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How Many Impulsivities? A Discounting Perspective

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Abstract

People discount the value of delayed and uncertain outcomes, and how steeply individuals discount is thought to reflect how impulsive they are. From this perspective, steep discounting of delayed outcomes (which fails to maximize long-term welfare) and shallow discounting of probabilistic outcomes (which fails to adequately take risk into account) reflect the same trait of impulsivity. Despite the fact that a hyperboloid function describes the discounting of both delayed and probabilistic outcomes, there is considerable evidence that the two kinds of discounting involve different processes as well as separate impulsivity traits. Several manipulations differentially affect delay and probability discounting, and correlational studies show that how steeply one discounts delayed rewards is relatively independent of how steeply one discounts probabilistic rewards. Moreover, people's discounting of delayed money and health outcomes are uncorrelated as are discounting of real, consumable rewards and hypothetical money. These results suggest that even within delay discounting, there may be multiple 'impulsivities,' each of which may be important for understanding a different aspect of decision making. Taken together, the pattern of findings reviewed here argues for a more nuanced view of impulsivity than that which is usually assumed in discounting research.

Keywords

discounting; impulsivity; traits; delay; probability

When offered the choice, people usually would prefer to have more (rather than less) of what they like, they would rather have it sooner (rather than later), they would like to pay less (rather than more), and they would prefer to expend less effort getting it. However, the choices we face daily are not usually one-dimensional. We do not choose just between more and less, or sooner versus later. Rather, outcomes are typically multidimensional, and tradeoffs are necessary. For example, one can work harder to get more, or choose to exert less effort but get less. There are not necessarily correct choices in such situations, but there are consequences, and these consequences can be personal, interpersonal, or even societal in nature. In large part because of these consequences, research on how people make such tradeoffs, what it says about them as individuals, and in some cases at least, what can be done about it, has become an important focus of much recent behavioral research. Researchers in a number of fields (including economics, genetics, neuroscience, pharmacology, and psychology) increasingly view people's choices between multidimensional alternatives from a discounting perspective (e.g., Anokhin, Golosheykin, Grant, & Heath, 2011; Frederick, Loewenstein, & O'Donoghue, 2002; Kable & Glimcher, 2007; MacKillop, Amlung, Few, Ray, Sweet, & Munafò, 2011; Madden & Bickel, 2010), in which variation along one dimension (e.g., delay) is associated with the discounting of another dimension (e.g., amount).

We begin with the hyperboloid function that describes the discounting of delayed and probabilistic outcomes and present a mathematical derivation of that function as it applies to delay discounting. Next, we discuss the similarities and differences between delay and probability discounting and argue that there is converging evidence that these two kinds of discounting involve different processes as well as separate ‘impulsivities’. We argue further that although there may be groups of individuals who are both impatient and risk-taking, there also are groups who are impatient and risk-averse, and that in any case, the existence of such groups, although important from a number of perspectives, is not necessarily relevant to understanding the nature of impulsivity in the general population.

We present evidence that even within delay discounting, and perhaps within probability discounting as well, there are important distinctions to be drawn between the way different types of rewards are discounted, suggesting the existence of even more ‘impulsivities’. For example, different types of rewards (e.g., money, food) may be discounted at different rates, even if the rewards are matched on utility. In addition, the degree to which an individual discounts a particular type of reward, relative to how steeply others discount that type of reward, sometimes predicts how steeply that individual will discount another type of reward; in other cases, however, there is little or no correlation between how steeply individuals discount rewards of different types. Taken together, such findings argue for a more nuanced view of impulsivity than one that views impulsivity simply in terms of how steeply an individual discounts. Finally, we consider the implications of this view for future research.

Derivation and Interpretation of Hyperboloid Discounting Functions

To date, discounting research has focused primarily on the tradeoff between delay and amount of reward and the tradeoff between probability and amount. In such tradeoffs, discounting refers to the tendency for a delayed or a probabilistic reward to be valued less than a comparable amount of reward that could be received sooner or with greater certainty. The value of a delayed or uncertain reward is described as being discounted relative to its nominal amount, and the extent to which such rewards are discounted increases systematically as a function of how delayed or how unlikely they are. This systematic decrease in subjective value is well described by the hyperboloid function,

$$V = A / (1 + bX)^s, \quad (1)$$

where V represents the subjective value of a delayed or probabilistic reward of amount A , X is the delay until or odds against its receipt, and b and s are free parameters (Green & Myerson, 2004). Fits of Equation 1 to delay and probability discounting data (taken from a study by Estle, Green, Myerson, & Holt, 2006) are presented in the top and bottom panels of Figure 1, respectively. In order to show discounting of different reward amounts on the same scale, the subjective value of each delayed or probabilistic reward is plotted as a proportion of its nominal amount. Note that amount has opposite effects on how steeply delayed and probabilistic rewards are discounted: Larger delayed amounts are discounted less steeply than smaller delayed amounts (e.g., \$40,000 vs. \$200 in Fig. 1), whereas smaller probabilistic amounts are discounted less steeply than larger probabilistic amounts.

The typical procedure in studies of delay discounting where the choice is between an immediate reward and a larger, later reward, is to adjust the amount of the immediate reward until it and the delayed reward are equally likely to be chosen. The amount of immediate reward at this indifference point is taken as the subjective value of the delayed reward. So, too, when the choice is between a certain reward and a larger, probabilistic reward, the amount of the certain reward is adjusted until both alternatives are equally likely to be

chosen, and the amount of certain reward at indifference is taken as the subjective value of the probabilistic reward.

This hyperboloid discounting function was first used to describe the discounting of delayed rewards, and its derivation by Myerson and Green (1995) was based on the assumption that people (and other animals) choose between rates of reward and that no reward, even an 'immediate' one, is instantaneous. That is, if one alternative provides a smaller amount of reward, A_S , sooner (i.e., after some minimal delay of m time units) and the other alternative provides a larger amount of reward, A_L , later (i.e., after a delay of $m+D$ time units), then at indifference, $A_S / m = A_L / (m+D)$. Rearranging reveals that the value of the delayed reward relative to its nominal amount, A_S / A_L , is equal to $m / (m+D)$, and dividing both the numerator and the denominator of the right side of the equation by m , one obtains the familiar hyperbolic discounting function: $A_S / A_L = 1 / (1+D/m)$, where $1/m$ corresponds to the parameter b in Equation 1. Note that as m increases, the rate of discounting (as indexed by the b parameter) decreases.

It is generally assumed that quantities like amount and delay are nonlinearly scaled and that such scaling is described by a power function (Stevens, 1957). It follows from this assumption that $A_S^a / A_L^a = m^d / (m+D)^d = 1 / (1+D/m)^{d/a}$, which may be rewritten as $A_S / A_L = 1 / (1+D/m)^s$, where s is the ratio of the exponents of the power functions describing the scaling of delay and amount. Note that the preceding equation is equivalent to Equation 1, the hyperboloid discounting function, rewritten in terms of relative subjective value (i.e., the subjective value of a delayed reward expressed as a proportion of its nominal amount). When $s = 1.0$, the equation reduces to a simple hyperbola (Mazur, 1987).

Support for the interpretation of the delay discounting function implicit in the preceding derivation comes from two findings. First, when the duration of m is experimentally manipulated by adding a common delay before receipt of both the smaller or larger reward, the rate of discounting decreases (Calvert, Green, & Myerson, 2011; Green, Myerson, & Macaux, 2005). Second, the s parameter remains constant when the amount of the delayed reward is varied across a wide range (Estle et al., 2006; McKerchar, Green, & Myerson, 2010), consistent with the psychophysical scaling interpretation.

Although an analogous interpretation of the probability discounting function is possible, consideration of the effect of reward amount on the s parameter of the function argues against such an interpretation. That is, as the amount of the probabilistic reward is increased, the s parameter increases systematically, rather than remaining constant as in the case of delay discounting (Estle et al, 2006; Myerson, Green, & Morris, 2011) and as the psychophysical scaling interpretation would predict. This finding may be interpreted in terms of probability weighting, a concept introduced by Kahneman and Tversky (1979) in their prospect theory account of decision making under risk, although they did not view such decision making as being amount-sensitive in this way.

Notably, increasing the amount of probabilistic reward appears to increase the degree of discounting by increasing the s parameter, while the b parameter remains constant, whereas increasing the amount of delayed reward appears to decrease the degree of discounting by decreasing the b parameter, while the s parameter remains constant. These differential effects of reward amount on delay and probability discounting functions, along with other evidence to be described below, demonstrate that different processes must be involved in delay and probability discounting (Green & Myerson, 2010).

Delay and Probability Discounting as Separate Impulsivities

The fact that delay and probability discounting involve different processes has important implications for our understanding of the relation between discounting and impulsivity. Steep delay discounting, in particular, has often been associated with impulsive decision making, as reflected in an inability to delay gratification. Consistent with this view, abusers of a wide variety of psychoactive substances, ranging from cigarette smokers to heroin addicts, have been shown repeatedly to discount delayed rewards more steeply than controls (Yi, Mitchell, & Bickel, 2010). In addition to showing steep delay discounting, one might expect individuals who engage in impulsive decision making to show greater than average risk taking, which would be reflected as insensitivity to the odds against winning a gamble. This insensitivity, in turn, would be manifested as shallow probability discounting.

The idea that impulsive individuals are both risk takers and unable to delay gratification would predict a negative correlation between probability and delay discounting. That is, shallow discounting of probabilistic rewards is a form of risk taking, whereas steep delay discounting may reflect an inability or unwillingness to wait for gratification. Nevertheless, the evidence is inconsistent with the idea of a single trait of impulsivity, one that involves both risk taking and impatience, where a trait is defined as an enduring behavioral tendency that manifests itself in multiple, diverse situations. In the present case, those situations would include those in which one has to choose between smaller rewards available sooner and larger rewards available later, as well as those in which one has to choose between smaller rewards available with a higher likelihood and larger rewards available with a lower likelihood. In contrast to the negative correlation predicted by a unitary trait of impulsivity, numerous studies have reported that the actual correlation is either not significant or even weakly positive (e.g., Myerson, Green, Hanson, Holt, & Estle, 2003; Ohmura, Takahashi, Kitamura, & Wehr, 2006; Olson, Hooper, Collins, & Luciana, 2007; Richards, Zhang, Mitchell, & de Wit, 1999; Shead & Hodgins, 2009).

Another way to examine the relation between impulsivity and probability discounting would be to take individuals who are known to be impulsive on other grounds and see if their probability discounting differs from controls. For example, studies that examine probability discounting in cigarette smokers, a particular group of substance abusers known to show steeper than normal delay discounting, fall into this category. Some studies have found steeper probability discounting by smokers (Reynolds, Richards, Horn, & Karraker, 2004; Yi, Chase, & Bickel, 2007), the exact opposite of what one would predict based on the view that because impulsive individuals are greater risk takers, they should be less sensitive to the odds against winning and discount probabilistic rewards less steeply. Although other studies have found no difference between smokers and controls (Mitchell, 1999; Ohmura & Takahashi, 2005), this result, too, is inconsistent with the prediction of a unitary impulsivity trait involving impatience and risk taking.

The failure to find shallower probability discounting in presumably impulsive cigarette smokers would appear to pose a serious problem for a definition of impulsivity that incorporates both an inability to delay gratification and a tendency toward risk taking. If probability discounting were not a valid measure of risk taking, of course, then this failure would not be a problem. However, probability discounting appears to be a valid measure, as evidenced by the finding that gamblers do show shallower probability discounting than controls (Holt, Green, & Myerson, 2003; Madden, Petry, & Johnson, 2009). Moreover, some studies have reported that gamblers discount delayed rewards more steeply than controls (Dixon, Marley, & Jacobs, 2003; Petry, 2001; but see Holt et al., 2003), and this result is somewhat more supportive of the idea that an inability to delay gratification goes with greater risk taking. In contrast, data from obese women with binge-eating disorder

(BED), who steeply discount both delayed and probabilistic rewards (Manwaring, Green, Myerson, Strube, & Wilfley, 2011), are inconsistent with this idea.

Thus, no simple pattern emerges from the data from special groups with respect to the relation between delay and probability discounting. We would argue, however, that studies involving special groups (e.g., women with BED, smokers, gamblers) actually address a different question than that addressed by correlational analyses of data from the general population. This may be seen in the scatterplot shown in Figure 2, which depicts hypothetical data from the general population showing a weak positive correlation between delay and probability discounting like that which has been reported (e.g., Myerson et al., 2003). As is apparent from the scatterplot, despite the weak correlation there would still be individuals who showed extreme tendencies, and those individuals who showed similar extreme tendencies with respect to discounting might well show similar behavioral problems.

For example, the solid circles in the lower right quadrant of Figure 2 represent hypothetical individuals who, like the pathological gamblers with substance abuse problems studied by Petry (2001), show steep discounting of delayed rewards but shallow discounting of probabilistic rewards. In contrast, the solid squares in the upper right quadrant represent hypothetical individuals who, like the obese women with BED studied by Manwaring et al. (2011), show steep discounting of both probabilistic and delayed rewards. Data from these two groups speak not to the relation between delay and probability discounting but rather to their consequences. Those who discount both delayed and probabilistic rewards steeply are likely to have one set of problems, whereas those who discount one steeply but the other very shallowly may have different problems, yet all may come from the same overall distribution.

Importantly, the same conclusions would follow if the distribution depicted in Figure 2 showed a negative correlation or no correlation at all. Although the existence of extreme groups does not inform us about the nature of the relation in the general population, the relation between delay and probability discounting in the overall distribution does not preclude the existence of such extreme groups, nor does it prevent those with extreme tendencies from experiencing the consequences of those tendencies. In the present case, the fact that there is no unitary trait of impulsivity (as evidenced by the fact that delay and probability discounting are not negatively correlated and the fact that there exist groups, such as obese women with BED, who exhibit impatience while being very risk averse) does not mean that there are not groups whose members exhibit multiple “impulsivities,” nor does it mean that the members of such groups may not have special problems as a result of their multiple impulsivities.

Discounting of Different Types of Outcomes as Separate Impulsivities

Further evidence for the existence of multiple impulsivities comes from studies that have focused only on delay discounting but have examined the discounting of different types of delayed rewards. For example, a number of studies have shown that although individuals discount both delayed health benefits and financial gains, individuals' discount rates for health gains are largely independent of their discount rates for financial gains (e.g., Cairns, 1992). This finding was replicated by Chapman and Elstein (1995) who also showed that three independent factors described the delay discounting of health, monetary, and vacation rewards (see also Foxall, Doyle, Yani-de-Soriano, & Wells, 2011). Moreover, in a series of experiments, Chapman (1996) found that even within a type of outcome (i.e., money, health), the correlations between gains and losses were relatively weak. For example, writing in regard to the final experiment in the series, Chapman noted that the correlations

between outcomes of the same type and the same sign (i.e., gains, losses) averaged .71, whereas correlations within a type of outcome but between signs averaged only .28.

This is not to say that the rates at which individuals discount different types of rewards always are uncorrelated or only weakly correlated. For example, Table 1 presents the results of a factor analysis as well as the correlation matrix based on data from a study by Estle, Green, Myerson, and Holt (2007) of the delay and probability discounting of money and three directly consumable rewards (candy, soda, beer). As may be seen, our reanalysis of Area-under-the-Curve discounting measures from the Estle et al. (2007) study provides further evidence that the rates at which individuals discount delayed rewards and the rates at which they discount probabilistic rewards are relatively independent. All four delayed rewards loaded strongly (all $>.76$) on one factor, whereas all four probabilistic rewards loaded strongly (all $>.76$) on a separate factor. These two separate factors reflect the fact that the correlations among the different types of delayed rewards (median $r = .530$) and among the different types of probabilistic rewards (median $r = .473$) both tended to be stronger than the correlations between delayed and probabilistic rewards (median $r = .207$). Although there was a tendency for those who steeply discount delayed candy and soda to also steeply discount probabilistic candy and soda (contrary to what would be expected from the perspective of a unitary impulsivity trait), the degree to which participants discounted delayed money or beer did not predict the degree to which they discounted probabilistic money or beer.

The question of whether individuals who steeply discount one type of reward or outcome steeply discount other types of rewards or outcomes is one way of approaching the issue of how many impulsivities there are. Another approach is to look at whether experimental manipulations or environmental changes have similar effects on discounting, as in the case of the differential effects of reward amount on delay and probability discounting already discussed. Yet another approach to this issue is to examine whether different types of outcomes are discounted at different rates. For example, consider the shallower discounting of delayed money, relative to delayed consumable rewards (Odum & Rainaud, 2003). This finding was replicated in the study by Estle et al. (2007), who also found that while delayed money and consumable rewards were discounted at different rates, no such differences between types of rewards were observed when money and consumable rewards were probabilistic. This may be seen in Figure 3. The left panel shows that delayed money was discounted much more shallowly than delayed consumable rewards of similar monetary value; in contrast, the right panel shows that probabilistic money and probabilistic consumable rewards were discounted at equivalent rates.

An exceptionally clear case of the need to distinguish between the discounting of different types of rewards was recently reported by Jimura, Myerson, Hilgard, Keighley, Braver, and Green (2011). Jimura et al. found that delayed real liquid rewards were discounted at an extremely steep rate, losing half their value when delayed by less than a minute, whereas the rates of discounting delayed monetary rewards were orders of magnitude lower than those for liquid rewards. When young and older adult participants were assessed again several weeks later, the steep discounting rates for liquid rewards showed high test–retest reliability, as did the rates at which they discounted the hypothetical monetary rewards. Despite the high reliability of both liquid and monetary discount rates, the two were uncorrelated: Those who steeply discounted monetary rewards did not necessarily discount liquid rewards steeply—they might or might not, but individuals' discounting of one type of reward was not at all predictable from their discounting of the other type. We believe that these kinds of distinctions may have much to tell us about the nature of discounting, in part because they suggest that even within delay discounting, there may be multiple impulsivities, each of which is important for understanding a different aspect of decision making.

Future Directions

Further research will be needed to determine not just which types of reward are discounted at similar rates at the group level, but also what determines when the discounting of one type of outcome will predict the discounting of another type at the individual level. Several suggestions as to how rewards might be categorized have been offered, such as distinguishing monetary and other fungible rewards from directly consumable rewards (Estle et al., 2007; Odum & Rainaud, 2003) or distinguishing between rewards (like money) that serve an exchange function from those that serve a direct metabolic function (Charlton & Fantino, 2008). Others have suggested that with some types of rewards, visceral factors are more likely to affect intertemporal choice as well as other aspects of decision making, whereas other types of rewards are usually associated with more deliberative or “cool” decision making (Loewenstein, 1996; Metcalfe & Mischel, 1999).

It may be noted, however, that even if these distinctions prove useful, it is not clear how they apply to delayed rewards as diverse as health, vacations, and money, all of which, at the group level, are discounted at different rates, and for which, at the individual level, the rate at which one discounts a particular reward type is a poor predictor of the rate at which one will discount another type (Chapman, 1996; Foxall et al., 2011). To complicate matters even more, the categories that are useful for distinguishing different types of delayed reward may not always apply to probabilistic rewards, as evidenced by the findings of Estle et al. (2007; see Table 1 and Figure 3). The fact that different categories may be needed for delayed and probabilistic rewards argues that the real basis for distinguishing rewards may reside not in the commodity alone, but rather in the interaction between the commodity and the type of decision.

To date, basic research on discounting has focused largely on determining basic laws: the forms of the delay and probability discounting functions, and the ways in which experimental manipulations (and differences between choice situations outside the laboratory) affect the rates at which delayed and probabilistic rewards are discounted (for reviews, see Frederick et al., 2002; Green & Myerson, 2004). Discounting research has been quite successful with this “natural laws” strategy, but at least two separate sets of laws appear to be emerging (Myerson et al., 2011): one law for delay discounting (Equation 1 with b as a function of amount of delayed reward), and another for probability discounting (Equation 1 with s as a function of amount of probabilistic reward).

As we have noted already, however, the differences between delay and probability discounting appear to be one instance (albeit an important one) of a more general situation, and we are coming to the point at which the focus needs to be expanded so as to include not only discovering “natural laws” but also determining what are the “natural kinds.” The need to discern “the natural lines of fracture along which behavior and environment actually break,” as Skinner (1938, p. 33) put it when discussing the generic nature of the concepts of stimulus and response, is a recurrent one in science. Natural laws describe the relations between natural kinds (e.g., different physical dimensions and different types of outcomes), and thus discovering the boundary conditions that define a natural kind is a necessary part of discovering laws. Indeed, the present discussion could be considered a review of the boundary conditions that are apparent so far.

As noted above, the clearest case of natural kinds requiring different laws is that involving delay and probability discounting. It has become increasingly apparent that choosing between an immediate and a delayed reward (or smaller, sooner and larger, later rewards) and choosing between a certain and a probabilistic reward (or between smaller, more likely and larger, less likely rewards) represent choices involving different natural kinds. This is

apparent both with respect to the laws that describe them and the “traits” they represent. Referring to both impatience and risk taking as ‘impulsivity’ may serve only to indicate that being extreme in either regard can cause people real problems, and thus it would not be surprising if people who are extreme in both regards were also likely to have problems. Nevertheless, that does not make impatient risk-takers a natural kind—a personality type consisting of “impulsive” people. Rather, we would argue, such people are characterized by at least two “impulsivities.” An important implication of the “multiple impulsivities” view is that there may not be a magic bullet for treating impulse-control disorders involving both impatience and risk taking, if only because this view suggests there may be at least two targets to be hit. Indeed, the existence of multiple impulsivities may mean that there are multiple ways for people to get into multiple kinds of trouble.

Of particular importance from this multiple-impulsivities perspective is the discounting of losses. This topic, which has received relatively little attention to date, is especially important for two reasons. First, basic research indicates important similarities between the discounting of gains and losses (e.g., delay and probability discounting of losses are both well described by the hyperboloid discounting function, Equation 1), but there are important differences, as well. Second, delayed and probabilistic losses appear to play a major role in many of the behavior problems attributed to impulsivity.

With regard to the differences between the discounting of gains and losses, delayed losses are discounted less steeply than delayed gains, and similarly, probabilistic losses are discounted less steeply than probabilistic gains (Estle et al., 2006; Mitchell & Wilson, 2010). Moreover, while delayed and probabilistic gains both show magnitude effects (albeit in opposite directions), the amount of loss has relatively little effect on the rate of either delay or probability discounting (Estle et al., 2006; Mitchell & Wilson). Further, although with gains, delay and probability discounting tend, at best, to be weakly positively correlated, with losses, delay and probability discounting have been reported to be negatively correlated (Shead, Callan, & Hodgins, 2008; Shead & Hodgins, 2009), but not always significantly so (Mitchell & Wilson). Although more research, including studies that compare discounting of different kinds of losses, obviously is needed, what is known strongly suggests that with respect to both traits and processes, there are fundamental differences in the discounting of gains and the discounting of losses.

Moreover, the discounting of delayed and probabilistic losses would appear to be at least as relevant to behavioral problems that have been attributed to impulsivity as is the discounting of gains. Consider the problem of substance abuse. One could argue that the reason it is a problem is not because substance abusers, by choosing immediate rewards, are failing to maximize their long-term gains. Rather, the real reason why substance abuse is a problem, for the individual and for society, is because substance abusers discount both the possibility of relatively immediate, but highly negative probabilistic outcomes (e.g., arrest, overdose) as well as the delayed negative consequences of their behavior (e.g., problems with family relationships, loss of employment).

Consider the problem of going clean and sober from the perspective of delay discounting. A substance abuser might decide that he would quit the following week, at which point he would experience the aversive (but time-limited) consequences of abstinence, rather than continue to use drugs and experience the larger, but later (and perhaps longer lasting) negative consequences of drug use for his social and family relationships. Despite having made this decision, come the next week he might choose to continue to use drugs. This choice represents a preference reversal of the kind typically discussed with respect to choices between smaller, sooner and larger, later rewards, but such preference reversals also

have been observed with smaller, sooner and larger, later losses (Holt, Green, Myerson, & Estle, 2008).

We are not arguing that delayed rewards do not play a role in the present example. Rather, what we are suggesting is that delayed losses also could explain this behavior (Woolverton, Freeman, Myerson, & Green, in press), and regardless of whether one focuses on the delayed gains or the delayed losses, in both cases the preference reversal may be explained in terms of the hyperboloid model. Although gains and losses both could be important in such a reversal, which way the problem is viewed (whether in terms of gains, or losses, or both) may affect success in solving it. Moreover, just as there are differences in the discounting of different types of gains, there may well be differences in the discounting of different types of losses, differences that could prove to be important from both theoretical and applied perspectives.

Conclusions

Despite the fact that a hyperboloid function (Equation 1) describes the discounting of delayed and probabilistic outcomes (both gains and losses), there is considerable evidence that the two kinds of discounting involve different processes as well as separate impulsivities. Although there may be groups of individuals who are both impatient and risk taking, there also are groups who are impatient and risk averse, and in any case, the existence of such groups is not necessarily relevant to the question of whether impulsivity is a unitary trait.

Personality researchers have long argued that what they often term *impulsiveness* (rather than impulsivity) is multifactorial in nature (e.g., Patton, Stanford, & Barratt, 1995; for a review, see Evenden, 1999). Indeed, when Kirby and Finch (2010) recently factor-analyzed self-report responses to questions from different personality tests representing all previously proposed dimensions of impulsiveness, they obtained at least seven interpretable factors. Discounting of delayed monetary rewards loaded on only one of these factors (which they termed Impatiently Pleasure Seeking). Which factor the discounting of probabilistic monetary rewards would load on, if it did at all, is not known. Nor is it known how discounting of negative outcomes (e.g., losses) or discounting of different kinds of positive and negative outcomes relate to the multiple factors that make up impulsiveness as assessed by self-report.

What we do know is that delay and probability discounting represent separate factors, and that within each, there are important distinctions to be drawn at both the individual and group levels between the discounting of different types of outcomes. At the individual level, in some cases the degree to which one discounts a particular type of reward predicts how steeply one will discount another type of reward. In other cases, however, there is little or no correlation between the discounting of different types of rewards, indicating that these reward types are associated with separate impulsivities. At the group level, there are differences with regard to the rate at which different rewards are discounted. Taken together, these differences at both the individual and group levels argue that thinking about impulsivity as if it were a unitary trait represents a vast over-simplification—instead, what is needed is a much more nuanced view, even when the focus is just on discounting.

We believe that this situation should be viewed as an important scientific opportunity rather than as a limitation of the discounting framework. Indeed, it is by working within the discounting framework that researchers have been able to examine the discounting of different outcomes in different choice situations and identify differences that reflect fundamental characteristics. Were it not for this common framework, the important

distinctions revealed so far might well have been obscured by differences in procedure and measurement. Finally, we would argue that a precise mapping of these fundamental behavioral distinctions is a prerequisite to discovering the multiple brain mechanisms and the genetic bases for individual differences in these mechanisms that presumably underlie what appear to be multiple impulsivities.

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Fig. 1.

Relative subjective value as a function of the delay until (upper panel) and the odds against (lower panel) receiving a smaller (\$200) and a larger (\$40,000) reward. Curves represent the best-fitting hyperboloid discounting functions (Equation 1). Data are from Experiments 1 and 2 of “Differential Effects of Amount on Temporal and Probability Discounting of Gains and Losses,” by S. J. Estle, L. Green, J. Myerson, and D. D. Holt, *Memory & Cognition*, 34, p. 926. Copyright 2006 by the Psychonomic Society, Inc. Reprinted with permission.

Fig. 2.

Probability discounting as a function of delay discounting. Each data point represents how steeply a particular individual drawn from a hypothetical population distribution discounts delayed and probabilistic rewards. The solid squares represent a group of individuals who steeply discount both delayed and probabilistic rewards, reflecting both impatience and risk aversion, respectively; the solid circles represent a group of individuals who steeply discount delayed rewards but shallowly discount probabilistic rewards, reflecting impatience and risk taking, respectively.

Fig. 3. Relative subjective value as a function of the delay until (left panel) and the odds against (right panel) receiving different types of rewards. Curves represent the best-fitting hyperboloid discounting functions (Equation 1). Data are from the large amount condition of “Discounting of Monetary and Directly Consumable Rewards,” by S. J. Estle, L. Green, J. Myerson, and D. D. Holt, *Psychological Science*, 18, p. 60. Copyright 2007 by Blackwell Publishers, Ltd. Reprinted with permission.

Table 1

Factor analysis (Varimax rotation) results and intercorrelations among different types of delayed and probabilistic rewards (based on data from Estle et al., 2007; $n = 47$).

Reward Type	Prob. Factor	Delay Factor	Prob. Money	Prob. Candy	Prob. Soda	Prob. Beer	Delayed Money	Delayed Candy	Delayed Soda
Probabilistic									
Money	.817	.024							
Candy	.819	.286	.482						
Soda	.818	.168	.530	.463					
Beer	.765	.064	.650	.459	.411				
Delayed									
Money	-.056	.770	.055	.110	.173	.031			
Candy	.335	.766	.272	.510	.294	.307	.456		
Soda	.231	.868	.166	.463	.319	.214	.507	.718	
Beer	.098	.831	.170	.249	.175	.200	.521	.539	.698

Note: r .29, $p < .05$; r .38, $p < .01$; r .47, $p < .001$.