Ordinaries

Intertemporal choice: biology informs economic theories of discounting

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Abstract

Neoclassical and behavioral economics disagree over the manner in which people discount the future. Neoclassical economics assumes that people make good, consistent decisions about savings and other intertemporal choices. In contrast, behavioral economics argues people are impatient and inconsistent in discounting decisions. Evolutionary biology suggests that, in natural settings, people will behave ‘as if’ they are following the neoclassical economic model. In novel settings, however, people will sometimes act as described by behavioral economic views, but at other times people will exhibit behaviors that are precisely the opposite of the predictions of the behavioral economic model.

Ordinary: “With no special or distinctive features; normal. Not interesting or exceptional; commonplace.”
–Oxford English dictionary.

1 Discounting is central to economics

In certain laboratory settings, blue jays (*Cyanocitta cristata*) seem to earn the label of ‘bird brains.’ Researchers in Professor David Stephens’s laboratory at the University of Minnesota presented jays with a choice. The birds could peck a disc and receive a single food pellet, or they could wait a very short time—just a matter of seconds—before pecking and receive two pellets. (This ‘later-larger’ reward varies across experiments and species, but we will use two throughout this article).

Only a bird brain would be so impatient as to choose half as much food now, instead of waiting a few moments for the double portion. But many animal species,

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including pigeons, tamarins, and chimpanzees, make similarly ‘impulsive’ choices in laboratories (Stevens & Stephens, 2010). And even though they can easily understand the cost, in some settings people, too, make choices betraying the same extreme impatience as the laboratory birds (Ainslie, 1975).

“Would you prefer \$10 today or \$11 tomorrow?” is the central question posed in a series of behavioral economic experiments. We once ran this experiment for real cash in an undergraduate class at the University of Michigan.

One student, we’ll call him Norm, chose \$10 on the day of the experiment. Coming to the front of the large auditorium filled with over 150 students, Norm collected his crisp \$10 bill. Before he had returned to his seat, we questioned Norm’s decision. “Norm, why \$10 today? Isn’t \$11 tomorrow better? Aren’t you being a little impulsive? Perhaps you are being irrational?”

Norm responded, “For me, the unit of wealth is ‘the beer’ and it costs \$5 at my favorite bar where I will be drinking right after this class. So, \$10 is equal to two of ‘the beer,’ and because they don’t sell fractional drinks, \$11 is also equal to two of ‘the beer’. As you taught us, two of ‘the beer’ today is better than two of ‘the beer’ tomorrow.” *Q.E.D.*

Norm sat down to thundering applause.

We will check in on Norm again later in this article. Let us return to the general topic of choice across time. ‘Discounting’ is the term for decisions that involve payoffs in multiple time periods. Should the world, for example, invest more now in electric vehicles? The consequences of a faster shift to electrification include a smaller economy today and a better world tomorrow. (Some environmentally positive projects make us both richer today and better off tomorrow. These environmental ‘free lunches’ should all be undertaken.)

Making the best investment decision in the electric vehicle situation requires a method for comparing payoffs in the different time periods. People face myriad discounting decisions. How much should we save from each paycheck? Over how many years should we spread out mortgage payments? Should we borrow money to attend graduate school? The list goes on.

In the Stephens’ lab, the jays always chose one pellet immediately, unless the delay was infinitesimally small. In doing so, the birds missed the possibility of doubling their money (pellets) in a very short period of time.

In economics, the currency of decision-making is happiness, typically labeled ‘utility.’ In the currency of utility, almost any single decision—even seemingly disastrous choices—can be viewed as optimal. Suicide increases happiness if it preempts a future life filled with negative utility. Drug addiction causing early death is optimal as long as the short-term pleasure outweighs the long-term loss of happiness (Burnham and Phelan, 2019).

An economist cannot say definitively that one pellet now is worse than two pellets in a minute. Choosing one pellet now may produce tremendous utility.

The driving force shaping bird decision-making, however, is not the maximization of utility. Rather, it is natural selection, a force leading to decision-making processes that maximize reproductive success.

The measure of the value of any behavior is its impact on an individual’s reproductive success relative to other individuals. Put another way, the currency of natural

selection is “relative reproductive success.” This currency is also called “inclusive fitness,” and it can be quantified.

With the unambiguously defined currency of inclusive fitness, we can make absolute statements about behaviors. We can compare alternatives, as well. Suicide does not increase inclusive fitness unless it produces benefits (measured as increased reproductive success) in genetic relatives. Similarly, choosing one bird pellet now instead of two pellets in a minute, is a biological mistake.

Why do birds and humans make discounting mistakes? This article explores discounting within the mission of this series (Burnham and Phelan, 2019):

The Ordinaries column will interpret economic behavior from the perspective of evolutionary biology. From this view of life, the anomalies of behavioral economics will disappear into a coherent biological framework that incorporates elements of neoclassical maximization.

2 Economic views of discounting without natural science insights

Neoclassical economics most often assumes exponential discounting—the simplest framework within which to make ‘rational’ discounting decisions. With exponential discounting, each time period holds the same value, relative to others. Consumption a year from now is, for example, worth 90% of consumption today. Consumption 2 years from now is worth 90% of consumption a year from now, and so on. The relative value of consumption in any two periods is constant.

Neoclassical discounters place more weight on the present than the future, and the relative value of different time periods remains consistent. For example, with a 90% discounting parameter, consumption in year 3030 is worth 90% of consumption in the prior year (3029), regardless of when the two periods are compared. The concept and the computations are straightforward. Observations, however, do not conform to expectations. We encounter anomalies.

In the behavioral economics literature, “An empirical result is anomalous if it is difficult to ‘rationalize,’ or if implausible assumptions are necessary to explain it within the [neoclassical] paradigm.” (Thaler, 1987, p. 198).

Do humans exhibit exponential discounting? No. Hundreds of studies of human behavior, in laboratory settings and in the “field” answer this question (see Frederick, Loewenstein, and O’Donoghue, 2002 for a review). Behavioral economic studies of discounting build upon earlier work outside of economics (Catania, 1963; Rachlin and Green, 1972). Two discounting anomalies are most salient in the behavioral economic literature.

2.1 Discounting Anomaly #1. People are inconsistent in their intertemporal decisions

“Grant me chastity and continence, but not yet.”—is St. Augustine’s famous prayer. And the first finding of the behavioral economics literature on discounting reprises

St. Augustine's sentiment. People want to undertake hard, unpleasant, righteous behaviors. They desire this in the future, however. Not today.

If you give people a choice between a 20-min work break in 101 days or a 15-min break in 100 days, they overwhelmingly choose to wait an extra day to get a longer break. But re-ask the same question 100 days later, in the form of "Do you want a 20-min break tomorrow or a 15-min break today?" Many people switch their decision and take the shorter break today (Angeletos et al., 2001).

A related study investigated people's willingness to watch serious movies. Subjects were asked to choose three movies to watch on each of the next three consecutive nights. When choosing for tonight, subjects preferred lighthearted romances, comedies, and action films. When choosing for future evenings—tomorrow or the next night—people selected more serious films, such as *Schindler's List*, which portrays Nazi concentration camps, as well as films in foreign languages.

In this study, the people were actually given the movies to watch. When the people returned on the second and third days of the study to watch, for example, some highly-regarded, deep 1950s film in Italian, they switched to a lighthearted movie if given the chance (Read and Loewenstein, 1999).

In summary, anomaly # 1 in the behavioral economics of discounting is that people are inconsistent. When making decision about future times, people make 'good' decisions and are willing to defer gratification. However, when one of the time periods is now, people want the good outcome today, and are less willing to wait for a better outcome.

2.2 Discounting Anomaly #2. People place an inordinately high premium on "today," in contrast to any future time period

As presaged above, when given a choice between \$10 today or \$11 tomorrow, many people choose the smaller amount immediately (Loewenstein and Thaler, 1989; Loewenstein and Prelec, 1992; Ainslie, 1992). These same people, however, choose \$11 in 101 days rather than \$10 in 100 days.

Hyperbolic discounting is a framework that incorporates these two behavioral features (or anomalies). A hyperbolic discounter is a rational, neoclassical exponential discounter for all decisions that do not include today. Thus, a hyperbolic discounter is usually willing to wait one day to receive \$11 over \$10 a day earlier. That is, as long as both days are far in the future.

"Today," however, holds a special place in hyperbolic discounting models. The relative value of consumption today is much higher in comparison with future time periods. For many people, the impatience that demands \$10 today instead of \$11 tomorrow seems like a mistake. The one day of waiting in this case is valued differently than the one day of waiting that is far in the future.

From the perspective of neoclassical economics, inconsistencies are cause for concern. Either the smaller-sooner or the larger-later choice can be rational. What is not rational, however, is to switch the decision when 'sooner' becomes now. And that is exactly what is built into hyperbolic discounting. A day is a day is a

Table 1 Economics and discounting, circa 2021*Phenomenon*

People make inconsistent discounting decisions, frequently displaying behavior that appears to overemphasize today, but at other times appears too patient.

Neoclassical economics	<i>Exponential discounting</i> Discounting decisions are made optimally. Different time periods are valued consistently, with lower value placed on happiness that occurs farther in the future.
Behavioral economics	<i>Hyperbolic discounting</i> People make two related types of mistakes. First, they put too much weight on the current time period. Second, people are inconsistent in their attitudes toward different time periods.

day. Unless that day is today. Then it is different, and cause for people to alter their decisions.

We plan to watch an educational movie in the future, to wait a day for a longer break at work, and to defer consumption in order to earn a high interest rate. When the future becomes today, however, we want it now.

In summary, neoclassical economics assumes that people make good discounting decisions, coolly and consistently trading off outcomes between different periods. In contrast, behavioral economics posits that people are inconsistent in intertemporal decisions and are too impatient (Table 1).

Contemplating related concepts, Plato went further, declaring that people ought to struggle against their impulsive selves. “Nothing is gained by impatience,” he wrote. “The higher principle is ready to follow this suggestion of reason? Clearly. And the other principle, which inclines us to recollection of our troubles and to lamentation, and can never have enough of them, we may call irrational, useless, and cowardly?” (Plato, *The Republic*, Book X)

Plato considered this internal human conflict as reason & patience vs. irrationality & cowardice. Plato thus provides an eloquent summary of neoclassical vs behavioral economic views of discounting.

3 Biological views on discounting

Let’s return to the bird-brained, impatient blue jays that choose 1 pellet now rather than waiting a minute to get 2 pellets. From the behavioral economics perspective, this is precisely the sort of impulsive behavior that gets people into trouble. If we could only learn to be more patient and more disciplined in our decisions, we could all get better outcomes.

The problematic behavior is choosing smaller-sooner over larger-later. It stands in contrast with “discipline,” which would manifest as choosing smaller-later over larger-sooner. We characterize extreme patience as a willingness to wait to receive less (see Table 2).

Table 2 Extreme patience chooses smaller-later

	Now	Future
Impatience	100	200
Extreme patience	100	33

Does extreme patience of this sort exist? In fact, we find it among our very same blue jays (*Cyanocitta cristata*). In the wild, blue jays cache food (mostly acorns, nuts, and seeds) by burying it in the ground (Darley-Hill and Johnson, 1981; Johnson et al., 1997).

The birds return to their specific food caches during winter and retrieve the food. Because some of the food is eaten by other animals and some food decays, the retrieval rate is always less than 100%. In many species of caching birds it is 40–70%, and it can be as low as 33% (see for example, Bossema, 1979; Vander Wall, 1982; Callo, 1996; Brodin, 2010).

Should we consider these blue jays the most impatient of animals, because they choose 1 pellet now over 2 pellets in a minute in the laboratory? Or should we consider them to be the most patient of animals, because in the wild they choose as few as 33 seeds in six months rather than 100 seeds today?

The answer is that natural selection favors behaviors that maximize inclusive fitness. Animals in equilibrium with their natural environment are neither too impatient nor too patient (see Hayden, 2016 for a critique of the ‘animals are impulsive’ argument). Natural selection produces animals that can place enormous significance on the present, which may look like impatience, or enormous weight on the future, which may look like discipline.

In each case—apparent impatience and extreme patience—the animals are exhibiting the behavior that maximizes dopamine release in their brains. The neurological systems have evolved to reward fitness-maximizing behavior. No will power is required.

Looking inside the blue jay’s brain, when the first food items are found, the bird receives more pleasure from eating than burying. As the bird’s stomach fills, the bird’s brain does a sophisticated, but nonconscious, calculation of the trade-off between food today and food in the future. When the unseen calculation’s result shifts to favor caching, the bird receives more dopamine for burying food than from eating. These neuronal and hormonal pathways have been studied extensively in rodents (Bartness, et al., 2011).

Are caching birds the only examples of this sort of deferral of consumption? Absolutely not. Just focusing on external food storage, for example, hundreds of species—including birds, squirrels, monkeys, and large carnivores—have well documented deferred-food-consumption behaviors (Vander Wall, 1990). There are two types of strategies: (1) store the food in one central location and defend the food, or (2) scatter the food in various places and remember the locations, but do not defend the stored food.

The neurological systems that modulate food storage are sophisticated and have been studied extensively. Food-storing birds return to the specific locations of their own caches. Memories of the locations are stored in the hippocampus.

Populations of black-capped chickadees (*Poecile atricapillus*) in environments with less food had ‘significantly larger hippocampal volumes,’ for example (Pravosudov and Clayton, 2002). Similarly, experimental interference with hippocampal function in the same species reduces the accuracy of returning to caches, but does not reduce the amount of stored food (Sherry and Vaccarino, 1989).

Squirrels, too, cache food and demonstrate sophisticated strategies shaped by natural selection. All caching animals face efforts by other animals to rob their food stores. Consequently, some animals have evolved behaviors to mitigate theft. Among eastern grey squirrels (*Sciurus carolinensis*), one tactic is to cover up false sites at which no food has been stored. Consistent with this view, these squirrels engage in more deceptive false activity in the presence of conspecifics (Leaver et al., 2003; Steele et al., 2008). Furthermore, squirrels of this same species (*Sciurus carolinensis*) preferentially avoid storing food in areas where experimenters have played recordings of blue jays (*Cyanocitta cristata*).

Animals in the wild are not impatient. Quite to the contrary, natural selection has produced mechanisms where a wide-variety of animals defer consumption today in return for even a much smaller amount in the future. These systems show evidence of sophisticated trade-offs in the discounting behavior. The associated brain regions and neurological mechanisms for these behaviors are well-understood.

Food caching is one area where animals display appropriate discounting behavior. But apparent patience among animals in the wild extends far beyond food consumption. What would you do if you came across a Bambi-like baby deer, just a few hours old and all alone? You might be tempted to try to rescue the fawn by intervening. But your well-intentioned intervention would not help the fawn.

In a variety of animal species, parents use the anti-predator strategy of leaving their babies unattended for long periods each day (Leuthold, 1973; Fitzgibbon, 1993). In fact, this apparent-abandoning of offspring for hours at a time is their primary anti-predator defense. This is because the adult animals cannot effectively ward off a predator.

Consequently, whether a parent is present or not, detection of the offspring by a predator equals death for the young up until they are old enough to evade predators on their own. This “potting” behavior leaves the infants sitting still like plants in one spot, relying upon lack of movement and camouflage to avoid detection.

What is the relationship between potting baby gazelles and discounting? The baby animals sit motionless for long time periods—sometimes exceeding 12 h. Conversely, when the infants are with their parents they run around and exhibit play-like behavior.

For a human, adult or child, to sit still for 12 h would require incredible self-control. For the baby gazelle, however, no will-power is required. Through the process of natural selection, populations have evolved in which infant animals can sit still for as long as is optimal—in this case up until the moment when the mother returns.

Evolution by natural selection can produce animals with cryptic coloration that protects them from predators. Similarly, it can produce populations in sync with their environment that make sophisticated trade-offs between different time periods. Natural selection can and has favored appropriate levels of discounting.

4 Biological economic views of discounting

People often make bad discounting decisions, exhibiting inconsistent and costly behaviors. Can biology help economics better understand human discounting, and also help people improve their own decision-making?

Yes. Let's first review the biological framework for all types of decisions before exploring the insights into economic discounting that it generates.

Economics is a house divided upon itself. Neoclassical economics assumes that people effortlessly and unconsciously maximize happiness. Behavioral economics documents anomalies where human behavior deviates systematically from that predicted by neoclassical economic theory.

Because neoclassical economics predicts maximization of invisible internal states, behavioral economics focuses on inconsistencies. Thus, the anomalies of behavioral economics often are restricted to inconsequential areas such as 'lack of transitivity' and 'failure of independence of irrelevant alternatives' (Burnham and Phelan, 2019). In contrast, suicide, heroin addiction, obesity, and avoidable mortality and morbidity attributable to poor diet and lack of physical activity, are all consistent with neoclassical models of maximization, and are not the focus of behavioral economics.

Advances in biology include discoveries with implications for both neoclassical and behavioral economics. Perhaps most importantly, both neoclassical and behavioral economics are equally wrong about happiness. In biological terminology, the proximate mechanisms that produce emotions result in the ultimate goal of maximizing inclusive fitness (Tinbergen, 1963). Pleasure and pain are genetic creations; brain states selected by evolution because they guide organisms to behaviors that favor certain gene variants.

Economics has causality backwards, assuming that happiness is the goal. Rather, happiness is an incentive scheme to achieve genetic replication (see our summary in Burnham and Phelan, 2020b).

Natural selection favors maximization, and that maximization need not be conscious. Examples abound, across all aspects of organisms' physiology and behavior. Consider, for example:

- * Horses switch gaits—from trotting to galloping—at the speed that reduces the peak forces on muscles, tendons, and bones (Farley and Taylor, 1991). This switch serves to reduce their risk of injury.
- * Across a wide range of taxa, researchers have demonstrated that birds produce a clutch size (number of eggs laid in a reproductive episode) that leads to the greatest gain in parental fitness (Lack, 1947; 1954). Using experimental manipulations, for example—such as removing eggs from a nest—researchers have demonstrated that even when they are physiologically capable of producing additional eggs, birds refrain and instead produce the number of eggs that leads to the maximum number of surviving offspring (Godfray et al. 1991).

Thus, biology supports neoclassical economic views of efficient, ruthless, and seemingly automatic optimization. Furthermore, biology suggests that neoclassical

economics should go further, predicting maximization of genetic replication. There's no reason to stop at abstract, invisible mental states and fuzzy notions of "utility."

Does biology, therefore, fully support the assumptions, predictions, and explanations of neoclassical economics? Absolutely not.

Animals in novel environments do not maximize anything. Not lifespan, not happiness, and not genetic replication (see the Ordinaries article on mismatch, Burnham and Phelan, 2020a). Behavior is produced by proximate, physiological mechanisms. In equilibrium, natural selection favors those behaviors that maximize genetic replication. When animals are mismatched with their environment, however, there is no stable or consistent relationship between behavior and outcomes.

Consider, for example, the question of whether or not rhesus monkeys seek to maximize genetic replication. Yes, in a manner, they do. Monkeys have neural reward systems that produce dopamine in certain circumstances. Monkeys have no conscious desire to produce offspring directly, nor any conscious desire (we presume) to help monkey genetic relatives such as nieces and nephews. However, in their natural settings, monkeys behave 'as if' they were seeking to maximize genetic replication, displaying a wide range of sophisticated behaviors (Bercovitch, 1997; Liao et al., 2018).

In laboratories, however—evolutionarily novel settings—monkeys very much do not maximize genetic success. In fact, given a choice between food or cocaine or amphetamines, 100% of rhesus monkeys self-administered drugs until they died. The cocaine using monkeys died in less than 1 week (Johanson, Balster, and Bonese, 1976).

The same monkey brain circuitry that—in the wild—elegantly solves complex problems of predator avoidance and arboreal navigation leads to starvation amidst plenty of food. How can it be that monkeys can fly between trees while holding their infants, but fail to eat a banana that is within easy reach next to them in a cage?

The resolution to the monkey genius and monkey addict paradox is that evolution has produced a repertoire of contingent behaviors, but only within the range of naturally-occurring environments. The appropriate behaviors are elicited as a result of a combination of neural mechanism and the environment. Change the environment and the behavior changes. But change the environment too much, and the animals no longer have any appropriate, adaptive response.

For humans, a modern city is as novel an environment as the experimenter's monkey cage with an IV drip of narcotics. Thus, humans suffer mismatch between our genes and the modern environment (Burnham and Phelan, 2000). Our environment is alien in many ways, for example, the amount and predictability of food, the number of individuals with which we regularly interact; the availability of medicines (i.e., insulin) and myriad technological innovations (i.e., eyeglasses).

Behavioral anomalies are the result of the mismatch between human genes and our evolutionarily novel, modern environment (Burnham, 2016; Burnham and Phelan, 2019). People make bad choices—including a large range of economic decisions—because our genes were selected in, and optimized for, a different environment.

What is the specific message for discounting and economics? For neoclassical economics, the message is that people will make inconsistent discounting choices.

There is no reason at all to expect that people will automatically make the ideal, exponential discounting decision in an evolutionarily novel environment. The neo-classical model of discounting simply is not an accurate description of human behavior.

The observations of behavioral economics, on the other hand, are correct. Humans fail to automatically and naturally discount the future. How can biology help behavioral economics? The framework of biology—specifically of evolution by natural selection shaping human behaviors—offers accurate explanations (and testable predictions) for the observations of behavioral economics (Table 3).

First, people are not hyperbolic discounters, just as they are not exponential discounters. In some situations, it may be productive to model behavior as either exponential or hyperbolic, but discounting is neither an accurate description of internal mental states, nor of human behavior.

Second, behavioral economics would do well to focus on situations where people are too patient. Currently, the behavioral economics anomalies literature focuses on situations where animals appear to be impulsive. However, the biological view predicts animals will make both sorts of mistakes—appearing too impatient in some situations and appearing too patient in others. Researching too much patience is a relatively unexplored space and one that biology suggests will be fruitful.

We have two thoughts about decisions for which people are too patient. The first, and most obvious, is the storage of extra calories on our bodies. Whereas some birds and squirrels store extra food in the environment, humans store extra food within our bodies. Most of us could live for months without eating (albeit with unpleasantness and some negative side effects).

Table 3 Economics and discounting with the natural sciences

Phenomenon

People make inconsistent discounting decisions, frequently displaying behavior that appears to put too much emphasis on today, but at other times appears too patient.

Neoclassical economics	<p><i>Exponential discounting</i></p> <p>Discounting decisions are made optimally. Different time periods are valued consistently, with lower value placed on happiness that occurs farther in the future.</p>
Behavioral economics	<p><i>Hyperbolic discounting</i></p> <p>People make two related types of mistakes. First, they put too much weight on the current time period. Second, people are inconsistent in their attitudes toward different time periods.</p>
Biological economics	<p>People are neither exponential nor hyperbolic discounters. Mismatch between ancestral genes and modern environments produces intertemporal choices that are internally inconsistent, and behaviors that can be too patient or not patient enough.</p> <p>Behavioral economics focuses on cases where people (often in the US or Western Europe) are not patient enough with financial decisions. Biology suggests that people may be too patient as well as not patient enough. Fruitful areas for future research into excessive patience may lie in other cultures, in food storage, and in social situations.</p>

Why are humans such naturally-good savers? The answer is that humans evolved in a world in which food was both uncertain and sometimes superabundant (Burnham and Phelan, 2000; Bellisari, 2008). Uncertainty came in the form of scarcity induced by environmental or social pressures. Superabundance occurred in the form of killing large game animals or in large amounts of naturally-produced plant food.

Humans invented ceramics between 20,000 and 12,000 years before present (Craig et al., 2013). Before ceramics, external food storage was difficult and inefficient. Even with ceramic pots, external storage of human food is subject to pilfering and rot. For humans, the solution to variability, including periods of saturation, is the ability to store vast amounts of energy within our bodies.

When it comes to financial savings, too many Americans have saved too little (people in some other cultures save much more). When it comes to saving calories most people in rich countries save too much. Both undersaving financially and oversaving physically are consequences of mismatch (Burnham and Phelan, 2000). Modern financial instruments are too new and too alien for humans to have evolved a genetic capacity to automatically use them efficiently.

We are not built to make good financial decisions, nor should we be expected to make them. Conversely, many people have far too many calories reliably available every day. Lugging around 6 months' worth of future caloric consumption is not needed for most people, and has negative health consequences.

The second area where humans might be too cautious is in taking social chances. In *Mean Genes*, we tell the story of 'Overeager John,' who asked Sandra out on 20 consecutive dates—all within an hour of their first meeting (Burnham and Phelan, 2000). This impulsive decision turned out to be great as John & Sandra got married, stayed married for decades, and she—Sandra Day O'Connor—became the first woman on the US Supreme Court.

Our speculation is that far too many people are not impatient enough when it comes to social choices. The reason being an unconscious fear of social punishment created, in part, by ancestral punishments for social mistakes. Being too impulsive socially may have produced fitness-reducing reputational consequences in the ancestral world. In that ancestral world, there was little anonymity and people tended to stay in their relatively small groups for most of their lives.

Social caution is merited in a hunter-gatherer community where mistakes have lifelong reputational impact. The consequences of social failure, however, may be far less dire in large, more anonymous cities. Thus, the mismatch between human reputation management genes and anonymous urban environments results in too much concern for the future (Burnham and Phelan, 2000).

In summary, animals—including humans—are neither exponential nor hyperbolic discounters. Neoclassical and behavioral economics are both wrong about discounting.

Let's return to Dave Stephens' blue jays and Norm from the University of Michigan. Blue jays in the Stephens' laboratory chose smaller-sooner over larger-later rewards. Similarly, Norm the human chose \$10, rather than waiting a day for \$11. Both of these behaviors are labelled 'impulsive' by behavioral economists, who try to fit the decisions into a hyperbolic discounting framework.

Do the jays even eat the 1 pellet that they so impatiently selected? Not usually! Frequently, the birds just cache the pellet. “The jays would cache food pellets in crevices they found in their cages. In one notorious case, a bird filled the projector behind one of its pecking keys with hundreds of uneaten pellets” (Stephens, pers. comm., 2021).

Let’s consider the economic and biological explanations for this behavior. Neoclassical economics argues that decisions are made optimally using a consistent framework. The jays decision to choose one pellet today instead of two pellets tomorrow is inconsistent with neoclassical economics.

Behavior economics highlights the “1 pellet now” choice as an anomaly. “You see,” the behavioral economist argues, “animals are hyperbolic discounters. The neoclassical model is wrong because it does not recognize how much animals value consumption today.” The hyperbolic discounting model fits the take one pellet now, but it does not predict the caching behavior.

Why would a hyperbolic discounter store hundreds of food items instead of eating them? The answer is that behavioral economics is wrong in viewing animals as hyperbolic discounters.

So if both neoclassical and behavioral economic models of discounting are wrong, what is correct? The answer is biology. Animals have mechanisms that were selected because they induced maximizing behavior. These mechanisms, however, do not maximize anything in novel environments.

Birds in the wild are built to take food that is in front of them before it is taken by another organism. The bird decision mechanism does not line up with the skinner box setup in a way that favors waiting for the larger-later reward. However, once the bird has food, it has a neural mechanism to store excess. Biologists understand the apparent impatience and patience in the same animal in the same few moments of time. Choosing the smaller-sooner amount of food and then caching it makes perfect sense.

What about humans? Surely, we are not so silly as to have analogous behaviors as these laboratory jays. Recall Norm, who consumed two beers today instead of waiting until tomorrow to have two beers and an extra \$1. Viewed from the biological perspective, Norm’s behavior is almost identical to that of the laboratory jays. Recall that humans store extra calories on our bodies, not by caching them externally. We are built to eat to excess, store the surplus in our bodily fat, and prepare for lean times.

Norm ‘impulsively’ chose the \$10 today, rushed out to the local bar, obtained hundreds of excess calories, then immediately “cached” those extra calories in his beer belly. Was Norm impatient or too patient? The answer is both, almost simultaneously. The impulsive monetary decision is coupled with the inappropriately-cautious physiological savings for a hungry day.

In summary, the discounting anomalies of behavioral economics derive from genetic mismatch. Because we live in a novel environment, we will not make great savings decisions without training and experience. Humans in novel environments are not exponential discounters as assumed by neoclassical economics. Equally wrong is the behavioral economic view that humans are hyperbolic discounters.

If we, as individuals, or as policy makers want to alter human discounting decisions, we must construct environments that alter behavior. These techniques are described in *Mean Genes* (2000) and in our prior “Ordinaries” column (Burnham and Phelan, 2020c). The biological- and genetically-based approaches that we favor overlap with behavioral economic strategies (e.g., Thaler and Sunstein, 2009). The biological perspective has the additional feature of illuminating the evolutionary cause of self-destructive behaviors.

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