Research Report

DISCOUNTING OF DELAYED REWARDS: A Life-Span Comparison

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Abstract—*In this study, children, young adults, and older adults chose between immediate and delayed hypothetical monetary rewards. The amount of the delayed reward was held constant while its delay was varied. All three age groups showed delay discounting; that is, the amount of an immediate reward judged to be of equal value to the delayed reward decreased as a function of delay. The rate of discounting was highest for children and lowest for older adults, predicting a life-span developmental trend toward increased self-control. Discounting of delayed rewards by all three age groups was well described by a single function with age-sensitive parameters (all* R^2*s* $> .94$*). Thus, even though there are quantitative age differences in delay discounting, the existence of an age-invariant form of discount function suggests that the process of choosing between rewards of different amounts and delays is qualitatively similar across the life span.*

Choosing a smaller, more immediate reward over a larger, but delayed reward has been described as "impulsive," as due to a lack of "self-control," and as an example of an inability to "delay gratification" (e.g., Ainslie, 1974; Green, 1982; Logue, 1988; Mischel, Shoda, & Rodriguez, 1989; Rachlin & Green, 1972). Such behavior is sometimes viewed as immature, maladaptive, or irrational because choosing smaller, more immediate rewards may result in less total reward being earned in the long run.

Alternatively, choosing smaller, immediate rewards over larger, delayed rewards can be viewed as the normal outcome of an adaptive process in which the subjective value of a reward decreases with time to its receipt (Kagel, Green, & Caraco, 1986). This change in the value of a reward as a function of its temporal proximity is termed delay discounting. Thus, a smaller, but immediate reward (e.g., $100 now) may be chosen because its value is greater than a larger reward for which one must wait a prolonged period of time (e.g., $300 in 5 years). This decrease in value with increasing delay has been attributed to an "implicit risk" associated with increased delay: A delayed reward is devalued because its receipt is less certain than that of an immediate reward (e.g., Benzion, Rapoport, & Yagil, 1989; Stevenson, 1986). Therefore, it has been proposed that discounting delayed rewards is an adaptive response to uncertainty in an animal's natural environment (Kagel et al., 1986).

Of various mathematical expressions that have been proposed to describe delay discounting, perhaps the most successful has been a function of the form

$$V = \frac{A}{(1 + kD)^s}, \quad (1)$$

where V is the discounted value of the delayed reward, A is the amount of the delayed reward, D is the delay until receipt of the reward, and k is the parameter describing the degree or rate of discounting; the larger the value of k, the greater the decrease in value as delay increases. Rachlin (1989) has proposed raising the denominator to a power, s, representing the scaling of or sensitivity to delay. However, it is unclear at present whether inclusion of this additional parameter is necessary. Exponential decay functions also have been considered but have been rejected on both theoretical and empirical grounds (Green, Fisher, Perlow, & Sherman, 1981; Mazur, 1987; Rachlin, Raineri, & Cross, 1991; Rodriguez & Logue, 1988).

Equation 1 accurately describes the discounting of real food rewards by pigeons (Mazur, 1987) and the discounting of hypothetical monetary rewards by young adults (Rachlin et al., 1991). The difference between pigeons and young adults in terms of discounting lies not in the form of the relation between value and delay, but rather in the rate at which each group discounts rewards over time (pigeons discount rewards at a much higher rate). The similarity of the results from both human and nonhuman subjects and with both hypothetical and real rewards argues for the utility and generality of Equation 1 in describing choice behavior. It remains to be seen, however, whether the choice behavior of humans other than young adults would be equally well described and, if so, whether differences in the k parameter, implying differences in the rate of discounting, or in the s parameter, implying differences in sensitivity to delay, would yield any insight into their decision making.

For example, children and young adults might not discount delayed rewards in the same manner, so that no single form of an equation would suffice to describe their choices. If mental development is characterized as involving qualitative changes, then it might well be that children discount delayed rewards in a manner qualitatively different from that of adults. The same function, then, might not adequately describe discounting by children. If Equation 1 were to describe their choices, however, then one would anticipate differences in the rate at which children discount delayed rewards, based on previous reports of children's greater impulsivity and inability to delay gratification.

Similar questions exist with regard to the choices of older adults. Although there has been considerable research on cautiousness and risk aversion in older adults, the results have been far from conclusive (see Botwinick, 1984, chap. 10). Mischel et al. (1989) noted that the ability to delay gratification increases with age in children. If this ability continues to increase throughout the life span, then older adults would be expected to discount delayed rewards at a

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lower rate than young adults. However, with increasing age comes the greater risk of not surviving to collect a delayed reward. This might lead to greater rates of discounting in older adults.

Alternatively, the increased risk associated with advancing age could play a role in changing the shape of the function. For example, older adults might discount delayed rewards in a manner similar to that of young adults when the delay is relatively short. However, at longer delays, some older adults might not expect to survive to collect the delayed reward. This could create a precipitous drop in the decay function, thus rendering Equation 1 inadequate as a descriptor.

The current study was conducted to compare young and older adults and children in their discounting of delayed monetary rewards. Our objectives were to determine whether Equation 1 describes the discounting of delayed rewards by children and older adults as well as it describes discounting by young adults and also whether the rate of discounting across the three age groups reflects a life-span developmental trend toward increasing ability to delay gratification.

METHOD

Subjects

Thirty-six volunteers from three age groups participated: 12 sixth graders (M = 12.1 years), 12 college students (M = 20.3 years), and 12 older adults (M = 67.9 years). The data from an additional 2 sixth graders and 2 older adults were excluded because these individuals did not do the task as directed.

The sixth-grade children were recruited from a Jewish Sunday-school class and from an Archdiocesan parochial school. The young adults were volunteer undergraduate students attending Washington University in St. Louis. The older adults were recruited from a subject pool maintained by the Aging and Development Program of the Department of Psychology at Washington University.

Procedure

The procedure, adapted from Rachlin et al. (1991), required participants to make a series of choices regarding hypothetical amounts of money. These amounts were printed on sets of 4″ × 6″ index cards that were hole-punched and attached to a two-ring desktop calendar holder.

Each participant was tested individually in a quiet room that contained a table and two chairs. Two sets of index cards were placed on the table at a comfortable distance from the participant. One set of cards, located to the participant's right, was the delayed, fixed-amount reward set, and the other set, located to the participant's left, was the immediate-amount reward set.

Participants made a series of choices between the fixed-amount reward (e.g., $1,000) that could be obtained after a delay and an immediately obtainable reward that varied in amount (e.g., from $1 to $1,000). In this manner, for example, the participants would have to make a choice between "$1,000 in 10 years" or "$650 now." Participants indicated their preference by pointing to one of the two cards (either the delayed, fixed-amount reward or the immediate reward).

The possible values of the delayed, fixed-amount rewards were $1,000 and $10,000 for the college-age and older adult participants and $100 and $1,000 for the sixth graders. There were eight possible delays at which each of the fixed-amount rewards could be obtained: 1 week, 1 month, 6 months, 1 year, 3 years, 5 years, 10 years, and 25 years. The immediate-reward cards depicted 30 values ranging from 0.1% to 100% of the delayed, fixed-amount reward with which they were compared.

For each fixed amount at each delay, a subjectively equivalent immediate amount was determined for each participant. These equivalence points were calculated by taking the average of two determinations: the value at which the participant switched preference from the immediate to the delayed reward when the immediate rewards were presented in a descending order and the value at which the participant switched preference from the delayed to the immediate reward when the immediate rewards were presented in an ascending order. Distributions of equivalence points are characteristically skewed because of the limits imposed on the participants' choices (see Rachlin et al., 1991). Therefore, for each group, the median equivalence point for each fixed amount at each delay was determined. These median equivalence points represent the values of V in Equation 1.

RESULTS

Figure 1 presents Equation 1 fit to the median amounts of the immediate rewards that the children, young adults, and older adults selected as being equivalent to the delayed, fixed-amount rewards (see Table 1 for parameter values).

Young Adults

As may be seen in Figure 1 (center), for young adults, the shape of the relation between discounted value and delay for both the $1,000 and $10,000 delayed rewards was very well described by Equation 1: The proportions of variance accounted for were .996 and .977, respectively. Moreover, the delay sensitivity parameter, s, was reliably different from 1.0 for both the $1,000 and $10,000 delayed-reward amounts ($t[12]$ = 28.34 and 5.15, respectively, $p < .001$), arguing for the inclusion of the exponent. Furthermore, the best-fitting functions for the two delayed-reward amounts differed significantly, $F(2, 12) = 26.47$, $p < .01$.

Older Adults

As was the case with the young adults, the relations between discounted value and delay for the older adults were very well described by Equation 1 (Fig. 1, right): The proportions of variance accounted for were .995 and .999. However, unlike for the young adults, the s exponents for the older adults for both the $1,000 and $10,000 delayed-reward amounts were not reliably different from 1.0 ($t[12]$ = 0.752 and 1.58, respectively). As for the young adults, the older adults' functions for the two delayed-reward amounts differed significantly, $F(2, 12) = 24.99$, $p < .01$.

Children

The relation between discounted value and delay for the children was well described by Equation 1 for both the

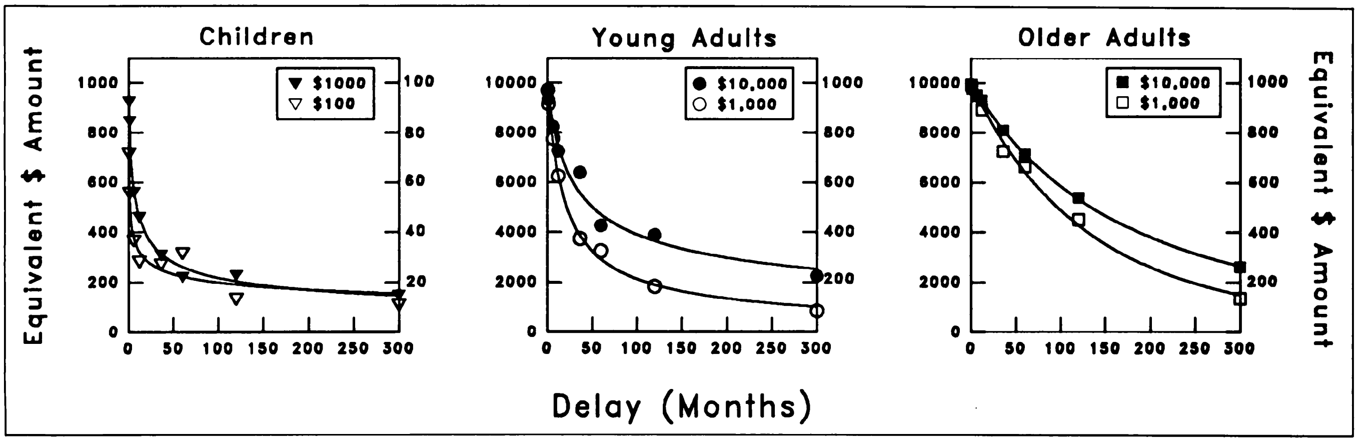

Fig. 1. Median amounts of the immediate rewards selected as being equivalent to the fixed amounts at each delay. Curves represent Equation 1; parameter values are given in Table 1.

$100 and the $1,000 delayed, fixed-amount rewards (Fig. 1, left): The proportions of variance accounted for were .945 and .995. Additionally, the exponent s was reliably less than 1.0 for both delayed reward amounts ($t[12] = 10.18$ and 7.63 for $100 and $1,000, respectively, $p < .001$), providing further support for the inclusion of the exponent. Moreover, the best-fitting functions for the $100 and $1,000 delayed-reward amounts differed significantly, $F(2, 12) = 30.76$, $p < .01$.

Between-Groups Analyses

Figure 2 compares the delay discounting functions of sixth graders, young adults, and older adults for the delayed $1,000 reward. As is suggested by the three distinct functions, there were statistically reliable differences in the rates (values of k; see Table 1) at which the three groups discounted this reward: Sixth graders reliably discounted $1,000 more steeply than did young adults, $t(12) = 4.424$, $p < .001$, and young adults reliably discounted more steeply than did older adults, $t(12) = 4.852$, $p < .001$. In addition, the s parameters for the children and young adults differed reliably, $t(12) = 4.281$, $p < .01$, and although those for the young adults and older adults did not, $t(12) = 1.206$, the value of s increased substantially across the life span (from 0.37 to 0.72 to 5.0; see Table 1).

DISCUSSION

Equation 1 successfully described the discounting of delayed rewards by 12-year-old children and older adults, as well as that by young adults. The observed discount functions reflect the interaction of discounting rates (k) and sensitivity to delay (s), both of which showed age differences.

There was a clear life-span developmental trend in the rate at which individuals discounted the value of delayed rewards, as reflected in the k parameter of Equation 1 (see Table 1 and Fig. 2). Values of k decreased with increasing age: Sixth-grade children reduced the value of delayed rewards at a faster rate than did young adults, who, in turn, reduced the value of delayed rewards at a faster rate than did older adults.

There was also a developmental pattern of differential sensitivity to delay reflected by increases in the value of the exponent s. The values of s less than unity observed in children suggest that children are more sensitive to differences between short delays than are adults, whereas the larger values of s observed in adults indicate that they are more sensitive to differences between long delays than are children. This pattern may be seen in Figure 2: The function fit to the data from the children "bottoms out" when the delay to the fixed-amount reward is approximately 5 years. In contrast, for the young and older adults, the value of the delayed reward continues to decrease up to 10 years and beyond. In fact, at very long

Table 1. *Parameter values for best-fitting discount functions*

Delayed fixed amount	Children k	Children s	Young adults k	Young adults s	Older adults k	Older adults s
$100 reward	12.5	0.226	—	—	—	—
$1,000 reward	0.618	0.368	0.075	0.724	0.002	5.01
$10,000 reward	—	—	0.083	0.422	0.003	2.18

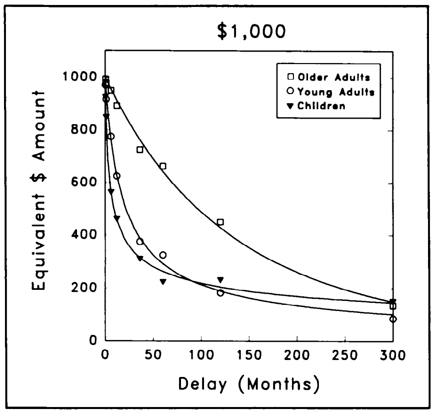

Fig. 2. Equation 1 fit to the data from children, young adults, and older adults for the delayed, fixed-amount reward of $1,000 (replotted from Fig. 1 to facilitate comparisons among age groups).

delays, the young adults discounted the value of rewards even more than did the children.

The differences between children and adults may, in part, be related to children's lack of experience with long delays. Indeed, it has been shown in animals that experience in choosing between delayed rewards affects delay discounting (Logue, Rodriguez, Peña-Correal, & Mauro, 1984). Differences between the discount functions of young and older adults may also reflect differences in the amount of experience with long delays, although the effect of experience may be counteracted somewhat by differences in the probability of surviving to collect long-delayed rewards.

Interpretation of the present results must be tempered until age differences in delay discounting have been examined in additional populations and with different procedures. However, the reliability of the present methodology is attested to by the systematic replication of previous findings that increases in delay produce greater decreases in the value of smaller rewards than of larger rewards (e.g., Benzion et al., 1989; Raineri & Rachlin, in press; Thaler, 1981; see Fig. 1). In the present study, there was a statistically significant difference between the discount functions for the larger and smaller rewards for each age group.

The greater impulsivity of children relative to young and older adults may be understood within the framework of differing rates of discounting and sensitivity to delay. As observed in the present study, children discount the value of delayed rewards to a greater degree than do adults. Therefore, relative to adults, children will accept a smaller, immediate reward in place of a large, delayed alternative, and will wait a shorter time for a large reward when they could choose instead a small, immediate reward.

These predictions follow from a single mathematical form of discount function that in the present study provides an excellent description of the discounting of delayed rewards at all ages. Differences between age groups (and even between individuals within an age group) are accounted for by differences in parameter values. Even though the ability to delay gratification may continue to increase well past adolescence into older adulthood, as reflected in the age-dependent values of the parameters, the age-invariant form of the discount function (Equation 1) suggests that the process of choosing between rewards of different amounts and delays is qualitatively similar across the life span.

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