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Correlates of delay-discount rates: Evidence from Tsimane' Amerindians of the Bolivian rain forest

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Abstract

Delay-discount rates (or rates of time preference) are associated with rates of consumption and a variety of impulsive behaviors. Despite the importance of discounting, little is known about its covariates. We estimated discount rates for money and candy rewards in each of four quarters for 154 Tsimane' Amerindians (10–80 years of age). The Tsimane' are a horticultural and foraging society in the tropical rain forest of Bolivia. Discount rates increased with age, decreased with educational levels and literacy, and tended to decrease as recent income rose. Rates were not associated with wealth, nutritional status, or moderate drug use. There were low but reliable correlations between discount rates across quarters, suggesting that a person's discount rate is a somewhat stable characteristic that is also strongly influenced by situational factors. © 2002 Elsevier Science B.V. All rights reserved.

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1. Introduction

All else equal, people and animals typically prefer to receive and consume a given reward sooner rather than later. Delayed rewards are *discounted* relative to immediate rewards, and the longer the delay, the greater the discounting. Individuals differ in how much they discount future rewards as a function of delay. A person with a high discount rate might prefer to have one piece of candy today over two pieces of candy next week. A person with a lower discount rate might rather wait for the two pieces of candy next week. In general, the more one discounts the future – the greater one's discount rate – the less weight future consequences will have in one's present decisions. Thus, delay discounting is likely to be an important determinant of rates of consumption, investment, and savings. In addition, the higher the discount rate the greater will be the appearance of impatience and impulsiveness. Delay discounting provides a quantitative framework for understanding impulsive behavior (Ainslie, 1992).

Because theoretical investigations of discounting have developed relatively independently in experimental psychology and in economics, researchers from different disciplines have used several terms to describe discounting. In this paper we use the term *delay-discount rate*, or simply *discount rate*, to refer to the degree to which the present value of a future reward is diminished with delay. More precisely, the discount rate determines the slope of the curve (the *discount curve*) relating present value to delay. A discount rate of zero indicates that delay has no effect on the present value of a reward. As the discount rate increases, so does impatience, impulsiveness, myopia, the inability to delay gratification, and the rate of time preference, which by convention is defined as the natural logarithm of the marginal rate of substitution between future and current consumption.

In this article we examine the relationships between discount rates and several demographic and socioeconomic variables. Our approach contains several notable features. First, we used information from Amerindians in a horticultural and foraging society of the Bolivian rain forest. This gave us an opportunity both to observe discounting in a society less influenced by modern market structures (e.g., credit markets) than in the typical studies of undergraduates in the US, and to see whether findings from Western societies also hold up in a different economic and social setting. Second, we estimated discount rates from the pattern of choices people made between immediate and delayed rewards, where each person actually received one of his or her choices. Third, we correlated individual discount rates with individual demographic, social, and economic characteristics; we avoided using aggregate information. Fourth, we measured discount rates during four quarters so that we could assess their stability over time. Last, we tested predictions about the origins of discount rates implied by a recent economic model proposed by Becker and Mulligan (1997). We drew mainly on that model because it has the strength of generating relatively clear predictions.

1.1. Determinants of discount rates

The essential features of the discounting model of impulsiveness have been verified with experiments using animals and humans in a large literature in psychology beginning with Rachlin and Green (1972) and Ainslie (1974). Ainslie (1992), Kirby (1997) and Rachlin (2000) review that literature. Furthermore, discount rates appear to be valid indicators of impulsiveness. For example, discount rates correlate reliably with self-report measures of impulsiveness (Kirby & Finch, 1997), and heroin addicts have higher discount rates than people who do not use drugs (Kirby, Petry, & Bickel, 1999).

At present we have very little evidence regarding the causes of individual differences in discount rates. As with individual differences in impulsiveness more generally, individual differences in discount rates are likely to have multiple causes. One might look for the sources of differences in discount rates in neurophysiological differences in sensation-seeking and arousal (c.f., research on impulsiveness by Evans, Platts, Lightman, & Nutt, 2000; Zuckerman, 1991) or in other factors underlying personality (c.f., Barratt, Pritchard, Faulk, & Brandt, 1987). These physiological differences could be hereditary (c.f., Apter, Van Praag, Plutchik, & Sevy, 1990; Rogers, 1994), environmentally determined, or both (Barratt, 1991). A physiologically determined discount rate could be either a stable trait or a transient characteristic (c.f., Meade, 1981; Wingrove & Bond, 1997).

Alternatively, one might view differences in implied discount rates as arising from differences in learned patterns of behavior. Rachlin (1995) describes how organisms could learn to exhibit less impulsive behavior as their behavior is restructured into more temporally extended patterns. For example, for a child who is feeding himself, dinner might involve of a series of choices between temporally brief behaviors: Should I eat a chocolate bar or a salad? Next, should I eat ice cream or pasta? For an adult, the dinner choice might be between "eating a healthy meal" (eating the salad and pasta, and skipping desert) and "eating an unhealthy meal", both of which refer to more temporally extended patterns of behavior. As the temporal extent of the pattern increases, immediacy plays less of a role in determining choices, and the discount rates implied by one's choice should decrease. Thus, individual differences in learning or in reinforcement histories could give rise to differences in discount rates. Of course, the learning and neurophysiological accounts are not only compatible, but probably linked. Learning is presumably represented neurophysiologically and there could be physiologically determined differences in learning rates.

1.2. Endogenous time preference

Becker and Mulligan (1994, 1997) have described a third kind of determinant of discount rates. They acknowledge that people vary in their discount rates, but they argue that people rationally spend resources to overcome discount rates. People do this by investing in *future-oriented capital*. In the Becker–Mulligan model, the observed discount rate is a function of the time and effort spent appreciating future pleasures and of the investments one makes on goods that direct one's attention away from current pleasures to future pleasures. This kind of investment will allow people to see the future with greater feeling, realism, and clarity, which, in turn, will lower their discount rates. Becker and Mulligan's (1997) model yields testable predictions, which are summarized in Table 1. Since we used the Becker and Mulligan (1997) model to guide our empirical analysis, we next discuss some predictions of the model and briefly review the literature bearing on those predictions.

1.3. Age

Becker and Mulligan's (1997) model predicts that age should have a U-shaped relationship with discount rates. During childhood, children are learning to imagine the future, partly because they are experiencing more and more "future" as it arrives, and partly because they are being taught to imagine and plan for the future. These factors work to decrease discount rates as people age. Since the probability of death increases as people get older, the weight placed on future consumption should decrease. Thus, after reaching some minimum, discount rates should begin to increase with age in a gradual way.

Rogers (1994) generates a nearly opposite prediction based on a model of the evolution of discount rates. Rogers says that individual discount rates should increase through young adulthood, and then decline sharply through middle age. This yields an inverted-U relationship. For women the peak discount rates should occur at about 20 years of age, drop to a minimum by around 40 years of age, and oscillate over a small range thereafter. For men the peak discount rates should occur between 20 and 40 years of age, drop to a minimum by around 50 years of age, and oscillate over a small range thereafter.

Direct evidence bearing on the relationship between age and discount rates does not fully support the predictions of either Becker and Mulligan (1997) or Rogers (1994). A decrease in implied discount rates throughout childhood is observed in a large body of research using the delay-of-gratification paradigm (e.g., Metcalfe &

Table 1
Predicted relationships between explanatory variables and discount rates, based on Becker and Mulligan (1997)

Explanatory variable	Proxy for variable in this study	Predicted relation	Observed relation
Age	Age in years	U	+ or U
Health	Nutritional status (BMI)	–	None
Wealth	Value of physical assets	–	None
Income	Cash received during previous month	?	– or none
Schooling	Years of education	–	–
	Numeracy	–	–
	Spoken Spanish	–	–
	Spanish literacy	–	–
	Tsimane literacy	–	–
	Father's years of education	–	–
	Father's literacy	–	–

Note: A + sign, − sign, and U means the explanatory variable was predicted to have a positive, negative, or U-shaped effect on the private discount rate. A question mark indicates that the predicted effect is ambiguous.

Mischel, 1999; Mischel & Metzner, 1962; Mischel, Shoda, & Rodriguez, 1989), which has consistently found that children become more patient with age. This result is consistent with Becker and Mulligan but would appear to contradict Rogers (see especially his Fig. 5, p. 472). (In bringing this body of evidence to bear, we are assuming that greater ability to delay gratification is associated with lower discount rates.) Green and colleagues have found that discount rates continue to decrease with age through young adulthood, reaching stable levels when people are, on average, in their 30s (Green, Fry, & Myerson, 1994; Green, Myerson, Lichtman, Rosen, & Fry, 1996; Green, Myerson, & Ostaszewski, 1999). This result would appear to contradict Becker and Mulligan's predicted upturn in discount rates, but is roughly consistent with Rogers' predictions beyond age 20.

1.4. Wealth and income

Becker and Mulligan's (1997) clearest and most important prediction is an inverse relationship between discount rates and wealth. Wealth (and possibly income) should decrease discount rates because richer people can afford to invest more in future-oriented capital and are less likely to be constrained by credit. We have found one study that directly examined the relationship between discount rates and wealth, and two others that measured the relationship between discount rates and income. In all three the results are consistent with Becker and Mulligan's prediction for wealth.

Pender (1996) offered 96 participants in Andhra Pradesh, India, choices between earlier and later amounts of rice. For the choice procedure Pender used an upward-staircase method (c.f., Rachlin, Raineri, & Cross, 1991) in which a series of choices was offered between a fixed earlier reward and later reward that ascended in magnitude across trials. For example, on one choice a participant might be asked whether she preferred to receive 10 kg of rice in one month or 15 kg of rice in seven months. On the next choice she would be asked whether she preferred to receive 10 kg of rice in one month or 16 kg of rice in seven months. Discount rates were estimated from the point at which the participant switched from choices of the earlier to choices of the later reward. Pender found that household net wealth per capita was inversely related to discount rates, and this relationship was reliable for one of the two groups of participants that he tested.

Hausman (1979) modeled the tradeoff between buying prices and long-term operating costs of room air-conditioners, and used the model to estimate individual (household) discount rates. In his sample of 46 households, discount rates were inversely related to household income. Green et al. (1996) offered participants choices between immediate and delayed hypothetical amounts of money at varying delays, also using an up–down staircase method (Rachlin et al., 1991) to estimate the participants' discount rates. They found that participants with annual incomes greater than $40,000 had lower discount rates than lower-income participants. Although Becker and Mulligan's (1997) model does not make a clear directional prediction about the relationship between income and discount rates, assuming that income is associated with wealth the results of both the Hausman and the Green et al. studies are consistent with Becker and Mulligan's prediction for wealth.

1.5. Schooling

Becker and Mulligan (1997) predict that more schooling should be associated with lower discount rates. Schooling focuses attention on the future, and helps children to learn how to simulate and plan for the future. We are aware of two studies with information relevant to this topic. Shoda, Mischel, and Peake (1990) found that scores on the scholastic aptitude test (SAT), which adolescents in the United States take when applying to post-secondary schools, were positively and reliably correlated with the ability to delay gratification measured at four years of age. If we assume that scores on the SAT measure investments in schooling, then this result is consistent with the prediction of Becker and Mulligan, but it also suggests that the ability to delay gratification is a stable trait. Also consistent with the direction of Becker and Mulligan's prediction, Kirby, Winston, and Santiesteban (2002) found reliable negative correlations between discount rates and college grade-point averages.

1.6. Mortality and immortality

Becker and Mulligan (1997) predict that good health should decrease discount rates, as increasing life expectancy increases the return on future-oriented capital investments. For similar reasons, belief in immortality should increase the value of future-oriented capital, and cause a decrease in discount rates, except in the unhappy case that one expects to burn in hell.

1.7. Summary

Neurophysiological, personality, learning, and economic explanations for individual differences in discount rates are not mutually exclusive. It will be very difficult experimentally to tease them apart and identify their individual contributions. Becker and Mulligan (1997) provide support for their predictions by reviewing aggregate economic data, using growth in consumption and income inequality across and within generations as a proxy for discount rates. Such evidence is indirect at best. Unfortunately, there is very little direct evidence on the relationships between their explanatory variables and discount rates. Our goal in this research was a modest one of attempting to determine the existence and direction of relationships between discount rates and several demographic and socioeconomic variables.

2. Method

2.1. Participants

The participants were 154 Tsimane' Amerindians (10–80 years of age) from 53 households in two villages along the River Maniqui, in the tropical rain forest of the Department of Beni, Bolivia. One village, Yaranda, was more traditional and had lower cash incomes. It is located 47.7 km up-river from the market town of San Borja, and accessible mostly by river transport. The other village, San Antonio, was more integrated with the market and had higher cash incomes. It is located only 10 km down-river from San Borja, and accessible all year by road. Neither village had running water or electricity. Tsimane' subsistence centers on slash-and-burn agriculture and foraging. They earn cash from selling thatch palm and agricultural goods and from working in nearby logging camps, ranches, and farms. There is no formal credit market in the area and therefore no formal interest rate. Chicchón (1992), Ellis (1996), Godoy (2001), Huanca (1999) and Reyes-García (2001) discuss the ethnography and the history of the Tsimane'.

The composition of the sample was relatively stable over time. Permanent attrition was not a problem. In fact, the number of households and adults in the sample grew. The number of households grew from 46 to 51 from the first to the fifth quarter because people formed new households at marriage. The total sample of adults grew by three people in part because outsiders married into the villages.

2.2. Procedure

2.2.1. Data collection

Fieldwork took place between May 1999 and November 2000 as part of a study to measure the effect of markets on quality of life of indigenous people. (The larger study included a large number of variables that are not discussed here.) Earlier version of the tests for time preference had been piloted in 1996 (Godoy & Jacobson, 1999) and 1997 (Godoy, Kirby, & Wilkie, 2001). We used the initial quarter to pre-test instruments and enhance inter-coder reliability. The systematic collection of information for analysis started during the second quarter. Every quarter we surveyed all households in the two villages. For each quarter we obtained information for each person on their measure of discount rates, income, wealth, health, drug use, and other socioeconomic variables. The final data set consisted of an even panel made up of four quarters. Below we refer to the quarters that we used (i.e., after the pilot quarter) as the first through fourth quarters.

We estimated each person's delay-discount rate based on a series of choices between smaller, immediate rewards and larger, delayed rewards. This was done separately for choices between monetary rewards and for choices between food rewards (pieces of candy). To provide an incentive to take each choice seriously we told participants that we would select at random one of the eight monetary choices and one of the seven candy choices at the end of the interview, and that they would receive the rewards that they chose on those questions in the number of days specified. To mitigate concerns on the part of participants about whether or not researchers would be around to deliver delayed rewards during the end of the study, we made sure that data collection during the fourth quarter was done early enough so that the delayed reward would be delivered before field work ended.

2.2.2. Estimating discount rates for money

Table 2 shows the eight monetary choices. For example, for question 5 (top row in Table 2) the participant was asked "Would you prefer to receive \$b 8.0 today or \$b 8.5 in 157 days?" (\$b = bolivianos; \$b 6.00 ≈ \$US 1.00). The values of the monetary rewards were not trivial. The daily wage in logging camps, ranches, and nearby towns was about \$b 20–\$b 25, so most of the rewards amounted to roughly a quarter day's work.

We estimated a person's discount rate from the choices they made using a procedure developed by Kirby and Marakovic (1996) and revised in Kirby et al. (1999). Previous research with both animals and humans using real rewards (Kirby, 1997; Mazur, 1987) has shown that a hyperbolic discount function, $V = A/(1 + kD)$, where V is the present value of a reward A at the delay D, and k is a discount rate parameter, fits actual discounting data better than does an exponential function. As the value of k increases a person is less willing to wait for a future reward. Using this equation, for each question we can solve for the value of k that would make a person indifferent between each of the immediate and the delayed rewards in Table 2. For example, in question 6 in Table 2 we offered people a choice between \$b 3.3 today or \$b 8.0 in 14 days. A person with a discount rate of 0.10 would be indifferent between the two rewards. If a participant selected the immediate reward on this question, one could infer that this person had a discount rate greater than 0.10. If a participant selected the delayed reward on this question, one could infer that this person had a discount rate less than 0.10. In this way the eight questions correspond to eight values of k at indifference (shown in the fifth column of Table 2), and taken together they define nine ranges of discount rates.

Seven of the ranges are bounded above and below. To illustrate, in question 2 (bottom row in Table 2) we offered participants a choice between \$b 3.1 today or \$b 8.5 in seven days. A participant with a discount rate of 0.25 would be indifferent

Table 2
The monetary-choice values and the associated discount rates for each of the eight questions used to elicit private time preference for money

Question #	Reward values		Delay	Rate at indifference	
	Today	Later		k	r
5	\$b 8.0	\$b 8.5	157	0.00040	0.00039
3	\$b 6.7	\$b 7.5	119	0.0010	0.00095
4	\$b 6.9	\$b 8.5	91	0.0025	0.0023
1	\$b 5.5	\$b 7.5	61	0.0060	0.0051
8	\$b 5.4	\$b 8.0	30	0.016	0.013
7	\$b 4.1	\$b 7.5	20	0.041	0.030
6	\$b 3.3	\$b 8.0	14	0.10	0.063
2	\$b 3.1	\$b 8.5	7	0.25	0.14

Note: "Rate at indifference" indicates the values of the hyperbolic (k) and continuously compounded exponential (r) discount rates at which the immediate and the delayed rewards are of equal value. \$US 1.00 ≈ \$b 6.00 [b = bolivianos]. All delays are in days.

between the two rewards. Suppose that a participant chose the immediate reward on question 6 (implying $k > 0.10$) but chose the delayed reward on question 2 (implying $k < 0.25$). Taking the two trials together, one can infer that this person has a discount rate between 0.10 and 0.25, and the midpoint of the interval provides our best estimate of the person's discount rate. We used the geometric mean of the range to avoid assigning less weight to the smaller of the two rate parameters. In this example, the procedure would produce an estimated discount rate of 0.16. Choices of all eight immediate rewards or of all eight delayed rewards represent the endpoints of our measure, and for such choices we cannot place bounds on the estimate of k. Participants who chose in this way were assigned the value of k corresponding to those endpoints.

The results that we present below do not depend on using a hyperbolic rather than an exponential delay-discounting function. The values of k generated using the hyperbolic discounting equation and the rates that would be generated using a continuously compounded exponential function are nearly identical over most of the observed range, as shown in the comparison of these values in the last two columns of Table 2. Because we measured delays in days, the hyperbolic discount rate parameters that we report, multiplied by 100, are approximately interpretable as expressing percent decreases per day. This is only an approximate interpretation, however, because for hyperbolic functions the percent decrease gets smaller as the delays increase. We use the hyperbolic rate k because the hyperbolic function is well established in the psychological literature and allows comparison with previously published results.

Because a person's choices were not always perfectly consistent with a single value of k, the parameter estimates could not be made simply by identifying the switch from the immediate to the delayed rewards moving down (Table 2). Instead, we assigned each participant a k value that yielded the highest proportion of consistent choices. That is, for each participant one can compute the proportion of that person's choices that are consistent with assignment to each of the nine values of k defined by the questionnaire (bounded or unbounded). Participants were assigned the value that yielded the highest consistency among her or his choices of any of the nine possible values. Consistency here is a relative rather than an absolute measure, with the discount rate that yields the highest relative consistency across trials providing the best estimate of the participant's k value. When two or more values yielded equal consistency, the participant was assigned a value corresponding to the geometric mean of those values. In the statistical analyses presented below we only use information from participants for whom we were able to assign values that were consistent with at least six of eight of the participant's monetary choices.

2.2.3. Estimating discount rates for candy

The method of estimating discount rates for candy was identical to that for money. Participants were offered choices between smaller and larger numbers of candies. For example, on question 2 (bottom row in Table 3) participants were offered a

Table 3
The candy-choice amounts and the associated discount rates for each of the seven questions used to elicit private time preference for candy

Question #	Number of candies		Delay	Rate at indifference	
	Today	Later		k	r
4	16	17	157	0.00040	0.00039
3	13	15	153	0.00101	0.00094
1	11	15	61	0.0060	0.0051
7	11	16	28	0.016	0.013
6	8	15	21	0.042	0.030
5	7	17	14	0.102	0.063
2	6	17	7	0.26	0.15

Note: "Rate at indifference" indicates the values of the hyperbolic (k) and continuously compounded exponential (r) discount rates at which the immediate and the delayed rewards are of equal value. All delays are in days.

choice between six candies now or 17 candies in seven days. Given the constraint of using whole numbers of candies, we generated seven questions with discount rates as similar as possible to those used for money. In the statistical analyses we only use information from participants for whom we were able to assign values that were consistent with at least five of seven of the participant's candy choices.

2.2.4. Explanatory variables

Through structured interviews, we collected quarterly information from participants on several of the explanatory variables proposed by Becker and Mulligan (1997). Participants reported their own ages, but because many people did not know their birth date, the variable for age contains measurement error.

We took a broad view of human capital and decomposed it into several parts, including formal school attainment, objective measures of proficiency in spoken and written Spanish and Tsimane', and knowledge of arithmetic. We collected objective measures because self-reports of language proficiency often contain significant measurement errors (Godoy, Huanca, & Rabindran, 2001). Participants reported their own years of formal education as well as that for their parents. We used simple tests to determine literacy in Tsimane' and Spanish, and knowledge of arithmetic. To determine literacy we picked at random one of several sentences written in Spanish or Tsimane' in large letters, and asked the participant to read it. Answers were coded as "could not read" (0), "could read with difficulty" (1), and "could read well" (2). Reading tests were administered in broad daylight to avoid measurement errors from poor vision. In the test of arithmetic participants were asked in the language of their choice to solve four problems requiring them to add, subtract, multiply, and divide. Each correct answer scored 1 point, yielding a scale of 0–4. We had four different tests of arithmetic, and chose one at random for each participant.

We measured wealth as the monetary value of the following physical assets owned (or co-owned) by the person: cattle, ducks, chickens, pigs, rifles, radios, canoes, mosquito nets, dogs, machetes, and axes. Assets were valued at the selling price (or bartering rate) in the village. Income refers to the cash and barter income earned by the person during the 30 days before the interview took place. Since some analysts might object to the use of Western concepts of wealth and income to analyze primitive economies, we also measured present nutritional status as a possible proxy for income and wealth, as well as health. Previous authors have suggested that nutrition affects patience (c.f., Loewenstein, 1996). We measured the height and the weight of each participant and computed a body-mass index, BMI (kg/mt^2) and several other measures of body muscle and fat to proxy for nutritional status.

2.2.5. Analyses

Discount rates were regressed on each explanatory variable, both separately and in multivariate analyses that included together the explanatory variable, gender, and age. In no case did the inclusion of gender and age change the reported results enough to merit discussion. For simplicity we focus on the results from the simple regressions. For all regression analyses we examined outliers in the univariate distributions (cases at or beyond the inner fences; Hoaglin, Iglewicz, & Tukey, 1986), cases with high leverage (greater than twice the mean leverage; Belsley, Kuh, & Welsch, 1980), cases with residuals from the regression line that would occur less than 1% of the time in a multivariate normal distribution, and cases with high influence, which were found by visually inspecting scatterplots of residuals and by assessing Cook's D (Cook, 1977). No values of Cook's D greater than 1.0 were found in any of the analyses and are not discussed below. To give the reader a sense of the robustness of the observed correlations, we report correlations using all of the data, and again after excluding unusual cases. Any instances in which reanalysis made a difference in the results are noted below.

Because our measure of discount rates is bounded at the extremes, it is possible that the rate estimates could be particularly inaccurate for participants who are assigned to values at the endpoints. Such participants always chose the immediate or always chose the delayed rewards, so it is also possible that their responses might be qualitatively different from the other participants. For example, if one did not believe that delayed rewards would ever be delivered, then one might always choose the immediate rewards regardless of one's discount rate. For these reasons we reanalyzed all data excluding participants who always chose the immediate or always chose the delayed rewards. Any instances where this made a difference are noted below.

3. Results

Table 4 contains summary statistics for each of the explanatory variables, and the estimated discount rates when using money or candy to make choices. Except for gender, all of our explanatory variables are potentially endogenous. We did not experimentally manipulate the explanatory variables. All relationships discussed here must be seen as correlations rather than as causal statements.

Table 4
Summary statistics for variables ($n = 154$)

Variable	Minimum	First quartile	Median	Third quartile	Maximum
Age (years)	10.9	19.9	27.4	39.0	80.0
Body-mass index	16.8	20.8	22.3	23.7	29.0
Wealth ($b)	9	290	475	1038	7078
Cash ($b)	0	8	31	75	804
Education (years)	0	0	1	3	10
Numeracy score	0	0	1	2	4
Spoken Spanish score	0	0	1	1	2
Spanish literacy score	0	0	0	2	2
Tsimane literacy score	0	0	0	2	2
Father's education	0	0	0	0	10
Father's literacy	0	0	0	0	1
Monetary discount rates (k)	0.0016	0.048	0.12	0.21	0.25
Candy discount rates (k)	0.0013	0.082	0.14	0.26	0.26

Note: $b = bolivianos ($US 1.00 ≈ $b 6.00).

3.1. Consistency

For the monetary choices we required that at least six of eight (⩾ 75%) of the participant's choices be consistent with the estimated discount rate. This eliminated estimates from one or more quarters for 12 participants, leaving 147 participants with discount rates that met this criterion for one or more of the four quarters. For the candy choices we required that at least five of seven (⩾ 71%) of the choices be consistent with the estimated discount rate. This eliminated estimates from one or more quarters for seven participants, but again leaving 147 participants with discount rates that met this criterion for one or more of the four quarters. For the included participants, the mean consistency for both money and candy was greater than 93% in each of the four quarters. Mean consistency is increased by participants who always choose the immediate or delayed rewards and thus are 100% consistent with the highest or lowest rate. (Because the former vastly outnumbered the latter in our data, this also created a positive correlation between rate estimates and consistency.) However, even excluding all participants who always chose the immediate rewards or who always chose the delayed rewards, mean consistency remained greater than 92% in each of the four quarters for both money and candy, except for choices over candy during the first quarter where the mean consistency was 89%. Including these participants, but excluding choices during the first quarter, which had the lowest consistencies and which we do not use for reasons described below, we were able to assign rates in all conditions such that over 94% of the participants' choices were consistent with the assigned rates.

3.2. Reliability over time

We assessed the reliability over time of the discount-rate estimates by computing all of the pairwise correlations between estimates from the four quarters. These corre-

Table 5
Pairwise correlations between discount-rate estimates from each of the four quarters

	Quarter		
	First	Second	Third
Money			
Quarter			
Second	0.004^{+} (95)		
Third	0.09^{-} (108)	0.33^{+} (116)	
Fourth	0.09^{-} (96)	0.15^{+} (101)	0.32^{+} (121)
Candy			
Quarter			
Second	0.12^{+} (100)		
Third	0.12^{-} (108)	0.23^{+} (120)	
Fourth	0.03^{+} (99)	0.23^{+} (106)	0.46^{-} (123)

Note: *n*s for each correlation are shown in parentheses underneath. A plus sign following the correlation indicates that cases with high leverage or large residuals tended to suppress the correlation. A minus sign following the correlation indicates that cases with high leverage or large residuals tended to increase the correlation.

lations for both monetary and candy choices are shown in Table 5. To assess the effects of unusual cases on the magnitudes of the correlations we repeated the analyses excluding cases with high leverage and cases with large residuals from the regression line. (We repeated this procedure iteratively until no such unusual cases remained.) A plus sign following a correlation in Table 5 indicates that unusual cases tended to suppress the correlation, whereas a minus sign indicates that unusual cases tended to increase the correlation.

The correlations between the second and third quarters, and between the third and fourth quarters are reliable for both monetary and candy choices (all ps $\leqslant$ 0.01). The first quarter rates were not reliably correlated with any of the other rates (all ps $\geqslant 0.24$). In a principle-components analysis of the discount rates (using Varimax rotation) over the four quarters, the second, third and fourth quarter rates all loaded highly on the first rotated component (all loadings $\geqslant 0.62$ for money; all loadings $\geqslant 0.52$ for candy). However, the first quarter rates loaded very low on the first component (0.04 for money; 0.02 for candy), and loaded alone on the second (loadings $\geqslant 0.94$). Taken together these results indicate that for both monetary and candy choices the first quarter rates were not reliably associated with the rate estimates from other quarters, but that the second, third, and fourth quarter estimates were associated with a single underlying factor. Perhaps in the first quarter participants did not yet trust the researchers (discount rates were higher in the first quarter than in the other three quarters, which one would expect if participants perceived a higher risk of not receiving delayed rewards in the first quarter), or were not clear about the nature of the task (perhaps evidenced by their slightly lower levels of choice consistency). For this reason, in the results below we used only the discount rates from the second, third, and fourth quarters. In cases where we used the mean rate across quarters in the analysis, we used the mean across only the last three quarters. There was one participant who had low outside values on the mean rate estimate across the last three quarters for both the money and candy rate estimates. This participant was excluded from the analyses below.

3.3. Correlations between discount rates for money and candy

The rate estimates for money and candy all were reliably correlated within quarters (all $ps < 0.0002$). Because these correlations were inflated by participants who always chose the immediate rewards for both money and candy, we report the correlations excluding those participants in parentheses. For the first quarter the correlation was 0.61 (0.32), for the second it was 0.34 (0.24), for the third it was 0.35 (0.09), and for the fourth it was 0.69 (0.56). For the mean rate across the last three quarters the correlation between money and candy rates was 0.63 (0.41). These correlations are strong, but also suggest that people may have different discount rates for different types of goods or for different magnitudes of goods.

3.4. Demographic variables and discount rates

3.4.1. Age

To explore the relation between age and discount rates, we plotted the logarithms of the estimated discount rates [$\ln(k)$] as a function of age, and estimated the trend using LOWESS smoothing (Cleveland, 1981) and distance-weighted least squares smoothing (McLain, 1974). Both smoothing methods yielded similar results. The results using LOWESS are shown in Fig. 1. In the top two panels the higher curves correspond to the smoothed fits for all of the data, and the lower curves show the smoothed fits when participants at the highest and lowest values of k, and two participants over 70 years, are excluded from the analyses. In all cases for both money and candy the smoothed trends were roughly U-shaped, with the minima in discount rates occurring at about 20 years of age. In the bottom two panels of Fig. 1 the fits are shown separately for men and women. Again, all fits have minima around 20 years of age.

This analysis offers suggestive support for a U-shaped function, as predicted by Becker and Mulligan (1997), but we have no evidence that the decreasing part of the pattern below 20 years is reliable. We ran separate linear regressions for ages below 20 years and for ages 20 years and above. For the below-20 group the correlations were negative, but not reliable for either money ($r = -0.06$) or candy ($r = -0.07$), both $t(37)\text{s} \geqslant -0.42$, $ps \geqslant 0.68$. Note that evidence from the delay-of-gratification literature (e.g., Mischel & Metzner, 1962) rather firmly indicates that impatience falls throughout childhood for populations in the United States. It is possible that our failure to find a significant decline in discount rates in our data results

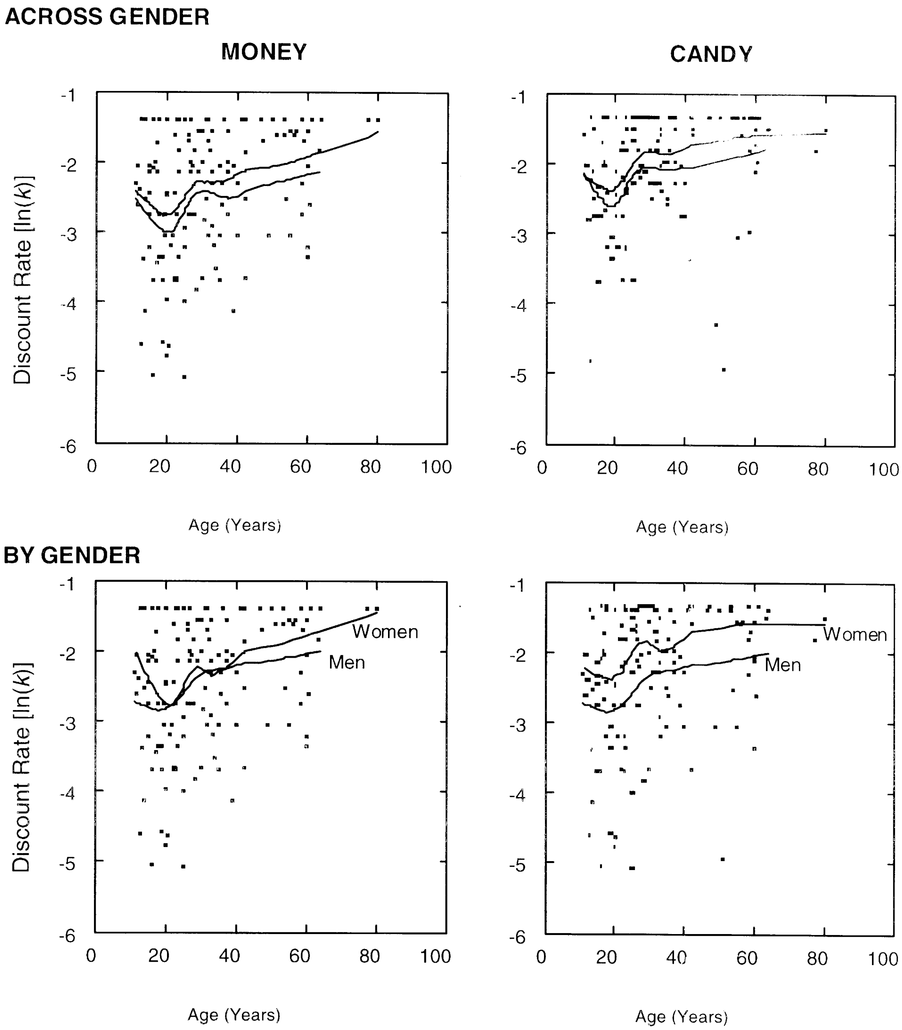

Fig. 1. Discount rates as a function of age, for both monetary and candy choices. In the upper panels the higher curves show LOWESS smoothing for all participants. The lower curve in each panel shows LOWESS smoothing when participants who chose only immediate or only delayed rewards, and the two participants over age 70, are excluded. The lower panels show the smoothed curves for all men and all women separately.

from a truncated sample at the low end of the age range; we did not collect information on discounting for people below about 10 years of age.

Evidence for the increasing part of the pattern is much stronger. For the 20-and-above group the correlation between age and discount rate was $r = 0.31$ for money, $t(99) = 3.26$, $p = 0.002$, and $r = 0.17$ for candy, $t(99) = 1.68$, $p = 0.10$. (Excluding two cases in the candy data for 20 and above with studentized residuals below

-4.0, the correlation between discount rates and age was $r = 0.29$, $t(97) = 2.95$, $p = 0.004$.) Across all ages the linear correlation between age and discount rates was 0.30 for money, $t(138) = 3.75$, $p = 0.0003$, and 0.27 for candy, $t(138) = 3.35$, $p = 0.001$. Thus, although Becker and Mulligan's (1997) predicted increase in discount rates through adulthood is not found in previous literature (e.g., Green et al., 1999), it is this increasing trend that appears most strongly in the present data. Our data does not support Rogers's (1994) predicted inverted-U-shaped relationship between age and discount rates.

3.4.2. Nutrition

BMI was very highly correlated across the four quarters (all rs $\geqslant 0.87$) so here we report only the relation between mean BMI and mean discount rate over the last three quarters. Nutritional status seems to have little relationship with discount rates. For money the correlation was -0.10, $t(141) = -1.21$, $p = 0.23$. (Two cases with large leverage made no difference in the correlation.) For candy the correlation was $+0.09$, $t(141) = 1.02$, $p = 0.31$. (One case with large leverage and three cases with large residuals made no difference in the correlation.) Correlations remained insignificant when we eliminated people under age 18, and when we did separate analyses for men and women. (We found similar insignificant relationship between discount rates and body fat, arm muscle area, and skinfold thicknesses at four different sites.)

For adults (over 17 years), values of BMI less than 18 indicate undernourishment, values from 25 to 29.9 are classified as overweight, and values over 30 indicate obesity (National Institutes of Health, 1998; Shetty & James, 1994). Only seven participants had mean BMI scores below 18 (three of these were under age 18), 25 had BMIs in the 25–30 range, and none had BMIs greater than 30. Excluding four missing cases, 118 participants fell into the "optimal" category. Thus, it is possible that our failure to find a relation between BMI and discount rates was due to a restricted range of nutritional status relative to Western societies (e.g., see Frisancho, 1990).

3.4.3. Gender

For money, women ($\bar{k} = 0.10$) had slightly higher discount rates than men ($\bar{k} = 0.083$), but the difference between the means was not reliable, $t(144) = 1.35$, $p = 0.18$, $r = 0.11$. The same was true for candy, where women ($\bar{k} = 0.13$) had slightly higher discount rates than men ($\bar{k} = 0.12$), $t(144) = 0.97$, $p = 0.33$, $r = 0.08$. The gender effect is in the opposite direction and slightly smaller than typically found in Western cultures (e.g., $r = 0.12$ in the opposite direction among American college students in Kirby & Marakovic, 1996).

3.5. Wealth and income

3.5.1. Wealth

To correct for positive skew, we transformed the wealth variable using $\log_{10}(\text{wealth} + 1)$. The correlations between discount rates and wealth within each

Table 6
Correlations between discount rates and wealth and cash income

	Quarter			
	Second	Third	Fourth	Mean
Wealth				
Monetary choices				
All participants	−0.03	−0.01	−0.01	−0.03
Excluding outliers and immediate-only	0.21	0.02	−0.15	0.07
Candy choices				
All participants	0.08	−0.01	0.20*	0.03
Excluding outliers and immediate-only	0.11	−0.01	0.08	
Cash income				
Monetary choices				
All participants	0.05	−0.08	−0.25*	−0.09
Excluding outliers and immediate-only	−0.10	−0.16	−0.16	0.02
Candy choices				
All participants	−0.05	−0.05	−0.20*	−0.11
Excluding outliers and immediate-only	−0.13	−0.19	−0.19*	−0.06

Note: $^*p < 0.05$, unadjusted for the number of tests performed.

of the second, third, and fourth quarters, and between the means across these three quarters, are shown in the top part of Table 6. Table 6 shows the correlations between wealth and discount rates for all participants, and excluding from the analysis all outliers, participants with zero wealth, and participants who chose only immediate or only delayed rewards. Only the correlation in the fourth quarter between wealth and discount rates for candy was reliable, even before adjusting for the number of tests performed. To the extent that there is any evidence of a relation between wealth and discount rates it is in a positive direction, which is the opposite of the prediction by Becker and Mulligan (1997).

3.5.2. Cash income

We transformed the cash variable using $\log_{10}(\text{cash income} + 1)$. The correlations between discount rates and cash income within each of the second, third, and fourth quarters, and between the means across these three quarters, are shown in the lower part of Table 6. In contrast with the results for wealth, the correlations between cash and discount rates are mostly negative, and are reliable in the fourth quarter. This suggests that discount rates may decrease as the amount of cash income a person has received within the past 30 days increases.

3.6. Schooling

3.6.1. Years of education

The variable for years of education contained a high proportion of zero values and had a positive skew. Transformations to reduce skew made little difference in the correlations, so we report only the results for the untransformed values. There was an inverse relationship between a person's own education and discount rates for both money, $r = -0.42$, $t(140) = -5.51$, $p < 0.0001$, and candy, $r = -0.39$, $t(140) = -5.07$, $p < 0.0001$. (This effect was reduced but remained significant after excluding points with high leverage and residuals, and both correlations increased slightly when people who chose all immediate rewards were excluded.)

Sixty-one people had no education, so to ensure that our results were robust to the influence of zeros, we repeated the analyses by coding education as a binary variable; people had either no education or some education. For money, people with no education had higher discount rates ($n = 61$, $\bar{k} = 0.13$) than people with some education ($n = 81$, $\bar{k} = 0.067$), $t(140) = 4.70$, $p < 0.0001$, $r = 0.37$. For candy, people with no education had higher discount rates ($\bar{k} = 0.17$) than people with some education ($\bar{k} = 0.10$), $t(140) = 3.91$, $p < 0.0001$, $r = 0.31$. Within the group that had some education the correlations between discount rates and years of education remained reliable for money, $r = -0.26$, $t(79) = 2.44$, $p = 0.02$, and candy, $r = -0.28$, $t(79) = 2.64$, $p = 0.01$.

3.6.2. Arithmetic

Fig. 2 shows the (geometric) mean discount rates for participants with each of the five scores on the arithmetic test, for both monetary and candy choices. We conducted the analyses using linear contrasts in an ANOVA on the five arithmetic scores. For both money and candy there was a negative relation between arithmetic and discount rates. For money, the linear decrease in rates was reliable, $r = -0.30$, $t(140) = 3.76$, $p = 0.0002$. The deviations from the linear trend were not reliable, $F(3, 140) = 3.06$, $p = 0.08$. For candy, the linear decrease in rates was reliable, $r = -0.24$, $t(140) = 2.87$, $p = 0.005$. The deviations from the linear trend were not quite reliable, $F(3, 140) = 3.60$, $p = 0.06$.

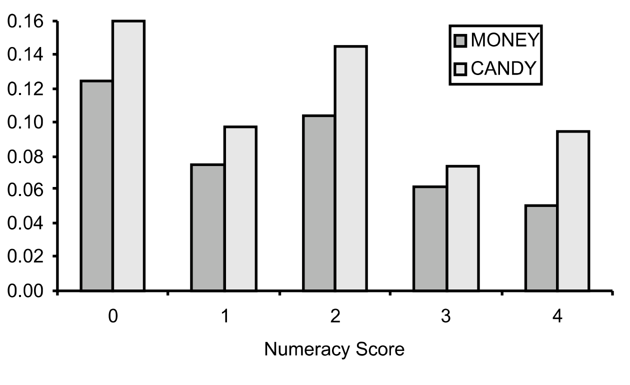

Fig. 2. Mean discount rates for monetary and candy choices for each of the five possible scores on arithmetic.

3.6.3. Fluency in spoken Spanish

Because our measure of fluency in spoken Spanish had only three levels, we examined the relation with discount rates using contrasts in an ANOVA framework. The upper panel of Fig. 3 shows the mean discount rate for each of the three levels for both money and candy. For both monetary and candy choices, as scores in fluency in spoken Spanish increased discount rates decreased. The negative linear relation between fluency in spoken Spanish and discount rates was reliable, $t(142) = -2.88$, $p = 0.005$, $r = -0.23$. The deviations from the linear trend were not reliable,

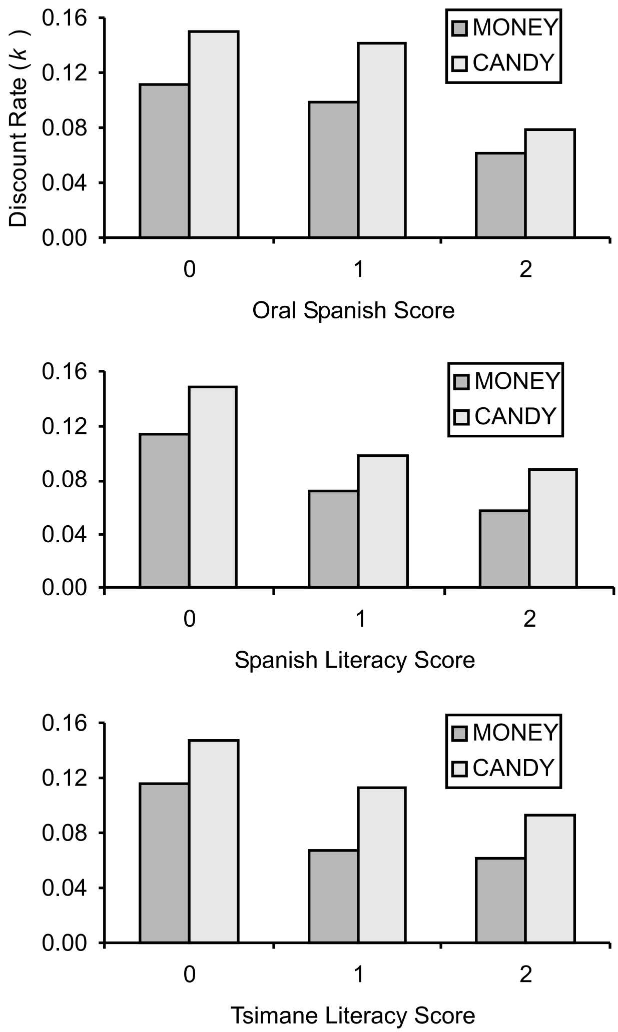

Fig. 3. Mean discount rates for monetary and candy choices for each of the three possible verbal scores for spoken Spanish (upper panel), Spanish literacy (middle panel), and Tsimane' literacy (lower panel).

$t(142) = 1.08, p = 0.28, r = 0.08$. For candy, the negative linear relationship between spoken Spanish and discount rates for candy was reliable, $t(142) = -3.89$, $p = 0.0002$, $r = -0.31$. The deviations from the linear trend were also significant due to a larger drop in discount rates from the middle to highest level than from the lowest to middle level, $t(142) = 2.12$, $p = 0.04$, $r = 0.18$.

3.6.4. Spanish literacy

Our measure of Spanish literacy also had three levels, so again we examined the relationship with discount rates using contrasts in an ANOVA framework. The middle panel of Fig. 3 shows the mean discount rates for each of the three levels for money and candy. For money, the negative linear relation between Spanish literacy and discount rates was reliable, $t(142) = -4.06$, $p < 0.0001$, $r = -0.32$. The deviations from the linear trend were not reliable, $t(142) = 0.44$, $p = 0.66$, $r = 0.04$. For candy, the negative linear relation between Spanish literacy and discount rates was reliable, $t(142) = -3.65, p = 0.0004, r = -0.29$. The deviations from the linear trend were not reliable, $t(142) = 0.63$, $p = 0.53$, $r = 0.05$.

3.6.5. Tsimane' literacy

The bottom panel in Fig. 3 shows the mean discount rate for each of the three levels of Tsimane' literacy for both monetary and candy choices. In both cases, as Tsimane' literacy increased discount rates decreased. For money, the negative linear relationship was reliable, $t(142) = -3.91$, $p = 0.0001$, $r = -0.31$. Deviations from the linear trend were not reliable, $t(142) = 0.87$, $p = 0.39$, $r = 0.07$. For candy, the negative linear relationship between Tsimane' literacy and discount rates was reliable, $t(142) = -3.24$, $p = 0.001$, $r = -0.26$, and deviations from the linear trend were not, $t(142) = 0.17$, $p = 0.86$, $r = 0.01$.

3.6.6. Father's education

Because only six participant's mothers had any education (and none of the participant's mothers could read), we limited the analysis to estimating the relationship between the education of the participant's father and the participant's discount rates.

There was an inverse relationship between the participants' fathers' years of education and the participants' discount rates for both money, $r = -0.32$, $t(144) = -4.07$, $p < 0.0001$, and candy, $r = -0.26$, $t(144) = -3.26$, $p = 0.001$. For money, people whose fathers had no education ($n = 128$) had higher discount rates ($\bar{k} = 0.097$) than people whose fathers had some education ($n = 18$, $\bar{k} = 0.058$), $t(144) = 2.23, p = 0.03, r = 0.18$. For candy, people whose fathers had no education had higher discount rates ($\bar{k} = 0.13$) than people whose fathers had some education ($\bar{k} = 0.095$), $t(144) = 1.57$, $p = 0.12$, $r = 0.13$. Within the group ($n = 18$) whose fathers had some education, the correlations were in the same direction and reliable for money, $r = -0.61$, $t(16) = 3.04$, $p = 0.008$, and candy, $r = -0.52$, $t(16) = 2.42$, $p = 0.03$.

3.6.7. Father's literacy

For money, people whose fathers could read ($n = 11$) had lower discount rates ($\bar{k} = 0.032$) than people whose fathers could not read ($n = 135$, $\bar{k} = 0.099$), $t(144) = 4.09$, $p < 0.0001$, $r = 0.32$. For candy, people whose fathers could read had lower discount rates ($\bar{k} = 0.060$) than people whose fathers could not read ($\bar{k} = 0.13$), $t(144) = 3.34$, $p = 0.001$, $r = 0.27$.

3.6.8. Combining education variables

A principle-components analysis (using Varimax rotation) of the education variables identified three components with eigenvalues greater than 1.0. The first component we call *own education*, and was associated with Tsimane' literacy, Spanish literacy, years of education, and knowledge of arithmetic, all with loadings greater than 0.82. The second component we call *father's education*, consisting of fathers' reading scores and years of education, both with loadings greater than 0.95. Last, *spoken Spanish* loaded on a third component (0.94) by itself. Together, these components were associated with 23% of the variance in discount rates for money, which was highly reliable, $F(3, 138) = 13.6$, $p < 0.0001$. These components were associated with 19% of the variance in discount rates for candy, which was highly reliable, $F(3, 138) = 10.9$, $p < 0.0001$.

3.7. Drug use

Kirby et al. (1999) found that heroin addicts had higher discount rates than did a control group that did not use drugs. There is no close analog to an illicit drug among the Tsimane'. In the present data we examined the relationships between discount rates and several proxies for drugs or substance abuse, including drinking commercial alcoholic beverages, a home-made alcoholic beverage known as *chicha* made from fermented manioc, the chewing of coca leaves, and the smoking of cigarettes. These substances are consumed as part of ordinary life, without the stigma attached in Western cultures. We did not find any meaningful associations between discount rates and drug use. The majority of our participants reported no use of these substances, and we had very few cases of immoderate use (the highest was smoking).

4. Discussion

The final column of Table 1 summarizes the main findings in this study. The relationships that emerged most clearly were between discount rates and the schooling and literacy variables. In all cases the relationships indicate that discount rates decrease as these human-capital variables increase. The results are consistent with Becker and Mulligan's (1997) model, which predicts that investments in education will reduce discount rates. It is also possible, of course, that more patient people are more willing to invest in schooling, which has delayed payoffs, or that they tend to do better in school and stick with school longer. The least interesting explanation would be if some third variable, such as intelligence, accounted for both performance in the choice task and the observed differences in educational variables. We have no reason to think this is true but we cannot rule it out.

We found a reliable positive relationship between age and discount rates. This is nearly opposite to the results found in the studies reported by Green et al. (1999), where discount rates were found to decrease until roughly age 30, beyond which they remained stable. These divergent results may indicate that cultural differences influence discount rates in age-specific manners. For example, differences in life expectancies, retirement plans, and mechanisms for passing along inheritances could affect discount rates in the second half of life. It is also possible that the differences in the procedures used in ours and Green et al.'s studies, or the use of hypothetical rewards in Green et al.'s study, could account for the difference in results. In any case, our data taken in isolation provides only weak support for Becker and Mulligan's (1997) predicted U-shaped relationship between discount rates and age. We found a small but unreliable decrease in discount rates up to age 20, and a strong and reliable increase thereafter. Becker and Mulligan's case is made stronger if our data is combined with the substantial evidence from the delay-of-gratification literature (e.g., Mischel & Metzner, 1962) that discount rates declines throughout childhood. Our age data would appear to contradict Rogers's (1994) predicted inverted-U-shaped relationship between discount rates and age.

We found no relationships between discount rates and nutritional status (our proxy for health), drug use, gender, or wealth. This last result is particularly important because Becker and Mulligan's (1997) predictions for wealth were central to their model. Our measure of wealth – the total value of the person's physical assets – would appear to be an optimal measure. However, Pender (1996) found a reliable inverse relationship between wealth and discount rates using a similar measure. We have no explanation for why our results are different from Pender's, but cultural differences are one possibility. Using data from the US, Green et al. (1996) and Hausman (1979) found inverse relationships between income and discount rates, and it is probably safe to assume that household income was highly correlated with wealth in their samples. However, we also tended to find inverse relationships between income and discount rates (within quarters), but no relationships between discount rates and wealth. The relationship with income makes intuitive sense if having more cash on hand makes one more willing to wait for a delayed reward. Recent cash income and the immediate rewards we provided may have been more substitutable in the consumption stream than were our rewards and the participants' physical assets. Although it is possible that income and wealth effects in the Becker–Mulligan model might be fleshed out differently for simple horticultural societies than for industrial societies, at present we see within the model no obvious grounds for doing so. Our failure to find any consistent relationship between discount rates and wealth would appear to pose a serious challenge to the cross-cultural generality of the Becker and Mulligan model.

One of the fundamental problems in personality psychology is trying to determine the extent to which a personality characteristic is a "trait", meaning a relatively immutable attribute of the person, or a "state", meaning a situationally or temporally dependent attribute. We face the same problem in trying to understand individual differences in discount rates. In personality, the answer is often, perhaps even typically, "both" (see e.g., Haan, Millsap, & Hartka, 1986; McCrae & Costa, 1994). Of course, we cannot distinguish temporal changes in discount rates from unreliability in our discount rate measure. Even so, the low but reliable correlations in discount rates between quarters (Table 5) suggest the possibility that discount rates have both stable and situational components. This is not surprising. Any measure of discounting is likely to be influenced by the person's momentary situation. Preferences between immediate and delayed candies, for example, are likely to be influenced by current hunger levels (c.f., Loewenstein, 1996). Preferences between immediate and delayed amounts of money are likely to be influenced by current cash income (as we observed). Given the myriad considerations impinging at any given point in time on choices between delayed rewards, from one perspective it is remarkable that discount rates were correlated across quarters at all. Furthermore, it would seem that the correlation between the participants' discount rates and their fathers' educational levels would rule out a purely situational account. Our data is consistent with the possibility that one's discount rate is a somewhat stable characteristic of the person that is also strongly influenced by situational factors.

Discount rates for money and candy were highly, but not perfectly, correlated within quarters. It is possible that people have different discount rates for different types of rewards, as has been suggested in other research (Kirby & Guastello, 2001). However, because our monetary and candy rewards were of much different magnitudes, it is also possible that the differences in observed rates could be attributable to individual differences in the size of the magnitude effect on discount rates (smaller rewards are discounted at higher rates than larger rewards; see Kirby, 1997). Of particular importance for our purposes, however, is the fact that nearly every relationship that we observed held for both money and candy choices. This increases the generalizability of our results, while also helping to rule out reward-specific artifacts in the data.

Last, we return to the issue of the lack of a correlation between discount rates in the first quarter and later quarters. We believe that this was because in the first quarter participants were unfamiliar with the procedure and many may not yet have trusted the experimenters to deliver the delayed rewards. Although the procedure had been piloted in an earlier quarter, the experimenters did not move into the village to live until the first quarter of actual data collection. This suggests that cross-sectional estimates of discount rates in developing nations, particularly in primitive economies, may yield noisy measures. This highlights the importance of using repeated measures from the same people to assess discount rates in future studies.

Acknowledgements

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