.8 New explanation: Dual-system competition

The preparation of this literature review has suggested a new account of delay discounting.  While hints of this account have appeared in existing literature, this account has not been explicitly proposed.  The hypothesis is that discounting behavior results from competition between two different cognitive systems, with a faster, more automatic system favoring the SS.  The LL is only chosen if a more deliberative system can effortfully override this initial impulse.

"Dual systems" views of cognition have received a great deal of attention in the last decade (e.g., Epstein, 1994; Evans, 2008; Kahneman, 2003). Though different researchers have conceived of the systems differently (e.g., "experiential vs. rational" systems, "System 1 vs. System 2," "hot vs. cold" systems, etc.) and used different research methodologies, there is a fair amount of evidence for two qualitatively different cognitive systems that operate in parallel, with one system (System 1) operating quickly and automatically, relying heavily on emotional and associative information, while the other (System 2) is slower and deliberate, operating in a more logical/rational manner. While this idea has rarely been discussed explicitly (though Metcalfe & Mischel, 1999, explicitly discuss the hypothesis with respect to delay of gratification), some research on delay discounting has hinted that two cognitive (and, perhaps, neural) systems may value rewards differently, with System 1 putting a high value on immediate receipt, and System 2 valuing outcomes more independently of temporal location. A good deal of empirical evidence is consistent with the idea that the automatic reaction to a delay discounting problem is to take the SS, and that the LL is chosen only if this initial reaction is countered by the more deliberate cognitive system.

There are two potential mechanisms that could underlie this process, but it is presently unclear exactly how theoretically distinct or mutually exclusive they are. Further, most of the relevant evidence can be interpreted in terms of either mechanism. According to one mechanism, delay discounting occurs when System 1 is relatively more activated than System 2. Discounting would be

increased as the relative activation of System 1 is increased (Li, 2008; Metcalfe &

Mischel, 1999). According to another mechanism, resisting the urge to discount

requires the use of self-control (Li, 2008), which is thought to be a limited

resource (Muraven & Baumeister, 2000). "Using up" self-control on an unrelated

task would increase delay discounting in subsequent decisions. For the moment,

no attempt will be made to differentiate between these two mechanisms; rather,

support for the overarching idea of dual-systems competition is considered.

The empirical support for the dual-systems competition hypothesis is

varied. First, some evidence (albeit circumstantial) is found in the fact that

people with self-control problems, such as smokers (e.g., Chession & Viscusi,

2000; Jaroni, Wright, & Lerman, 2004), pathological gamblers (e.g., Alessi &

Petry, 2003), problem drinkers (e.g., Vuchinich & Simpson, 1998), and heroin

addicts (e.g., Madden et al., 1997) have higher delay discounting rates than

normal controls. If self-control ability (which could be framed as the ability of

System 2 to override System 1) is a trait of individuals, the fact that people who

have demonstrated deficits in self-control discount more is suggestive of a

relationship between self-control and delay discounting.

Second, rewards that can be directly consumed such as food and alcohol

(for college students with no substance, gambling, or eating problems; Odum et

al., 2006) as well as drugs such as heroin (among heroin addicts; Madden et al.,

1997) have been shown to be discounted more than money, which cannot be

directly consumed. As it is plausible that directly consumable rewards cause

relatively more activation of the "hot" system than non-directly consumable

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rewards, these results could be viewed as evidence that delay discounting involves competing cognitive systems.

Third, and somewhat related to this, exposure to appetitive stimuli such as pictures of desserts, the smell of baking cookies (both Li, 2008), or pictures of attractive women (for male participants; Wilson & Daly, 2003) increases delay discounting behavior for money, a presumably non-appetitive reward.  It is plausible that the appetitive stimuli increased the relative activation of the "hot" system or decreased the ability of the "cold" system to override impulses to discount (e.g., through the depletion of a finite supply of self-control, cf. Muraven & Baumeister, 2000).

Fourth, Hinson, Jameson, and Whitney (2003) demonstrated that taxing working memory in various ways led to higher discounting rates.  Working memory load is generally believed to interfere with processes that require cognitive control, making overriding initial response impulses less successful (e.g., Lavie, 2005).  If delay discounting decisions result from dual-system competition, working memory load should allow the decisions of the more automatic system to be executed more readily.  The fact that higher discounting rates were observed under working memory load implies that the automatic response is biased toward the SS.

Fifth, some evidence from the delay of gratification paradigm appears to bear on the hypothesis.  Mischel and Baker (1975) found that children could learn to increase their delay time by thinking about food rewards in non-

consummatory ways (e.g., imagining that a pretzel is a log). Such thinking could be viewed as reducing the activation of the hot system.

Sixth, preschool age participants in whom a negative mood was induced showed more delay discounting than participants in a positive or neutral mood (Moore, Clyburn, & Underwood, 1976). According to ego depletion theory, the regulation of a negative mood requires the use of self-control, while positive or neutral moods do not (Muraven & Baumeister, 2000).

The final, and perhaps most compelling, evidence comes from McClure and colleagues, who showed that different neural systems in humans seem to value immediate and delayed rewards differently, for both money (McClure et al., 2004) and juice rewards (McClure et al., 2007). They found that activation of parts of the limbic system (i.e., neural areas associated with reward and emotion) was relatively high when the decision problem included an immediate reward, but parts of the prefrontal and parietal cortex (i.e., neural areas associated with planning and deliberation) were activated regardless of when the rewards could be received. Further, it was shown that when people chose the LL, there was significantly more activation in prefrontal and parietal areas than in the limbic areas, but when the SS was chosen, activity in the two areas was comparable. Additionally, McClure et al. (2007) showed that the relative activation of the two areas predicted actual choice behavior.

While no evidence from the delay discounting literature apparently contradicts the dual-systems competition hypothesis, some work in the delay of gratification arena is potentially inconsistent. Mischel and Baker (1975) found

that instructing participants to think in consummatory ways about foods that were very different from the reward food would increase wait time.  Metcalfe and Mischel (1999) generalize this to posit that "external distraction that activates irrelevant hot spots" should increase wait time (p. 11).  These ideas are at odds with the present hypothesis, which would predict that such stimulation would cause a general activation of the hot system, thereby increasing delay discounting.

# Chapter 3

# Empirical Work

In this section, I discuss the empirical work I undertook to elucidate the drivers of delay discounting. The studies are organized in the order in which they were executed, as results from earlier studies informed the design of later studies.

## 3.1 Study 1: Inducing concrete construals I: What would you do?

### 3.1.1 Overview

Study 1 was designed to test two hypotheses about the relationship between Construal Level Theory (CLT) and delay discounting. The first hypothesis is: differences in how the SS and LL are construed drive delay discounting. As discussed in section 2.4, CLT states that sooner events are represented in relatively concrete terms, while later events are represented in relatively abstract terms. One potential explanation for why people would choose the SS over the LL for positive outcomes is that the concrete construal of the SS is more desirable than the abstract construal of the LL, possibly because of the motivating affective content of low-level construals. It follows that causing people to think of the SS more abstractly or to think of the LL more concretely should lead to less delay discounting behavior – at least in cases where the SS and LL

have similar abstract and concrete construals (e.g., when the SS and LL are both amounts of money).  The reasoning is that if the SS and LL are construed of in a similar way (both abstractly or both concretely), the difference in construal level would not drive the decision.  Presumably, the difference in the *amounts* of the rewards then *would* drive the decision, leading people to choose the LL.  So, one goal of this study was to cause one group of participants to construe both the SS and LL concretely, and observe whether this group discounted less than a control group.  If the manipulation resulted in less delay discounting behavior, this would indicate that CLT may be a viable contributor to such behavior.

The second hypothesis of interest in this study was: CLT explains the magnitude effect in delay discounting.  As discussed in section 1.4.4, smaller delayed rewards are discounted more than larger delayed rewards, though there is no consensus on why this occurs.  It has been proposed that the magnitude effect could be a result of difference in construal level: Making decisions about larger (vs. smaller) amounts of money may activate more abstract (vs. concrete) construals, which would lead to less delay discounting (Trope & Liberman, 2003). Thus, in this study, some participants chose among relatively large rewards, while others chose among relatively small rewards.  Then, participants completed a measure designed to assess their construal level.  If those choosing among larger amounts of money did indeed engage in more high-level construal, this would be evidence that CLT is a viable explanation for the magnitude effect.

While it has been proposed that CLT can account for delay discounting behavior and the magnitude effect (Trope & Liberman, 2003, discussed in section 2.4), this has never been directly tested.  The present study was an attempt to do just that.

*3.1.2 Method*

*3.1.2.1 Participants.*  One hundred thirty-six students in the Introductory Psychology Subject Pool at the University of Michigan participated in the study for class credit.

*3.1.2.2 Procedure*.   All participants made a single decision between a hypothetical SS that could be received "today" and a hypothetical LL that could be received "one year from today."  The nature of this decision varied by condition.  This study involved two manipulations crossed to produce four conditions; each participant was randomly assigned to one condition.  The first manipulation was designed to cause participants to think of both the SS and LL in concrete terms before making their decision (the "prompt" condition).  These participants were presented with the decision that they would be asked to make, and then instructed:

Before you make your choice, we would like you to consider some things.

Think about the [SS] you could choose to receive today.  Name 3 things you could do with this [SS].

Think about the [LL] you could choose to receive in one year.  Name 3 things you could do with this [LL].

The order of these prompts was randomized between participants. The values of the SS and LL were filled in as dictated by the other manipulation. After the participants listed three things for each prompt, they were asked to indicate their choice of the SS or LL. Participants in the "no prompt" condition did not receive these prompts and simply indicated their choice of the SS or LL.

The second manipulation varied the amounts of the SS and LL. In the "small rewards" condition, participants chose between a SS of $68 and a LL of $100. In the "large rewards" group, participants chose between a SS of $22,750 and a LL of $25,000 (the selection of these reward amounts is discussed below in section 3.1.2.3).

After choosing the SS or LL, all participants indicated the strength of their preference by moving a slider to a point on a continuous scale that ranged from "I am indifferent between the two options" and "I strongly prefer the option I chose."

Finally, all participants completed a subset of the Behavior Identification Form (BIF, Vallacher & Wegner, 1989). This questionnaire was designed to measure whether the participants were engaging in high-level (i.e., abstract) or low-level (i.e., concrete) construal. The BIF asks participants to choose whether each of twenty-five actions (e.g., "pushing a doorbell) is, in the participant's opinion, better described by a low-level description (e.g., "moving a finger") or a high-level description ("seeing if someone is home"). This scale has been used an indication of participants' construal level (e.g., Liviatan, Trope, & Liberman, 2008; Liberman & Trope, 1998). As in these previous uses, we excluded six

questions that referred to actions in which college students would be unlikely to engage (e.g., "joining the army," "growing a garden").

*3.1.2.3 Choice of stimuli.* The delay of one year used in the delay discounting question was chosen to be congruent with both existing delay discounting studies and CLT studies. In 10 of 14 CLT studies reviewed, the delay used was one year. The magnitudes of the SS and LL rewards were chosen based upon data from Green, Myerson, and McFadden (1997), who demonstrated the magnitude effect in a college student population for hypothetical rewards. They showed that the rate of delay discounting decreased as the LL increased, until the LL reached about $25,000. Thus, $25,000 was chosen for the larger LL while the smallest amount used by Green et al. (1997), $100, was chosen for the smaller LL. The SS rewards were based upon the median discount rates provided by Green et al. (1997) for each LL. The SS/LL choice pairs were designed so that without any manipulation, participants would be, on average, indifferent between the SS and LL.

*3.1.3 Results*

*3.1.3.1 Excluded participants.* Eight participants were excluded for failing to complete the prompt when requested.

*3.1.3.2 Scoring.* The decision and preference rating given by each participant were translated into a "discounting score" from -100 to 100. A score of -100 indicates that the participant shows minimal discounting (i.e., the participant strongly favors the LL). A score of 0 indicates that the participant is

indifferent between the SS and LL.  A score of 100 indicates that the participant shows maximal discounting (i.e., the participant strongly favors the SS).  This discounting score was used as a proxy for the participant's discounting rate (similar techniques were used by Li, 2008).

*3.1.3.2 Effect of concreteness prompt on discounting.*  A Mann-Whitney U test was used to compare the prompt and no-prompt groups since the discounting scores were non-normally distributed.  Among participants who chose between small rewards, those receiving the concreteness prompt had significantly lower discounting scores ($\bar{x} = 6.04$) than those not receiving a prompt ($\bar{x} = 36.34$), $z = 2.386$, $p < 0.01$.  This indicates that the prompt group discounted less, as hypothesized, potentially because the concreteness prompt caused the to think about both the SS and LL in a concrete way.  The comparison between the prompt and no-prompt groups in the large reward condition was not of theoretical interest, since the potentially abstract-construal-inducing nature of the large rewards would interfere with the intended concrete-construal-inducing nature of the prompt.

*3.1.3.4 Effect of reward size on BIF score.*  Among participants in the no-concreteness-prompt conditions, the BIF scores of those choosing between larger amounts of money ($\bar{x} = 12.20$) were significantly higher than those choosing among smaller amounts of money ($\bar{x} =10.43$), t(74)=-2.205, p = 0.016.  As higher BIF scores indicate more abstract, higher-level thinking, these results support the hypothesis that choosing among larger amounts of money leads to more abstract thinking.

*3.1.3.5 Secondary analyses.* Interesting analyses not central to the main aims of this study can also be performed with these data. First, a participant's degree of delay discounting could not be predicted from his BIF score – the correlation between the two was not significant for any condition. Second, our prompt, which was intended to induce concrete construals, did not significantly change BIF scores. These null findings are a potential cause for concern, and prompted Study 2, where another attempt was made to invoke concrete construals.

*3.1.4 Discussion*

The results of the study appear to generally support the two hypotheses the study was designed to test: (1) that delay discounting can be (at least partly) explained by differences in how the SS and LL are construed and (2) that the magnitude effect can be (at least partly) explained by differences in how people construe small versus large amounts of money. However, because our manipulation, which was designed to induce lower-level construal, did not result in a change in BIF scores, we were concerned that the manipulation did not do what we intended it to – perhaps it swayed discounting behavior through another means. In fact, it can be argued that, according to CLT, our manipulation induced higher-level construal because it prompted people to think of their *goals* for the money. In CLT, goals are thought to be related to higher-level construal (Trope & Liberman, 2000). But, since the BIF scores were not pushed toward the abstract side by our manipulation, this is also questionable. So, to

investigate this further, Study 2 was constructed, where a different manipulation, also designed to evoke lower-level construal, was used.

Another alternative potential explanation for our results is that the prompt caused people to be more thoughtful and deliberate in their decision making, and required them to explicitly consider their future wants and needs. This may have bridged the intrapersonal empathy gap, thereby leading to less discounting. Or, the prompt may have preferentially engaged System 2 processes, also leading to less discounting. Neither of these theories would have predicted that the prompt would change BIF scores (and, in fact, such a change was not seen). Thus, Studies 5 and 8, discussed later, were intended to explore these explanations further.

## 3.2 Study 2: Inducing concrete construals II: Photos and graphs

### 3.2.1 Overview

Study 2 was designed as a follow-up to Study 1. In this study, we continued to pursue the hypothesis that differences in how the SS and LL are construed can at least partially explain delay discounting. Again, in this study, participants made a single decision between a SS and LL, and we attempted to sway the decisions of some participants by inducing them to think in a more concrete way about the rewards.

### 3.2.2 Method

*3.2.2.1 Participants.*  One hundred sixteen students in the Introductory

Psychology Subject Pool at the University of Michigan participated in the study

for class credit.

*3.2.2.2 Procedure.*  Each participant made a single decision between a

hypothetical $60 that could be received "today" and a hypothetical $100 that

could be received "one year from today." The amounts were changed from the

SS = $68, LL = $100 used in Study 1, for two reasons.  First, we noticed that

people tended to prefer the SS rather than being equally split between the SS

and LL, which was our goal for the control condition.  Second, making this

change made constructing the photo stimuli (discussed below) simpler.

Each participant was randomly assigned to one of three conditions.  In the

control condition, participants simply indicated their choice of the SS or LL.  In

the "photo" condition, when participants were presented with the decision, they

were also presented with photographs of the rewards in cash, each with a

caption indicating when it could be received (see Figure 4).
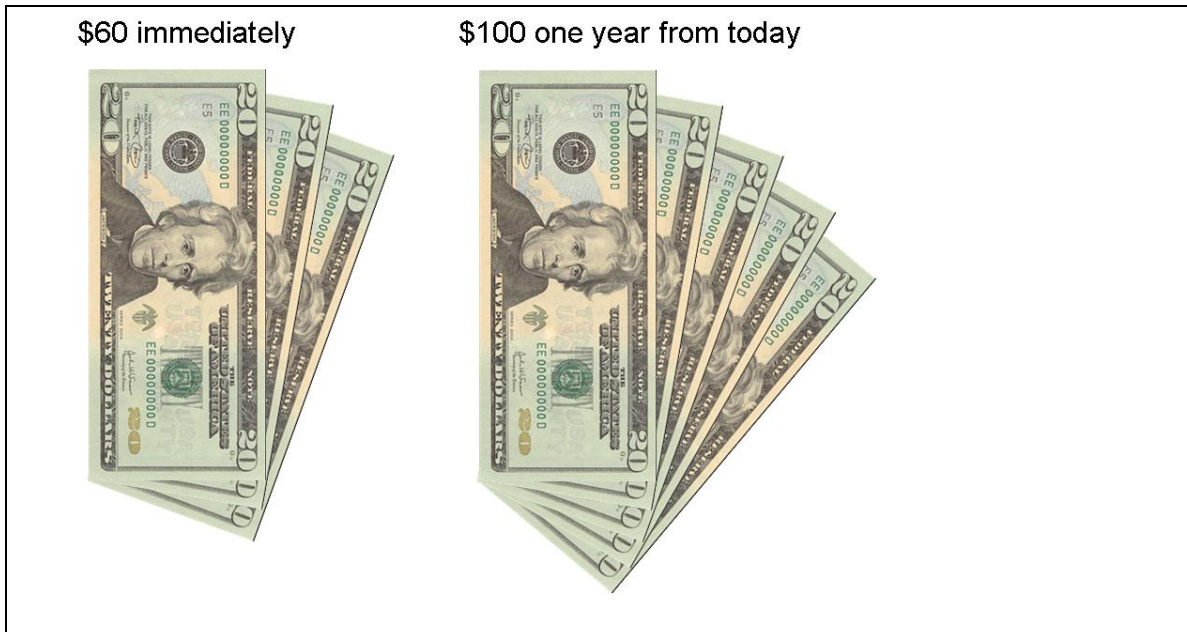
*Figure 4: Stimuli presented to participants in the "photo" condition. (Note: the photographs above are reduced in size relative to those actually used in this study.)*

The goal of the photographs was to induce a concrete, low-level construal of the rewards. The fan-style display was chosen because it is a naturalistic way to display amounts of money. The $20 denomination was chosen because it is very familiar to our participants (i.e., college students may not have much experience with, e.g., $100 bills). However, we were concerned that the photographs may change discounting behavior by simply emphasizing the difference in the amounts of the rewards. Thus, a "graph" condition was added as a second sort of control condition. In the graph condition, the photos in Figure 4 were replaced with graphs (Figure 5):
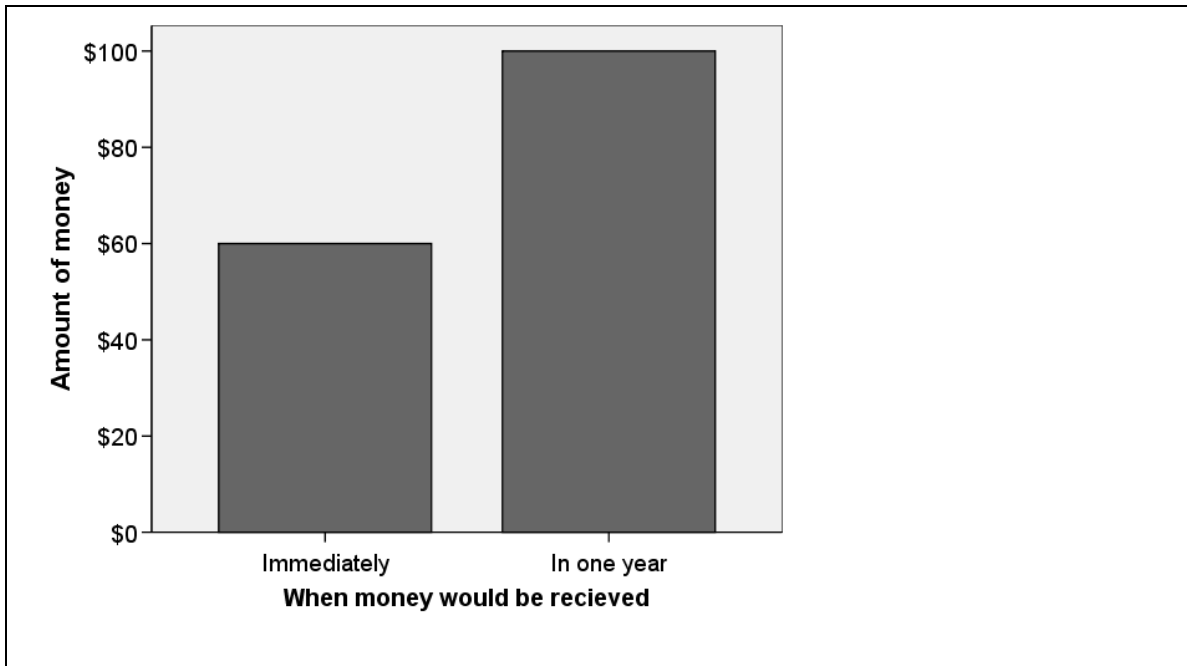
*Figure 5: Stimuli presented to participants in the "graph" condition. (Note: the graphs above are reduced in size relative to those actually used in this study.)*

The goal of the graphs was to communicate the difference in the amounts of the rewards without inducing concrete construal of money. We expected, if anything, that the graphs would induce abstract construal, as graphs present conceptual information extracted from its typical concrete context.

After choosing the SS or LL, all participants indicated the strength of their preference by moving a slider to a point on a continuous scale that ranged from "I am indifferent between the two options" and "I strongly prefer the option I chose."

*3.2.3 Results*

    *3.2.3.1 Scoring.* A "discounting score" from -100 to 100 was calculated as in Study 1.

*3.2.3.2 Effect of condition on discounting.* There was no effect of condition on the mean discounting score. However, the photo and graph stimuli appear to have had a (non-significant) polarizing effect, with participants in those two conditions reporting stronger preferences for their choice (regardless of whether they chose the SS or LL) than those in the control condition.

*3.2.4 Discussion*

Unfortunately, the correct interpretation of these results is unclear: Either our attempt to manipulate construal level was unsuccessful, or CLT is not an important contributor to delay discounting behavior. However, because there are reasonable alternative explanations for the results found in Study 1 that would not be invalidated by the null results in this study (e.g., System 2 activation, increasing empathy with future self), these alternative explanations are pursued further in Studies 4, 5, and 8.

**3.3 Study 3: Taxing self control I: Crossing out "e"s**

*3.3.1 Overview*

Study 3 was designed to test the dual-systems competition hypothesis, detailed in section 2.8. Specifically, the aim was to test the "self-control" mechanism proposed, using an ego depletion paradigm. According to ego depletion theory, self-control is a limited resource (e.g., Muraven & Baumeister, 2000). Many studies have tested this theory using a paradigm wherein participants complete a first task that requires a lot of (or a little/no) self-control,

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and performance on a subsequent, quite dissimilar, self-control task is measured.

Participants required to exert self-control on the first task showed a major

decrement in performance on the second task relative to a control group (e.g.,

Baumeister, Bratslavsky, Muraven, & Tice, 1998; Muraven, Tice, & Baumeister,

1998).

According to ego depletion theory, a process requires self-control if the

person must override simple or automatic responses and effortfully implement a

different response (Muraven & Baumeister, 2000).  Delay discounting behavior is

plausibly such a process. To test this idea, delay discounting decisions followed

a self-control-depleting (vs. non-depleting) task.  If the depleted group showed

increased discounting relative to the non-depleted group, this would be support

for the idea that discounting delayed outcomes is a self-control failure.


*3.3.2 Method*

*3.3.2.1 Participants.* One hundred forty-five students in the Introductory

Psychology Subject Pool at the University of Michigan participated in the study

for class credit.

*3.3.2.2 Procedure.*   Participants were randomly assigned to the "non-

depleted" group or the "depleted" group.  For the first task, participants were

presented with two pages of text, and instructions that varied by condition.  The

non-depleted group was instructed to cross out the letter "e" each time it

occurred on both pages of text.  The depleted group was instructed to cross out

the letter "e" each time it occurred on the first page of text.  For the second page,

they were asked to cross out the letter "e" each time it occurred unless it was next to a vowel or one letter away from a vowel. This manipulation has been used successfully in ego depletion studies (e.g., Baumeister et al., 1998); the task is designed to make the "depleted" group develop an automatic response (crossing out every "e") on the first page, and then require them to override that automatic response on the second page, "using up" self-control.

For the second task, participants made a series of binary choices between hypothetical SS and LL rewards, using the delay discounting "web" shown in Figure 6, adapted from Critchfield and Atteberry (2003). The web is used to determine each participant's indifference point (present subjective value) for $100 in one year. A lower indifference point indicates more delay discounting.

*3.3.3 Results*

*3.3.3.1 Excluded participants.* Eleven participants were excluded from analysis for failure to follow the web instructions (e.g., filling in an answer for every box, only filling in an answer for one box, etc.). Four participants were excluded for showing negative discounting (indicating a preference for $100 in one year over $100 right now). A total of 130 participants were used for analysis.

*3.3.3.2 Effect of depletion manipulation on discounting.* The non-depleted group ($\bar{x} = 53.85$, $\sigma = 27.23$) and depleted group ($\bar{x} = 52.97$, $\sigma = 29.21$) did not have significantly different indifference points.

On this page, you'll be asked to make some simple decisions. Each decision you make will determine what decision you'll be asked to think about next. There are no right or wrong answers; we are only interested in **what seems best to you** in each box. Please answer as honestly as you can. All of the choices involve money amounts. In each box, one money amount is offered now, and the other would be paid after some wait. Begin at the far left. After answering each question by filling in the circle next to your choice, **follow the curved line** from your answer to the next box. Eventually, you'll reach a box that leads nowhere else. When you reach this box, fill in the circle next to your choice and then go on to the next page or packet.
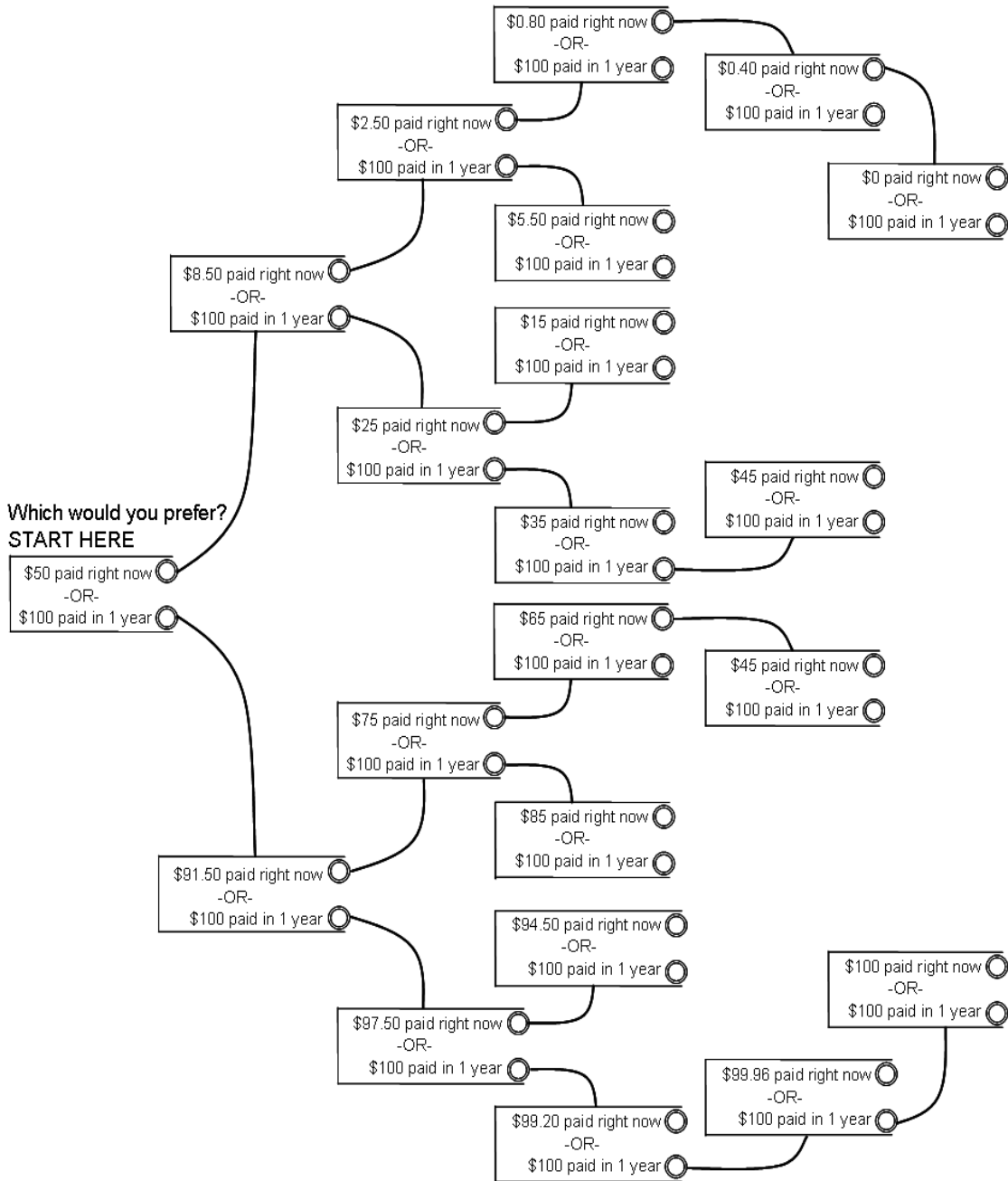


*Figure 6: Delay discounting "web" and instructions adapted from Critchfield &*

*Atteberry (2003).*

*3.3.4 Discussion*

The fact that our ego-depletion manipulation did not increase the discounting rate in the predicted way indicates that delay discounting may not be a self-control process. However, it is possible that the difference in depletion between the conditions was not sufficient to elicit a significant difference in discount rate. In some ego depletion studies, rather than giving the "non-depleted" group instructions like the ones used in this study, that group simply typed a paragraph (Muraven, Shmueli, & Burkley, 2006), or were given no task at all (Tice, Baumeister, Shmueli, & Muraven, 2007). Using a control condition of this nature would surely lead to a greater difference in ego depletion between the two groups, since the "non-depleted" group's task would be considerably easier than the one we used in this study. Such a study may be fruitful to conduct in the future.

## 3.4 Study 4: Taxing self control II: Discounting over several hundred questions

*3.4.1 Overview*

Study 4 was designed with two major goals in mind. First, this study was another attempt to test the question of whether delay discounting is a self-control process, as in Study 3. Here, we aimed to deplete participants' supply of self-control by having participants make several hundred binary choices between various SS and LL rewards; decision making itself is thought to deplete self-

control (Baumeister, Vohs, & Tice, 2007).  We predicted that decisions made early in the study session would indicate less delay discounting than decisions made later in the study session, due to depletion of self-control.  We expected that at the end of the study, people would be less able to suppress the urge to choose the SS.

An incidental aim of this study was to assess the adequacy of typical research methodology in delay discounting studies.  A common method of assessing discounting rates involves asking participants to make several hundred binary choices ("typically more than 400" per Madden et al., 2003, p. 140).  Thus, finding that the discount rate increases with the number of questions answered would be quite problematic for this methodology.

The second major goal of this study was to check for associations between certain personality variables and delay discounting rate.  Investigations of this sort have received very little attention from delay discounting researchers. But we maintain that such explorations could provide critical clues about the psychological mechanisms underlying delay discounting, particularly for the dual-systems hypothesis and the intrapersonal empathy gap hypothesis.  In this study, we looked at four measures (Actively Open-minded Thinking, Need for Cognition, SAT/ACT scores, and the Rational-Experiential Inventory) that are shown to be associated with the ability to correctly solve problems when the correct answer requires purposefully overriding an initial conclusion (Pacini & Epstein, 1999; Stanovich, 1999).  That is, they are associated with the ability to allow System 2, rather than System 1, to "answer the question."  If it were the case that scores on

these measures were negatively correlated with discounting rate, this would be evidence that successfully discounting less requires the overriding of an initial response. It is also plausible that people scoring highly on a measure of intellectual engagement such as Need for Cognition may also have superior intrapersonal empathy because they are more likely to engage in the additional cognitive work necessary to put themselves in their future selves' shoes.

*3.4.2 Method*

*3.4.2.1 Participants*. Eighty students in the Introductory Psychology Subject Pool at the University of Michigan participated in the study for class credit.

*3.4.2.2 Procedure*. In order to encourage participants to remain engaged and attentive for the several hundred choices they would make in this study, participants were informed that some participants would have one of their choices selected at random to be honored with real money. The procedure for this was as follows: Each participant would choose a number, 1-6, to be their "winning number". If, at the end of the study, the participant rolled two dice and both landed on that number, one of their choices would be selected at random. If, for that choice, the participant selected the SS, a check for the appropriate amount would be issued that day. If the participant chose the LL, a check for the appropriate amount would be issued after the indicated delay. Participants were given the details of this scheme, both verbally by the experimenter and in the

form of a "contract" signed by the experimenter, the supervising professor, and the participant.

The participants then made 459 binary choices between various SS and LL rewards, in a set of nine blocks. Each block represented a different delay. The length of the delay for a certain block was randomized according to Table 2 (e.g., if a person was assigned a delay of 37 days for Block 1, she would have a delay of 39 days for block 5).

| Block # | Trial #s | Delay |
|---------|----------|-------|
| 1 | 1-51 | 37 or 39 days |
| 2 | 52-102 | 9 or 10 days |
| 3 | 103-153 | 225 or 227 days |
| 4 | 154-204 | 4 or 5 days |
| 5 | 205-255 | 37 or 39 days |
| 6 | 256-306 | 9 or 10 days |
| 7 | 307-357 | 225 or 227 days |
| 8 | 358-408 | 4 or 5 days |
| 9 | 409-459 | 38 days |

*Table 2: Block design of Study 4*

Within each block, participants chose between a LL of $200 to be received after the delay, and a SS that started at $200. For each new question, the SS was decreased incrementally until it was $1, then it was increased incrementally until it was again $200. This yielded 51 questions per block.

Next, because we were concerned about how believable it would be to participants that they had a chance for one of their choices to be honored with real money, we asked the following three questions as manipulation checks:

> To what extent do you believe that you will be given the opportunity to play the dice roll as described at the beginning of the study? To make your rating, use a scale where 1 = I am certain that it will NOT happen (i.e., I believe the experimenter was lying) 10 = I

am certain that it will happen (i.e., I believe the experimenter was telling the truth)  Feel free to choose a number in between as appropriate.    Please make a rating on the scale below by clicking on a number.

If you ARE given the opportunity to play the dice roll as described, how likely do you think it is that you will WIN the dice roll? That is, how likely do you think it is that both your dice will roll the winning number you chose?    To make your rating, use a scale where  1 = I am certain that I will win the dice roll  10 = I am certain that I will NOT win the dice roll  Feel free to choose a number in between as appropriate.    Please make a rating on the scale below by clicking on a number.

If you DO win the dice roll (that is, if both dice roll your winning number), how likely do you think it is that you will have one of your money choices honored with real money as described at the beginning of the study?    To make your rating, use a scale where  1 = I am certain that it will NOT happen (i.e., I believe the experimenter was lying)  10 = I am certain that it will happen (i.e., I believe the experimenter was telling the truth)  Feel free to choose a number in between as appropriate.    Please make a rating on the scale below by clicking on a number.

Next, participants completed (in random order) the four scales discussed in the overview (the Need for Cognition scale from Cacioppo, Petty, Feinstein, & Jarvis, 1996; the Rational-Experiential Inventory from Pacini & Epstein, 1999; and an Actively Open-minded Thinking scale from Macpherson & Stanovich, 2007).  They also completed a numeracy scale (Lipkus, Samsa, & Rimer, 2001) as we suspected that ability to interpret numerical information may interact with delay discounting in the way that it interacts with decisions involving risk (Peters

& Levin, 2008).  Finally, participants reported their sex, age, and ACT/SAT scores.

*3.4.3 Results*

    *3.4.3.1 Excluded participants.*  This study was (intentionally) monotonous, so, despite the potential for real payment, we were concerned with our participants rushing through the study or failing to be sufficiently attentive.  Two classes of participants were excluded because of apparent inattention.  Ten participants were excluded for displaying negative discounting (i.e., indicating that they would prefer to receive $200 after a delay over $200 immediately) in more than one block.  An additional three participants were excluded because of marked nonmonotonicity in their responses (they did not consistently value rewards less as delay increased).  These latter participants were identified by fitting the hyperbolic discounting equation to each participant's data (for all 9 blocks) using nonlinear regression with $k$ as a free parameter (as in, e.g., Johnson & Bickel, 2002).  This provided an estimate of $k$ as well as residual sum of squares (RSS) for each participant.  The three excluded participants had RSS of over 20,000.  The average RSS was 3418.21.  A total of 67 participants remained for use in analysis.

    *3.4.3.2 Effect of number of questions on discounting.*  If answering several hundred questions changed discounting rates, the greatest difference in discounting rates should be observed by comparing Block 1 to Block 9. A $k$ value was determined for each participant for both Block 1 and Block 9.    Because the

distribution of these *k* values was highly skewed and contained potential outliers, the nonparametric Mann-Whitney U test was used to compare k values at Block 1 (mean = 0.0355, median = 0.0295) and Block 9 (mean = 0.0365, median = 0.0292).  No difference in *k* values was detected, $U = 2133.00$, $p = 0.620$.

*3.4.3.3 Correlation between discounting and individual difference measures.*  We examined correlations between the overall *k* value for each participant (using data from all 9 blocks) and participants' scores on the individual differences measures.  Since the overall *k* values were highly skewed and contained potential outliers, the nonparametric Spearman's rho measure was used.  Table 3 presents the correlations between overall *k* and each individual differences measure.  The Rational-Experiential Inventory provided both a Rational score and an Experiential score (each score indicates a preference for thinking in the specified way, with "Rational" scores mapping onto System 2, and "Experiential" scores mapping onto System 1); these were analyzed separately. The N for ACT scores is lower than 67 (the number of otherwise usable participants as discussed above) because several participants did not report an ACT score.

| Measure | Numeracy | Need for Cognition | Rational score | Experiential score | Actively Openminded Thinking | ACT score |
|---|---|---|---|---|---|---|
| **Correlation Coefficient** | 0.041 | -0.173 | -0.151 | 0.080 | -0.021 | -0.216 |
| **Sig. (1-tailed)** | 0.372 | 0.081 | 0.111 | 0.260 | 0.433 | 0.060 |
| **N** | 67 | 67 | 67 | 67 | 67 | 53 |

*Table 3: Spearman's rho correlations between individual difference measures and overall k.*

The correlations between overall *k* and Need for Cognition as well as between overall *k* and ACT scores are in the predicted direction (i.e., higher ACT scores and more of a need for cognition are associated with *less* delay discounting) and are approaching significance.

*3.4.4 Discussion*

The fact that no change in discounting behavior was observed across several hundred questions further detracts from the ego depletion hypothesis. But, this same result also alleviates concerns about the appropriateness of delay discounting measures that use several hundred questions.

The near-significant negative correlations between the discounting parameter, *k*, and Need for Cognition and ACT scores could be interpreted as supporting the dual-systems hypothesis, as we know that high Need for Cognition and ACT scores are positively correlated with the ability to correctly solve problems when answering correctly requires effortfully overriding an initial incorrect conclusion (Pacini & Epstein, 1999; Stanovich, 1999). These results also appear to support the intrapersonal empathy gap hypothesis, as people scoring highly on measures of intellectual ability and engagement may plausibly be more willing and able to consider their future needs and wants. Study 5 was designed to further explore the intrapersonal empathy gap hypothesis.

**3.5 Study 5: Ease and difficulty**

*3.5.1 Overview*

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As discussed in section 2.6, it has been established that that there is a negative correlation between a person's tendency to think about the future and his discounting rate, which supports the intrapersonal empathy gap hypothesis (Adams & Nettle, 2009). Further support for that hypothesis would be seen if discount rates could be *manipulated* by making future wants and needs easier or more difficult to bring to mind. Study 1 was a start down this path – we showed that asking people to think about how they would spend the SS and LL made people more likely to choose the LL. It is plausible that this occurred because we caused them to consider their future wants and needs more than they otherwise would have. However, it is also possible that the change in discounting behavior we observed was due to changes in construal level instead.

In this study, we used a different tactic to manipulate discount rates: one that, if effective, would support the intrapersonal empathy gap hypothesis but not the differences in construal level hypothesis. In this well-known method, used heavily by Schwarz and colleagues (see Schwarz, 1998, for a review), the subjective ease with which instances of a class come to mind is manipulated. A person could be asked to list a few instances from a class, which leaves her feeling that it is easy to generate instances. Or, the person could be asked to list many instances, which leaves her feeling that it is difficult to generate instances. This metacognitive feeling of ease or difficulty gives rise to different judgments about that class, per the availability heuristic. If it feels easy to generate instances, the person concludes that the class is well-populated. If it feels difficult to generate instances, the person concludes that the class is not well-

populated (Tversky & Kahneman 1973).  In this study, we manipulated the

feeling of ease or difficulty our participants had about generating uses for the SS

or LL, and observed the effects of this manipulation on discounting behavior.


*3.5.2 Method*

   *3.5.2.1 Participants.* Two hundred students in the Introductory Psychology

Subject Pool at the University of Michigan participated in the study for class

credit.

   *3.5.2.2 Procedure.*   Participants were randomly assigned to one of five

conditions, described in Table 4.  All participants were first presented with a

hypothetical choice between receiving $60 today and receiving $100 in a year.

Before making the choice, participants in the 3LL, 12LL, 3SS, and 12SS

conditions were asked to list ways they might use one of the rewards, as

described in Table 4.   These manipulations were designed to cause the

participant to make the respective metacognitive inferences listed in Table 4.  We

hypothesized that participants in the 12LL and 3SS conditions would discount

similarly to control participants, reflecting the notion that it is typically easy to

think of present desires and difficult to think of future desires.  We expected that

participants in the 3LL condition would discount less than control participants,

demonstrating that when it feels easier to think of future wants and needs, people

are more apt to aim to serve those wants and needs by choosing the LL.  The

12SS condition was added for the sake of completeness; ideally, generating 12

uses for the SS would cause participants to find it difficult to think of present

desires, but we were dubious that participants could actually be convinced that they had few present desires.

Note that in both the 3LL and 12LL conditions, the lists themselves contain the same *sort* of information, so there should be no differences in construal level. However, the metacognitive feeling of ease/difficulty would be different, which could plausibly lead to a change in discounting behavior. Additionally, such a change in behavior could not be accounted for by other theories of discounting, such as the uncertainty hypothesis.

Participants who did the list-generating exercise reported how difficult the task was on a 7-point scale from "very difficult" to "very easy." Then, all participants indicated their choice of the SS or LL, and indicated the strength of their preference by moving a slider to a point on a continuous scale that ranged from "I am indifferent between the two options" (assigned a preference score of "0") and "I strongly prefer the option I chose" (assigned a preference score of "100"). Finally, participants reported their sex, year in school, present annual income, and anticipated annual income one year from the present.

| Condition | The participant is asked to… | Leading him/her to infer that… | Anticipated change in discounting behavior |
|-----------|------------------------------|-------------------------------|--------------------------------------------|
| 3LL | List 3 ways he/she would spend the LL | "I have many future wants/needs" | Less delay discounting |
| 12LL | List 12 ways he/she would spend the LL | "I have few future wants/needs" | No change or slightly more delay discounting |
| 3SS | List 3 ways he/she would spend the SS | "I have many present wants/needs" | No change or slightly more delay discounting |
| 12SS | List 12 ways he/she would spend the SS | (*potentially*) "I have few present wants/needs" | No change or less delay discounting |

| Control | -- | -- | No change |

*Table 4: Design of Study 5*


*3.5.3 Results*

 *3.5.3.1 Scoring.* A "discounting score" from -100 to 100 was calculated as in Study 1.

 *3.5.3.2 Manipulation checks.* Participants reported that, as expected, the 12LL list task was more difficult than the 3LL list task ($t(64) = 6.705$, $p < 0.001$) and the 12SS list task was more difficult than the 3SS list task ($t(98) = 8.767$, $p <0.001$).

 *3.5.3.3 Effect of condition on discounting.* Because the discounting scores were non-normally distributed, a Kruskal-Wallis test was used. The conditions did not differ on discounting rate, $KW(4) = 2.236$, $p =.693$.

 *3.5.3.4 Relationship between task difficulty and discounting.* Because the discounting scores were non-normally distributed, the correlations reported here are Spearman's rho. Within the 3SS ($R(48) = 0.253$, $p = 0.01$) and 12SS ($R(52) = 0.192$, $p = 0.037$) conditions, there were significant correlations between reported task difficulty and discounting, in the predicted direction. That is, in these conditions, participants who reported more difficulty thinking of present wants and needs were more likely to choose the LL. This correlation was not significant in either of the LL conditions.


*3.5.4 Discussion*

Despite the effect the list-generating manipulation has had in many other domains, we were not able to use it to cause changes in discounting behavior. However, the fact that reported difficulty with the task correlated with discounting behavior in the SS conditions lends some modest support to the theory, or at least an isotope of it. The intrapersonal empathy gap hypothesis predicted, "the more difficult it is to think of future desires, the more discounting will occur." What was demonstrated in this study was, "the more difficult it is to think of present desires, the less discounting will occur." However, it is unclear why there was no relationship between reported task difficulty and discounting behavior in the LL conditions.

Also it is surprising that in Study 1, when we asked people to list three ways they would use both the SS and LL, discounting rates changed relative to a control condition, but in this study when people listed three ways they would use *either* the SS or LL, there was no change in discounting. The reasons for this are not apparent.

## 3.6 Study 6: Anticipated income

### 3.6.1 Overview

As discussed in section 2.1.1, one reason people may discount is that they anticipate that their financial situation will improve over time. Thus, receiving the SS at a sooner time would provide more utility than receiving the LL at a later time. To empirically test this idea, we studied two populations: college

juniors and college seniors.  While college juniors presumably would not expect

much financial improvement over the course of a year, college seniors would

likely anticipate full-time employment and thus a significant jump in income.  If

these two groups differ in discounting behavior, this would be evidence that

anticipated financial improvement plays a role in delay discounting.  In this study,

college juniors and seniors first answered delay discounting questions, and then

reported their current annual income and their anticipated income one year in the

future.

*3.6.2 Method*

    *3.6.2.1 Recruitment.* Participants for this study were recruited in two

different ways.  First, the "snowball" method was used.  I e-mailed friends and

colleagues with the survey information and an appeal asking the recipient to

forward the message to any college juniors and seniors they knew.  Second, an

e-mail was sent to a random selection of two thousand University of Michigan

juniors and seniors.

    *3.6.2.2 Participants.*   Two hundred seventy-nine people participated in

this study.  Participants were not compensated for their participation.

    *3.6.2.3 Procedure.*   Participants first completed a computerized version of

the delay discounting "web" used in Study 3 (Figure 6).  The web was used to

determine each participant's indifference point (present subjective value) for

$100 in one year.  Then, participants reported their sex, year in school,

anticipated graduation date, their present college, their current annual income, and their anticipated annual income one year from the present.

*3.6.3 Results*

     *3.6.3.1 Excluded Participants.*  Of the 279 participants, seven were excluded for failing to complete the survey.  Thirty-four were excluded because they were not college juniors or seniors.  The responses from the remaining 238 participants were examined to determine whether their reported present and future incomes were consistent with our assumptions.  Specifically, we considered a participant to be a "financial junior" if each of the following held:

1.  The participant reported being a college junior.

2.  The participant provided both present and anticipated future income.

3.  Anticipated future income was not more than 25% greater than present income.

4.  Anticipated future income was not lower than present income.

We considered a participant to be a "financial senior" if each of the following held:

1.  The participant reported being a college senior.

2.  The participant provided both present and anticipated future income.

3.  Anticipated future income was at least 50% higher than present income.

Eighty of the 132 college juniors qualified as "financial juniors."  Fifty-seven of the 106 college seniors qualified as "financial seniors."

     *3.6.3.2 Reported Income.*  Financial juniors reported an average present income of $4,298.00, and an average anticipated future income of $4,373.85.

Financial seniors reported an average present income of $4,578.95, and an average anticipated future income of $33,553.00.

*3.6.3.3 Effect of year on discounting.* Financial juniors and seniors did not differ on their present subjective value for $100 in one year ($t(121) = 0.508$, $p = 0.612$).

*3.6.3.4 Effect of income on discounting.* Neither present nor anticipated future income correlated significantly with discounting behavior, either across all participants or within groups.

*3.6.4 Discussion*

Our failure to find an effect based upon year discredits the idea that people make discounting decisions based upon anticipated future income, at least in typical circumstances. Perhaps we would have seen an effect if we first asked about present and anticipated future income, and then asked the discounting questions. However, people are not usually made to consider their present and future financial states before making discounting-type decisions.

Unfortunately, we were unable to replicate the finding that discount rates are correlated with present income. This may be because our discounting measure was insufficiently sensitive, or because there simply was not enough variation in present income.

**3.7 Study 7: Field dependence**

*3.7.1 Overview*

As discussed in section 2.6, delay discounting behavior could result from devoting relatively little thought to one's future wants/desires. Another way of framing this is that discounting is caused by being preoccupied by present wants/desires. It is plausible that discounting behavior is positively correlated with field dependence as measured by such tasks as the rod-and-frame test (cf. Witkin & Goodenough, 1977). Both concern a tendency to be primarily concerned with one's immediate surroundings, and being unable to abstract away salient information. As field dependence is a well-established psychological concept, relating to such wide-ranging constructs as learning styles, culture, and social anxiety (e.g., DeBell & Crystal, 2005; Goodenough, 1976), detecting a relationship between it and discounting could prove fruitful. In this study, the relationship between field dependence and discounting behavior was explored. To make the relationship more clear, we controlled for visuospatial ability.

*3.7.2 Method*

*3.7.2.1 Participants.* Ninety-five students in the Introductory Psychology Subject Pool at the University of Michigan participated in the study for class credit.

*3.7.2.2 Procedure.* Participants completed a measure of field dependence (the Group Embedded Figures Test, Witkin, Oltman, Raskin, & Karp, 2002), a

measure of visuospatial ability (the Paper Folding Task; Ekstrom, French, & Harman, 1976), and the delay discounting web as in Studies 3 and 6.

### 3.7.3 Results

*3.7.3.1 Excluded participants.*  Nine participants were excluded for failing to follow the directions of the delay discounting web.  Eight participants were excluded for showing no discounting or negative discounting.

*3.7.3.2 Relationship between field dependence and discounting behavior.* There was no significant correlation between field dependence and discounting behavior, both before ($r = 0.03$, $p = 0.8$) and after ($r = -0.013$, $p = 0.9$) controlling for visuospatial ability.

### 3.7.4 Discussion

The null results of this study indicate that a tendency to be distracted by immediately available, salient information apparently cannot be used to explain discounting behavior.

## 3.8 Study 8: System 1/System 2 priming

### 3.8.1 Overview

As discussed in section 2.8, there may be multiple mechanisms whereby dual-system competition leads to delay discounting. The first is that discounting decisions involve self-control: one has an urge to choose the SS but can

effortfully override this urge by using some of one's limited self-control resource. The results of Studies 3 and 4 cast doubt on this mechanism when tasks designed to use up self-control failed to increase discounting. However, the second mechanism – that discounting depends upon the relative activations of System 1 and System 2 – remained untested. In this study, we attempted to preferentially activate System 1 or System 2 through a priming task before participants made discounting decisions.

*3.8.2 Method*

   *3.8.2.1 Participants.* Ninety students in the Introductory Psychology Subject Pool at the University of Michigan participated in the study for class credit.

   *3.8.2.2 Procedure.* Participants were randomly assigned to the "System 1" or "System 2" condition. All participants first completed a sentence-unscrambling priming task, then completed two delay discounting measures. The literature provided no clues on how to reliably induce System 1 versus System 2 thinking, so a sentence-unscrambling priming task was constructed for this study. The priming method adapted from a similar-style manipulation used by Bargh, Chen, and Burrows (1996), in whose studies participants were primed to be, among other things, rude or polite.

   In the priming task used in the present experiment, participants were presented 20 sets of 4-6 words. For each set of words, the participants were asked to change the order of the words to make a grammatically correct

sentence.  The content of these sentences varied by condition.  In the System 1 condition, ten of the sentences contained a "keyword" related to System 1 thinking, such as "hunch," "automatically," and "emotional."  The remaining ten sentences contained neutral content.  In the System 2 condition, ten of the sentences contained a keyword related to System 2 thinking, such as "slowly," "thoughtful," and "rational."  The remaining ten sentences were the same neutral sentences as in the other condition.  The order of the twenty sentences was randomized for each participant

Then, participants completed the same discounting task as in Studies 1, 2, and 6 (choosing between $60 today and $100 in a year, and indicating their degree of preference).  Finally, participants completed a computerized version of the delay discounting "web" as in Studies 3, 6, and 7.

*3.8.3 Results*

*3.8.3.1 Scoring.* A "discounting score" from -100 to 100 was calculated as in Study 1.

*3.8.3.2 Effect of condition on choice discounting task.*  A Mann-Whitney U test was used because the discounting scores were non-normally distributed.  There was a trend for the System 1 group to discount more ($\bar{x}$ = 7.085, σ = 73.005) than the System 2 group ($\bar{x}$ = -7.116, σ = 66.769).  This is in the predicted direction, though the difference was not significant, (z = --.881, p = 0.189).

*3.8.3.3 Effect of condition on web discounting task.* There was no effect of condition on the indifference point elicited from the web discounting task.


*3.8.4 Discussion*

While condition had no effect on the web discounting task (which was always administered second, and therefore may not be affected by a short-lived priming-based manipulation), the trend observed in the first discounting measure is intriguing. Unfortunately, time limitations preclude running additional participants or attempting different manipulations or dependent measures. However, this may be a worthwhile avenue for future research.

**Chapter 4**

**General Discussion**

**4.1 General conclusions**

The work reported in this dissertation aimed to help answer the question: "What causes delay discounting?" These studies tested several distinct hypotheses that had previously received little or no empirical attention: economic reasons, differences in construal, intrapersonal empathy gap, and dual-system competition. Assuming that, in each study, the manipulations each had their intended effect and the dependent measures adequately captured the intended construct, what conclusions can be drawn?

First, per Studies 1 and 2, it appears that delay discounting is not driven by differences in how the SS and LL are construed. Second, per Study 6, anticipated future income is apparently not a driver of discounting. Third, per Studies 3 and 4, the self-control mechanism of the dual-systems hypothesis is most likely not implicated in discounting decisions. In fact, after this study was completed, relevant data from other two other studies were discovered. First, Cox (2005), in an unpublished master's thesis, used the same ego depletion manipulation, but a different delay discounting measure, and similarly failed to find the anticipated effect. Second, Joireman, Balliet, Sprott, Spangenberg, and Schultz (2008) used a different ego depletion manipulation (controlling vs. not

controlling emotions while watching a video clip) as well as a different

discounting measure. They found the anticipated effect in only a very small

subset of people (i.e., those who scored more than one standard deviation above

average on the "immediate" subscale of the Consideration of Future

Consequences scale). Given the results of our Study 3, as well as the results of

these other studies, it appears fairly conclusive that ego depletion plays at best a

limited role in delay discounting.

The verdicts on the other two theories tested are more complicated. First,

the role of relative system activation is ambiguous. Study 4 showed a trend for

Need for Cognition and ACT scores, measures thought to be associated with the

ability to preferentially activate System 2, to be negatively correlated with

discounting rates. Study 8 hinted that priming System 1 (versus System 2) led to

more discounting, though this effect was not significant and was only present in

the first of two discounting measures.

It is also unclear how, based on the studies reported here, to evaluate the

intrapersonal empathy gap hypothesis. The prompt in Study 1 could be plausibly

interpreted as a way to increase empathy with one's future self, and it led to less

discounting. But, the similar prompts used in the LL conditions of Study 5, which

presumably would also increase intrapersonal empathy, had no effect on

discounting.

## 4.2 Limitations

The studies here are affected by a problem endemic to scientific (and, particularly, psychological) research: I am not confident that the experimental manipulations accomplished what they were designed to accomplish. For example, in Study 1, the fact that BIF scores did not change across prompt conditions causes one to suspect that the prompt manipulation was not changing construal level. In Study 8, was the priming manipulation sufficient? The design of the priming manipulation was original, since the literature provides no clues on how to preferentially induce System 1 versus System 2 activation.

Further, I am skeptical about the adequacy of the delay discounting measures used. Across the studies, three different measures of discounting were used, and each had some apparent problems. In all of these measures, some participants expressed preferences that indicated no discounting (e.g., equally preferring $100 in a year and $100 today) or negative discounting (preferring $100 in a year *over* $100 now). Do these responses indicate actual preferences, or simply misunderstanding or inattention?

The web method used in Studies 3, 6, 7 and 8 was apparently confusing in paper form, with a non-trivial portion of participants failing to follow the instructions. While this was not an issue for the computer-implemented version, another problem persists: apparent lack of sensitivity. While a person's true indifference point for $100 in one year could be any value between $0 and $100, the web method only allowed for 22 possible endpoints. Further, in the range where most people's responses fell ($40-60), there were only three possible

endpoints: $40, $50, and $60.  Perhaps if more and more-closely spaced

endpoints were available, subtle effects may have been observable.

The choice-and-preference discounting measure used in Studies 1, 2, 5,

and 8 suffered from a different problem: huge variations.  While the possible

responses ranged from -100 to 100, the average standard deviation within a

condition across studies was 71.05.  Perhaps in some of the studies where this

measure was used, effects would have been observed with a different measure

but were instead washed away by incredible amounts of noise.

The stepwise method used in Study 4 was probably the most accurate

measure, but even here, some participants gave inconsistent (at times *wildly*

inconsistent) responses.  Additionally, this measure took quite awhile to

administer, and would not have been appropriate to capture subtle and short-

lived manipulation effects.


**4.3 Broader impacts and future research**

While the research presented in this dissertation cannot unequivocally

support particular underlying causes of delay discounting, it appears that future

research examining relative system activation and the intrapersonal empathy gap

may be the most promising.  Are there other, more effective ways to change a

person's discounting rate by manipulating either of these factors?  If so, this

could be potentially useful in many real-world domains.  Perhaps marketers could

preferentially engage System 1 to cause people to discount more, driving up

indulgent and impulsive purchases?  Perhaps drug abuse counselors could help

clients to bridge their own intrapersonal empathy gap, reducing their tendency to

relapse.

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