

Models and Methods in Delay Discounting

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Delay discounting (DD) is a term typically used to describe the devaluation of rewards over time, and much research across a wide variety of domains has illustrated that people in general prefer a smaller reward delivered soon as opposed to a larger reward delivered at a later stage. Despite numerous attempts, a single unified model of DD that accounts for the varied pattern of results typically observed has been elusive. One of the difficulties in deriving a unified model is the presence of many framing and context effects, situations in which changing, apparently irrelevant, aspects of the choice scenarios lead to different selections. Additionally, different paradigms of DD research use quite different methodology, which poses challenges for a unified model. This chapter describes some of the difficulties in creating a single DD model and suggests some experiments that would help integrate different paradigms to create a clearer picture of DD.

Key words: choice; decision making; delay discounting; reward; framing

Traditional models of decision making, both in the economic¹ and psychological² domains, have largely considered how gains, losses, and their associated probabilities are combined to compute the decision utilities that are subsequently used to determine choice. However, an additional factor in the processing of decisions that has received much recent attention is the degree to which the immediacy of rewards and losses may be an important determining factor in decision making. This effect is typically seen in people's willingness to forgo larger rewards delivered after a delay, for smaller rewards that are collected immediately. This aspect of decision making, whereby smaller rewards with shorter delays are preferred to larger rewards with longer delays, is commonly called delay discounting (DD).

Demonstrations of DD can be found in the fact that people are often willing to pay a premium to avoid reward delays. Many companies provide services that allow customers to avoid delay of reward for a price. The company *Fandango*, for example, allows you to skip movie ticket lines by buying tickets online for a service fee. One of the perks of getting a first-class ticket on an airline is that you often have shorter lines at the ticket counter and can get on the plane at your leisure. Many law firms specialize in turning long-term settlements with monthly payments into smaller immediate lump sums. A growing business in America is check-cashing,

which allows immediate payments for larger promised future paychecks or postdated checks. Finally, experimental evidence, outlined below, has shown there are many situations where people will take smaller monetary rewards immediately over larger delayed rewards (for a review see Ref. 3).

Situations that require people to delay immediate rewards in order to receive larger future rewards are common in our society, and, in fact the inability to delay gratification may also be a factor in producing many social problems. Children with Attention Deficit Disorder (ADD) show significantly higher DD than controls, suggesting that both DD and ADD share neural circuitry.⁴ DD in people with drug addiction is also significantly greater than in controls, pointing to a possible role of hyper-discounting in the pathology of addiction.^{5,6} For example, a greater discount rate might make it more likely that gambling or drugs (and their concomitant immediate rewards) will be chosen over the long-term rewards of abstinence (e.g., longer life, safe investments, social rewards). To this end, Bickel and Marsch⁷ suggested that discounting rates could be a way of determining the likelihood of success in drug treatment programs. Additionally, it has been suggested that a reason for the failure of many diets may be a result of the temporal discounting of the long-term benefits of healthy eating and the tendency to indulge in the immediate gratification of unhealthy food.⁸ However, it should be noted the findings connecting psychological disorders and DD are not universal and more research needs to be done to understand the link between DD and these impulsive behaviors.⁹

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Standard Methodologies

In order to model people's choices over time, DD studies typically attempt to estimate the shape and magnitude of the discounting function (the degree to which rewards are devalued over time) by using a series of choices to determine points where the participant is indifferent between a relatively large reward after a delay and a smaller reward presented either immediately or after a short delay. By estimating a series of these indifference points for different delays, a subjective value curve can be plotted for that participant and a corresponding discount rate computed. For example, participants might be asked whether they prefer \$20 next month to a series of smaller amounts delivered now (i.e., \$5 now versus \$20 next month, \$10 now versus \$20 next month, \$15 now versus \$20 next month, and so on) in order to find the indifference point for that amount. This is repeated for other amounts and delays, and eventually a function can be computed for each individual participant.

DD studies in nonhuman animals present DD choices as different reinforcement schedules. Pigeons or rats are trained to peck at disks or press levers to get food rewards with options given between two schedules of reinforcement. For example, one lever or disk gives one pellet of food after 1 s and the other gives four pellets of food after 5 s. DD is demonstrated when animals pick a reinforcement schedule that gives a small food reward after a short delay (i.e., 1 s) over a schedule that gives a larger reward after a longer delay (i.e., 5 s), even though they pick the schedule that gives the larger food reward when both delays are long (i.e., 10 s). Indifference points are found by changing the schedules of reinforcements until the animals are indifferent to either schedule of reinforcement.

Patterns of Delay Discounting

By using methods similar to these, experimental studies have produced a rich body of findings in an effort to better understand DD. The first theories of DD assumed that the subjective value of rewards would decay exponentially.¹⁰ This assumption was founded on the belief that subjective values should be consistent over time. However, DD studies have consistently found that hyperbolic functions better fit the subjective value curves.¹¹ This finding is in line with the discovery that decisions about delayed rewards are often temporally inconsistent. For example, people are often not willing to wait a day for \$11 if they could have \$10 immediately but generally will wait a year and a day

for \$11 rather than a year alone for \$10.^{12,13} Additionally, hyperbolic discounting has been found in animal models of DD suggesting a common process for both paradigms.^{14,15}

Context and Framing Effects

Despite attempts to create a single model to explain how the value of delayed rewards are discounted, research in this area has found that the degree to which a person devalues rewards over time (i.e., the discount rate) is often dependent on the context and framing of both the delay and the choices. For example, research has found that discounting rates are greater for smaller rewards as opposed to larger rewards^{16–19} and that adding more options to the choice set also increases the discounting rate.²⁰ Participants generally prefer improving to declining sequences of rewards of the same overall value.²¹ For example, they prefer the choice set of \$5 now, \$10 in a week, \$15 in 2 weeks, over the choice set of \$15 now, \$10 in a week, and \$5 in 2 weeks. They require more compensation to delay delivery of a reward than they are willing to speed up delivery of that reward by the same amount of time.²² People also prefer to spread out the time over which they receive the rewards in question.²³

Further, shifting participants' attention to or away from the delay interval can modify discounting rates. Mischel *et al.*²⁴ found that distraction is an effective way to increase willingness to delay rewards, i.e., a child that sings a song or falls asleep is more likely to successfully delay eating one cookie now in order to get two cookies later. Finally, the type of reward being discounted also produces different degrees of DD, with primary rewards (i.e., alcohol, food) inducing greater rates of discounting than their monetary equivalent.²⁵ Finally, Thaler¹⁹ showed losses are typically discounted less than gains.

There is ample evidence, as outlined above, that DD can be affected by a host of task-related variables. These results raise the possibility that subtle changes in the way choices are presented may affect the degree of discounting demonstrated. It has long been known by decision-making researchers that context and framing effects can have a powerful influence on judgments.²⁶ The canonical Asian disease problem,²⁶ for example, describes how the way a question is asked can evoke very different mental representations and hence different judgments and decisions. Another set of studies shows that the way choices are presented can change judgments according to an "anchor and adjust" heuristic.²⁷ For

example, when participants estimated the product of $1 \times 2 \times 3 \times 4 \times 5 \times 6 \times 7 \times 8$, their average answer was 512; however, when estimating the (numerically identical) product of $8 \times 7 \times 6 \times 5 \times 4 \times 3 \times 2 \times 1$, their average estimate was 2250.²⁷

The influence of these framing effects on judgment means that DD choices may also be affected by the method by which discounting choices are elicited, with different choice frames and contexts perhaps producing different patterns of discounting. Indeed, Read *et al.*²⁸ found framing effects in a DD paradigm when delays are framed as either future dates or regular delays. For example, participants might not be willing to delay a larger reward for a month but other participants would be willing to delay the very same reward until February 2, also a month away at the time of the experiment but specified as a future date.

Another framing effect that has only recently been investigated is the effect of choice presentation methods. The standard method used in human studies, as described previously, is to hold constant a delayed reward and vary the immediate reward until an indifference point is reached for each time interval.²⁹ We call this the fixed delayed rewards (FDR) method. However, an alternative method that has been used in the animal literature is to fix the *immediate* reward and vary the delayed reward until the participant is indifferent between alternatives,³⁰ which we call the fixed immediate rewards (FIR) method.³¹ For example, a FIR experiment would ask a participant to choose between a small immediate reward (\$5) and a variable, larger, delayed reward (\$25, \$20, \$15, or \$10 after a month), whereas FDR would present the choice between a variable immediate reward (\$5, \$10, \$15, or \$20) and a fixed, delayed, larger reward (\$25 after a month). Of course these methods are theoretically equivalent and it should not matter in terms of discounting rates whether the participants see FDR or FIR. However, experimental tests of these two modes of presentation demonstrated that there was indeed a difference. Delays presented using FIR choices are discounted at a greater rate than FDR choices,³¹ with FDR participants earning a correspondingly greater amount of money with the same choice set, demonstrating that seemingly inconsequential changes in the way choices are presented can greatly affect discounting behavior and raising questions about the comparability of human and animal research paradigms.

Short and Long Time Frames

An open question in DD research is the degree to which discounting may operate differently when the

time frame is short (seconds or minutes) as compared to when the time frame is long (months, years, or even decades). Much of what we know about the physiological processes involved in DD comes from work done with animals, using very short delays (e.g., seconds as opposed to days). Although animal DD research is being directly applied to the understanding of human DD processes³² in an effort to posit a central DD system operating across species, there have been few studies which specifically attempt to assess the degree to which discounting may differ using varied time frames. One recent experiment did find that DD across different time frames produced distinct patterns of discounting.²⁹ This study investigated “standard” (i.e., between 1 week and 25 years) discounting using hypothetical rewards of up to \$1000, “compressed” (between 5 and 90 days) discounting using hypothetical rewards of up to \$150, and “contingent” discounting using real delays (between 1 and 60 s) and rewards (between 1 and 15 cents). Interestingly, the researchers did not find a significant correlation between discounting rates in these different time frames, suggesting long and short DD might be separate processes.

With the above exceptions, very few human studies use delays of less than a day, although, of course, we often encounter delays of this magnitude when making choices in the real world. For example, as mentioned above, many companies make money by charging fees in order to avoid waiting in lines. Additionally, the study of short DD can more directly be compared with animal studies of discounting, possibly allowing for greater use of physiological measures to assess the underlying neural basis of discounting.

Despite the implied connections between long delay (all human) discounting and short delay (mostly animal) discounting, there continues to be sparse direct evidence connecting short- and long-term discounting paradigms. Future research should continue to investigate the connections, if they exist, of the degree of discounting observed across these different time frames in an effort to discover whether the same or similar cognitive (and perhaps neural) processes underlie these types of discounting.

Hypothetical Rewards and Delays

A final important issue in DD research is the use of hypothetical rewards and delay periods. In most human studies, participants do not actually experience the delays they choose and do not actually earn real money. Many DD studies using humans do use monetary choices but couch these choices in hypothetical terms; for example, Lane *et al.*²⁹ used a “standard

hypothetical” condition that presented options with hypothetical delays up to 25 years and hypothetical rewards up to \$1000. Indeed, there has been considerable debate as to whether hypothetical rewards have real ecological validity, especially in situations that require short-term discounting.³³ Therefore, it is still an important open question as to how well the discounting findings uncovered with hypothetical choices are predictive of real consequential choices over time. It is also unclear if some of the context effects described previously may be artifacts of hypothetical framing. Formal comparisons of these approaches (hypothetical versus real) would be useful in resolving this debate, although of course it is not a trivial matter to design studies to look at delays over months or years. A useful first step might therefore be to examine short-term discounting in both real and hypothetical contexts.

Delay Discounting and Risk

One oft-proposed explanation for DD is that people’s preference for the immediate reward may also reflect innate risk aversion tendencies in that people are drawn to the certainty of the immediate reward and discount the delayed reward because of the lower probability that this will be delivered. For example, although \$100 in a year appears more tempting than \$20 today, there is no guarantee that the experimenter or the participant will be still around after that delay. This is an explanation that has not been tested very rigorously but is supported somewhat by experiments showing that discounting rates are lower for people who are older.³⁴ Therefore, an examination of the relationship between risk sensitivity and discounting rates would be productive, exploring the extent to which discounting may be underpinned by attitudes towards risk. While the presence of DD in both animals and in humans over very short time scales (seconds to minutes) does suggest that some discounting of the future takes place independent of concerns about uncertainty, this question is worthy of future study.

Possible Future Directions

As suggested here, a productive avenue for future research in this field would be an investigation of whether short- and long-term DD have the same underlying process, or whether they are distinct and separable. Use of different methodologies, and indeed species, in assessing DD has made it difficult to draw conclusions about the make-up of these processes. Knowledge of

these processes might also help us understand real life circumstances that elicit DD. For example, the finding that primary food rewards induce greater discounting than monetary rewards of the same value, findings that have been observed in long-term DD, could possibly predict what we should expect for primary versus monetary rewards in short DD paradigms.²⁵ The addition of short-term paradigms into the study of human DD would allow wider use of nonhypothetical rewards and delays, as these are, of course, much more practical in these settings. This approach might also allow the study of DD across species, which in turn could open up interesting directions for understanding DD neurophysiology. A major problem in the application of animal DD findings to human long DD is that the time frames are radically different.

It seems likely that the processes seen in long and short DD are related in some way, as evidenced by their very similar patterns of discounting. However, despite the promise of greater understanding of DD by studying the similarities of short and long DD and these similar discounting patterns, it is of course possible that long and short DD are completely unique processes. Indeed, Lane *et al.*²⁹ suggest short and long DD are uncorrelated and thus unlikely to reflect a common process. New productive directions in the study of DD, as outlined here, could help answer these important questions and integrate the experimental investigation of DD across fields.

Conflicts of Interest

The authors declare no conflicts of interest.

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