

On the Interaction of Risk and Time Preferences: An Experimental Study

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Abstract. *Experimental studies of risk and time preference typically focus on one of the two phenomena. The goal of this paper is to investigate the (possible) correlation between subjects' attitude to risk and their time preference. For this sake we ask 61 subjects to price a simple lottery in three different scenarios. At the first, the lottery premium is paid 'now'. At the second, it is paid 'later'. At the third, it is paid 'even later'. By comparing the certainty equivalents offered by the subjects for the three lotteries, we test how time and risk preferences are interrelated. Since the time interval between 'now' and 'later' is the same as between 'later' and 'even later', we also test the hypothesis of hyperbolic discounting. The main result is a statistically significant negative correlation between subjects' degrees of risk aversion and their (implicit) discount factors. Moreover, we show that the negative correlation is independent of the method used to elicit certainty equivalents (willingness to pay versus willingness to accept).*

1. INTRODUCTION

Most major economic decisions are made under conditions of uncertainty and affect the future as well as the present (e.g., the classical consumption/savings allocation problem). The optimal decisions thus typically depend on risk attitudes as well as on time preferences. But how are these two aspects interrelated? Are risk attitudes and time preferences, for instance, independent in the sense that risk attitudes are no reliable indicator of time preferences and vice versa? Or will risk aversion usually coincide with impatience?

In this paper we approach the problem empirically by performing appropriate (classroom) experiments. In fact, the experimental literature on decision and choice contains many references exploring the risk attitudes (see,

for example, the survey by Camerer, 1995) and time preferences (see, for example, Loewenstein and Elster, 1992) of human subjects. To the best of our knowledge, however, there have not been yet any direct attempts to investigate the correlation between risk attitudes and time preferences.¹

Previous experiments on intertemporal consumption in stochastic environments (see the survey by Anderhub and Güth, 1999) typically adopt a very complicated design of the environment. In these cases it seems unreasonable to expect that participants would choose the optimal consumption plan given their individual risk attitudes and time preferences. Hey and Dardanoni (1987), for instance, report the results of a large-scale optimal consumption experiment where subjects' actual behaviour departed significantly from the optimal plan. In such a context, it seems impossible to disentangle the impact of the cognitive limitations from the impact of the various constellations of time and risk preferences. We therefore chose to run a very simple distinct experiment to examine the relationships between individual risk attitude and time preferences.

In our experiments each participant had to evaluate (i.e., state his certainty equivalent to) three lotteries which differed only in the timing of their payments. The premium from the first lottery (L_0) was paid to the subjects immediately after the experiment (date 0). The premium from the second lottery (L_4) was paid four weeks after the experiment. The premium from the final lottery (L_8) was paid eight weeks after the experiment.

Since lotteries are risky prospects, the certainty equivalents should reveal some information on the basic risk attitudes. Time preferences were revealed since each participant had to decide on all three lotteries simultaneously. Since the payments from the three lotteries were fixed at three equidistant points in time, the experiment can also be used to test the hypothesis of **hyperbolic discounting** (see, for instance, Ainslie and Haslam, 1992; Loewenstein and Prelec, 1992; Laibson, 1996).² Owing to the rather robust evidence for an **endowment** or **status quo** effect (see Samuelson and Zeckhauser, 1988; Thaler, 1980; Tietz, 1992; for a sample of experimental evidence) it also seems interesting to check how impatience and risk aversion interact with the status quo.³ In particular, we wanted to check whether our findings are robust with respect to the method of eliciting certainty equivalents. In principle, it is

1. Prelec and Loewenstein (1991) and Keren and Roelofsma (1995) study the interaction between choice with uncertainty and intertemporal choice. Prelec and Loewenstein (1991) formulate two general psychological principles that explain the different 'anomalies' that have been found in choice with uncertainty and in intertemporal choice. Keren and Roelofsma (1995) study the interrelations between the certainty effect in choice with uncertainty and the immediacy effect in intertemporal choice. These references, however, do not deal explicitly with subjects' attitudes to risk.
2. Hyperbolic discounting means that discounting per a given period is greater the nearer this period. See Section 3 for more details.
3. The endowment effect says that potential sellers ask for higher prices than those offered by potential buyers. See the references above for more details.

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possible that willingness to pay-data will reveal another (cor)relation of time and risk preferences than the corresponding willingness to accept-data. We have thus divided our subjects into two groups. The first group (of 27 subjects) was asked to state the maximal price they are willing to pay for the lottery. The second group (of 34 subjects) was endowed with the lottery and asked to state the minimum price for which they are willing to sell the lottery. We, henceforth, refer to the first treatment as the *P*-treatment (where *P* stands for 'willingness to pay') and to the second treatment as the *A*-treatment (where *A* stands for 'willingness to accept').

In Section 2 we describe in detail the experimental procedure. The main experimental results are presented in Section 3. Section 4 concludes.

2. METHOD

2.1. Subjects

The subjects were 61 undergraduate economics students recruited at the University of Haifa, Israel.

2.2. Procedure

Participants were seated isolatedly in a large lecture hall to discourage any kind of communication. Appendix A presents the written instructions for each one of the two basic treatments. At the beginning of the experiment, the subjects were requested to read the instructions independently. We then went over the instructions with the subjects and answered questions individually.

The instructions start by introducing a risky prospect that pays a 'premium' of 25 NIS (new Israeli shekels) or 125 NIS with equal probabilities.⁴ Subjects are told that at the end of the experiment it will be randomly decided whether the realized premium will be paid immediately, after four weeks or after eight weeks, where the probability of each payment date is 1/3. The subjects are then asked to state the maximal buying price that they are willing to pay for the lottery (in the case of the *P*-treatment) or the minimal selling price that they require for the lottery (in the case of the *A*-treatment). Each subject is asked to state three valuations, one value for each possible realization date of the lottery. The actual realization date was randomly determined (for all subjects simultaneously) at the end of the experiment. We henceforth use L_0 , L_4 , L_8 to denote the values stated by the subjects; \bar{L}_t is used to denote the average value of L_t (across all subjects).

We use the random price mechanism (Becker *et al.*, 1964) to determine whether each subject will actually get (in the *P*-treatment), or sell (in the *A*-

4. The conversion rate of the NIS (new Israeli shekels) with respect to the American dollar at the time of the experiment was approximately 4 shekels per dollar.

treatment) the lottery and the actual price that he will pay or receive for the lottery. That is, we randomly draw an integer k between 0 and 125 and sell the lottery to the subject at the price k (in the P -treatment) if the maximal buying price stated by the subject for the corresponding realization date is not lower than k ; we buy the lottery from the subject at price k (in the A -treatment), if the minimal selling price stated by the subject for the corresponding realization date is not higher than k . Since the random mechanism is incentive compatible,⁵ we assume that L_0 , L_4 and L_8 represent the individual certainty equivalents for the lottery with payments today, in four weeks and eight weeks, respectively.

2.3. Deferred cheques

A special problematic feature of building an incentive scheme for such an experiment is that some of the payments to the subjects should be made 'in the future', one or two months after the experiment. The corresponding incentive scheme might be ineffective if the participants have doubts whether future payments will actually be made as described in the instructions. To avoid the problem, we have exploited the Israelian practice of using 'deferred cheques'; i.e., cheques whose monetary transfers are supposed to take place at a pre-specified future date. Note, however, that by using deferred cheques to guarantee future payments we decrease (even eliminate) the risk that is typically associated with postponed payments. In the concluding discussion we argue that this might have a significant effect on the experimental results. Thus, subjects were told that they will receive a 'deferred cheque' immediately after the experiment, where the payment time specified on the cheque will be either now, in four weeks or in eight weeks, depending on the realized payment date, as explained above.⁶

In particular, in the case of treatment P , we have endowed each subject with 75 NIS.⁷ If the subject 'won' the lottery for the price k , the buying price k was subtracted from the initial endowment and the subject received a cheque (for date 0) for the difference, $75 - k$. In addition, the subject received a (possibly) deferred cheque for the realized premium payment.⁸ If the subject did not win the lottery he simply received an immediate cheque for 75 NIS (his endowment).

5. That is, stating one's true certainty equivalent as the buying or selling price is the only undominated strategy.
6. Note that deferred cheques serve just like regular cheques when the prespecified withdrawal date arrives. In particular, the cheque-holder can deposit it in any bank in his favourite location.
7. Since $L_t^P \leq 75$ universally and $L_t^A > 75$ for only seven of the 102 A -treatment cases, it seems that the arbitrary choice of initial endowment did not have a significant effect on our results. With this regard, note also that only 4 per cent of the prices stated in the P -treatment were equal to 75 (while the corresponding percentage for the A -treatment was 36 per cent).
8. The two sums were combined and paid in one cheque when the realization date of the lottery was zero.

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In the case of treatment *A*, we have endowed each subject with the lottery. If the subject 'won' the possibility to sell the lottery for the price k , the subject got an immediate cheque for the realized selling price k . Otherwise, the subject got a (possibly) deferred cheque for the realized lottery premium.

The chance moves deciding whether the premium is high or low and whether it will be paid now, in four weeks or in eight weeks were publicly performed immediately after the experiment by throwing a die to decide whether the premium is high or low and throwing the die once more to determine the payment timing. We have then used the results to fill out the individual cheques for the subjects.

3. RESULTS

The experimental data for the two treatments are presented in Appendix B. The first three columns of the table represent the ordered decision vectors L_0 , L_4 , L_8 for each treatment. The next column represents the quotient

$$\delta_1 = \frac{L_4}{L_0}$$

which we take as a measure of the discount factor from date 4 to date 0. The fifth column represents the corresponding measure of the discount factor from date 8 to date 4,

$$\delta_2 = \frac{L_8}{L_4}$$

The last column presents an estimate of the degree of risk-aversion of the corresponding subject:

$$r_0 = \frac{75 - L_0}{75}$$

Note that since the expected value of our basic lottery is 75, risk-averse subjects should evaluate the lottery at a price lower than 75 when the payment date is 0; i.e. r_0 should be positive. Risk-seeking subjects, on the other hand, should be willing to pay more than 75 for the same risky prospect; i.e. r_0 should be negative. The data in Appendix B show that only two subjects (in the *A*-treatment) have asked more than 75 for the lottery.

From the data in the Appendix one can easily verify that the endowment effect carries over to the current investigation.

Observation 1. The cumulative distributions of L_0 , L_4 and L_8 for the *A*-treatment stochastically dominate the corresponding cumulative distributions for the *P*-treatment; i.e. for every number L , $\text{Prob}\{L_t^A \leq L\} \leq \text{Prob}\{L_t^P \leq L\}$, for $t = 0, 4$ and 8 , where L_t^P denotes the cumulative distribution of L_t in the *P*-

treatment, L_t^A denotes the distribution of L_t in the A -treatment, and the inequality is strict in the overlapping range of L_t^P and L_t^A .

To check the statistical significance of the stochastic dominance effect, we have applied the Kolmogorov–Smirnov test ($Z = 2.962, 2.506$ and 1.851 ; $p = 0.000, 0.000$ and 0.002 for $t = 0, 4$ and 8 , respectively) and the Mann–Whitney test ($Z = -5.765, -4.621$ and -3.274 , $p = 0.000, 0.000$ and 0.001 for $t = 0, 4$ and 8 , respectively). Since all tests clearly support the status quo effect, we can safely state

Conclusion 1. Even when the object under consideration is a lottery, and the date at which the lottery’s payoff will be realized is uncertain, subjects’ willingness to accept is on average significantly higher than their willingness to pay, for each possible realization date.

As explained above, we measure the individual degree of risk aversion by the ratio r_0 . Observation 1 immediately implies that the distribution of r_0^P stochastically dominates the distribution of r_0^A . This leads to the next conclusion:

Conclusion 2. The status quo has a significant effect on the revealed risk preferences. In particular, the individual risk-aversion measures generated from the P -treatment are significantly higher (in the sense of first-order stochastic dominance) than the ones derived from the A -treatment.

The hyperbolic discounting conjecture (see the references mentioned in the introduction) basically says that the discount factor applied to payoffs that are expected at date t , $\delta(t)$, is decreasing hyperbolically in t , so that $\delta(t) - \delta(0) > \delta(t+K) - \delta(K)$ for every positive t and K . Thaler (1981), for instance, suggests that decision-makers might prefer one apple today to two apples tomorrow and at the same time prefer two apples in 51 days to one apple in 50 days. Hyperbolic discounting is considered one of the ‘anomalies’ (see Loewenstein and Prelec, 1992) that characterize human behaviour in intertemporal choice and contradict Samuelson’s discounted utility model.

In the context of our experiments hyperbolic discounting implies that $\delta_2 > \delta_1$. On average, $\delta_2 = 0.9587$ and $\delta_1 = 0.9398$ in the P -treatment while $\delta_2 = 0.9185$ and $\delta_1 = 0.9110$ in the A -treatment. The average implicit discount rates thus satisfy the hyperbolic discounting conjecture. The difference between δ_1 and δ_2 , however, is statistically insignificant (see the test results in Table 1 for each treatment separately and for both treatments combined).

Table 2 indeed shows that only 23 per cent of the subjects conformed with the hyperbolic discounting hypothesis in our experiments. These findings are summarized in the next observation.

Observation 2. Only 14 of our 61 participants satisfy hyperbolic discounting in the sense of $\delta_2 > \delta_1$. There is no significant treatment effect with respect to the percentage of subjects conforming with hyperbolic discounting (22.2 per cent for the P -treatment and 23.5 per cent for the A -treatment). The average

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Table 1 Test results for the difference between δ_1 and δ_2

	P-treatment	A-treatment	Both treatments
Kolmogorov–Smirnov	$Z = 0.544$ $p = 0.928$	$Z = 0.606$ $p = 0.856$	$Z = 0.815$ $p = 0.520$
Mann–Whitney	$Z = -0.664$ $p = 0.507$	$Z = -0.413$ $p = 0.680$	$Z = -0.818$ $p = 0.414$

Table 2 Number of subjects with ($\delta_2 > \delta_1$) or without ($\delta_1 \geq \delta_2$) hyperbolic discounting

	P-treatment	A-treatment	Total
$\delta_1 = \delta_2 = 1$	14	10	24
$\delta_1 > \delta_2$	7	16	23
$\delta_2 > \delta_1$	6	8	14
Total	27	34	61

discount factors for the second period are slightly higher than the corresponding factors for the first period, but the differences are not statistically significant.

Note also that the implicit discount rates (δ_1^A , δ_1^P and δ_2^A , δ_2^P) are not significantly different across treatments⁹ (Kolmogorov–Smirnov test $Z = 0.824$, $p = 0.506$, and Mann–Whitney test $Z = -1.043$, $p = 0.297$ for δ_1^A , δ_1^P ; Kolmogorov–Smirnov test $Z = 0.913$, $p = 0.375$, and Mann–Whitney test $Z = -1.625$, $p = 0.104$ for δ_2^A , δ_2^P). Still, the data show that

$$\frac{\odot L_0^P}{\odot L_0^A} = 0.71 < \frac{\odot L_4^P}{\odot L_4^A} = 0.73 < \frac{\odot L_8^P}{\odot L_8^A} = 0.76$$

so that the relative size of the endowment effect decreases slightly the longer the delay.¹⁰

How are the risk attitudes and time preferences interrelated? Table 3 gives the coefficients of correlation between r_0 and δ_1 and between r_0 and δ_2 for each of the treatments and for the aggregated data. The Spearman coefficients for

9. We use δ_i^j to denote the discount factor for period i in treatment j .
10. The quotient δ_1/δ_2 takes higher values more often in the P-treatment than it does in the A-treatment. The difference between the corresponding distributions, however, is insignificant (Kolmogorov–Smirnov test $Z = 0.913$, $p = 0.375$, and Mann–Whitney test $Z = -1.274$, $p = 0.203$).

Table 3 Correlations with respect to r_0

	δ_1	δ_2	δ_2/δ_1
A-treatment	-0.476***	-0.285*	0.080
P-treatment	-0.316**	-0.364**	-0.252*
Both treatments	-0.140	-0.064	0.046

* $p = 0.1$; ** $p = 0.05$; *** $p = 0.01$.

each treatment separately turn out to be negative and significantly different from zero (one-sided). However, when we pool the data together the negative significant correlation disappears: the difference between the results for both treatments are not statistically significant. The results are summarized in the next conclusion.

Conclusion 3. The data reveal a statistically significant negative correlation between the degree of risk aversion and the intensity of discounting. That is, subjects that exhibit a relatively high degree of risk aversion tend to discount the future more heavily than subjects that are less risk averse.

To check whether risk attitudes are somehow correlated with the (in)consistency of time preferences, we have also calculated the correlation between r_0 and δ_2/δ_1 . The results here, however, are not significantly different from zero (see Table 3).¹¹

4. DISCUSSION

The main result of the paper suggests that risk-averse agents tend to discount the future more heavily (than agents that are less risk averse or risk seeking). This observation is in agreement with previous research (Keren and Roelofsma, 1995) suggesting that discounting is (partially) due to the uncertainty encapsulated in future payoffs.¹² In general, the literature on intertemporal choice distinguishes between two different components underlying time discounting. The first is related to the fact that delaying reward implies delay of gratification. A reward of \$100 in one year is worth less than a reward of \$100 today because in the former case one has to wait a year before actually using the

11. Note, however, that the measures of r_0 , δ_1 and δ_2 used above are 'arbitrary' in the sense that they have not been derived from any formal theory of choice. To take a more rigorous approach, one may adopt some parametric family of utility functions (e.g. $u(x) = x^\alpha$) and use the individual L_0 's to solve for the individual α 's. One may then use the individual L_4 and L_8 to derive the implicit discount factors δ_1 and δ_2 . We have made a few attempts to analyse the data in this approach but the results were uninformative.
12. See also the discussions in Chapman (1977), Richards *et al.* (1999), Gafni and Torrance (1984), Rachlin *et al.* (1991, 2000).

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money. The second component concerns the risk associated with delaying the reward. A reward of \$100 in a year carries the risk that, due to unforeseen contingencies, in a year, the reward will not be received after all. This risk does not exist when the reward is paid today.

Keren and Roelofsma (1995) demonstrate that introducing external uncertainty (i.e., probabilistic outcomes) has a similar effect on subjects' behaviour as the expansion of time delays. For example, Keren and Roelofsma report that in choosing between (A) Fl.100 now or (B) Fl.110 in four weeks, 82 per cent chose A. When the probability of getting the positive prospect (in each alternative) was decreased to 50 per cent, the proportion of subjects choosing A has decreased to 39 per cent. The effect of postponing the payment date by 26 weeks was similar: only 37 per cent of the subjects chose 'Fl.100 in 26 weeks' over 'Fl.110 in 30 weeks'. This suggests that risk-averse agents might indeed discount future payoffs more heavily to compensate for the uncertainties associated with the postponed payoffs. In particular, risk-averse agents might be more inclined towards myopic behaviour.

Note, however, that since we have used ('risk-free') deferred cheques to 'guarantee' future payments and since the time intervals used in the experiment were rather short (four weeks and eight weeks) it is reasonable to assume that the risk associated with future payoffs was relatively small in our experiment. This might explain the relatively low discount rates observed in the data and the fact that 39 per cent of the subjects did not discount the future at all. Given this qualification, one may argue that the observed negative correlation between subjects' degree of risk aversion and their implicit discount factors mainly reflects the inclination of risk-averse decision-makers to be more sensitive to the delay of gratification associated with postponed payoffs.

Somewhat surprisingly, we found that only 22.8 per cent of our subjects comply with the hyperbolic discounting conjecture.¹³ A possible explanation lies in the framing of the experiment. In our experiment, the subjects were asked to state the three conditional prices L_0 , L_4 and L_8 concurrently. The typical experimental evidence on hyperbolic discounting is composed of two separate binary choice problems (as demonstrated by the one or two apples example described in Section 3) where the subjects inconsistently prefer the smaller and closer outcome when both outcomes are close but switch to preferring the larger and remote outcome when both outcomes are remote. We speculate that this inconsistency will become weaker if subjects are asked to make both choices at the same time; for example, if we ask the subjects to choose whether they want to consume one apple today or two apples tomorrow and (at the same time) decide whether they prefer one apple in 50 days or two apples in 51 days. We also guess that in the framework of our experiments the evidence in favour of hyperbolic discounting might have been

13. Note, however, that 39 per cent of the subjects did not discount at all. The percentage of subjects complying with hyperbolic discounting out of the 'discounting' subjects is 37.8 per cent (14/37).

stronger if the subjects were asked to state the price they will be willing to pay (or willing to accept) in four weeks for a lottery that is paid in eight weeks (and the corresponding number will be divided by L_4 to approximate δ_2).¹⁴

Note also that previous experimental investigations of hyperbolic discounting did not use deferred cheques to guarantee future payoffs. Thus, the effect might have been more pronounced than in the previous investigations since the subjects doubt that the future money transfers will actually occur.

Finally, our experiment also demonstrates that subjects' degree of risk aversion might be highly sensitive to the experimental procedure that is used to elicit the risk preferences. In particular, the endowment effect carries over to the case of lotteries' evaluation so that subjects exhibit a significantly higher degree of risk aversion in the *P*-treatment (than in the *A*-treatment).¹⁵

Note also that the endowment effect documented in our study seems quite large in size given the fact that we compare a fixed endowment of 75 with a 75-expected-payoff lottery. A possible explanation might be found in the fact that the *P*-treatment either pays a fixed amount (i.e., the initial endowment of 75) or a complicated two-stage lottery (where one payoff is at the present and the other may be postponed). The *A*-treatment, on the other hand, always pays an uncertain lottery. This suggests that our documented endowment effect might (at least partially) be attributed to a certainty premium that subjects are willing to pay against the stronger uncertainty associated with the *A*-treatment.¹⁶

APPENDIX A: INSTRUCTIONS

Introduction (general)

In the experiment you have to decide whether you want to engage in a risky prospect or not. We start by describing the risky prospect. Afterwards you will be informed how you decide whether or not to engage in it. The **risky prospect** pays you the high premium of NIS 125 when a toss of a die yields the numbers 1, 2 or 3, otherwise (i.e. in case the die shows the numbers 4, 5 or 6), it yields the low premium of NIS 25. The **timing of the premium payments** is not yet decided. The three possibilities are that the premium will be paid today, in four weeks, or in eight weeks. When you decide whether or not to engage in the risky prospect, you can, however, condition your decision on the timing of the premium payment. In other words: you decide whether or not to engage in the risky prospect when the payment date is today, whether or not to engage in the risky prospect when the payment date is in four weeks, and whether or not

14. However, an experimental investigation of this conjecture seems difficult since the corresponding experiment requires that the subject pays (in the *P*-treatment) for the lottery four weeks before he receives the payoffs.
15. For additional evidence on the dependency of risk preferences on the decision-makers' position with respect to the underlying lottery, see Shavit *et al.* (2000).
16. We thank an anonymous referee for this interesting interpretation.

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to engage in the risky prospect when the payment date is in eight weeks. How will we decide **which payment timing applies**? After you make your decisions we will roll a die. If the die shows 1 or 2 the payment date will be today. If the die shows 3 or 4 the payment date will be in four weeks. If the die shows 5 or 6 you will be paid in eight weeks. In the next subsection we explain how you decide whether or not to engage in each of the three prospects.

Instructions (P-treatment)

You will receive a monetary endowment of NIS 75 which you can either keep or invest in the risky prospect. The price p that you will be asked to pay for the prospect will be randomly chosen from the interval $0 \leq p \leq 125$. The urn in front of you contains many such prices p . We will randomly select one of these numbers. You are requested to choose a limit price L such that you are willing to buy the risky prospect at all prices p not exceeding L , i.e. at prices $p \leq L$, whereas you do not buy it at all prices exceeding L , i.e. at prices $p > L$. Note that your limit price L does not determine the price p that you pay in case of buying the risky prospect. It only determines the prices p in which you are willing to buy the prospect, namely all prices p not exceeding L . Note that you can choose three different limit prices for the three possible payment dates. A limit price L_0 for the case where the prospect is paid today, a limit price L_4 for the case where the prospect is paid in four weeks, and a limit price L_8 for the case where the prospect is paid in eight weeks. These will be the only choices you are requested to make. At the end of the experiment we will toss a die to determine the actual payment date. If it turns out that you do not buy the risky prospect, you will simply receive your monetary endowment of NIS 75 immediately after the experiment. If it turns out that you buy the risky prospect at price p , you will receive a monetary payoff of NIS 75 minus p immediately after the experiment. In addition we will toss a die to determine the realized payment of the prospect (125 or 25) and give you a cheque for the corresponding amount, for the corresponding payment date.

Instructions (A-treatment)

You will receive the risky prospect as an endowment. You can either keep it or sell it for money. The price p that you will be offered for selling the prospect will be randomly chosen from the interval $0 \leq p \leq 125$. The urn in front of you contains many such prices p . We will randomly select one of these numbers. You are requested to choose a limit price L such that you are willing to sell the risky prospect at all prices p not lower than L , i.e. at prices $p \geq L$, whereas you do not sell it at all prices below L , i.e. at prices $p < L$. Note that your limit price L does not determine the price p that you get in case of selling the risky prospect. It only determines the prices p in which you are willing to sell the prospect, namely all prices p not lower than L . Note that you can choose three different limit prices for the three possible payment dates. A limit price L_0 for

the case where the prospect is paid today, a limit price L_4 for the case where the prospect is paid in four weeks, and a limit price L_8 for the case where the prospect is paid in eight weeks. These will be the only choices you are requested to make. At the end of the experiment we will toss a die to determine the actual payment date. If it turns out that you do not sell the risky prospect, we will toss a die to determine the realized payment of the prospect and give you a cheque for the corresponding amount, for the corresponding payment date. If it turns out that you sell the risky prospect at price p , you will receive a monetary payoff of p immediately after the experiment.

Decision form (general)

For the **today prospect** whose premium is due today I choose the limit

$$L_0 = \dots \text{(you can choose any non-negative limit)}$$

For the **four weeks prospect** whose premium is due in four weeks from now I choose the limit

$$L_4 = \dots \text{(you can choose any non-negative limit)}$$

For the **eight weeks prospect** whose premium is due in eight weeks from now I choose the limit

$$L_8 = \dots \text{(you can choose any non-negative limit)}$$

APPENDIX B: RESULTS

<i>P</i> -treatment	L_0	L_4	L_8	δ_1	δ_2	r_0
1	26	26	26	1	1	0.653
2	40	35	30	0.875	0.857	0.467
3	45	35	30	0.778	0.857	0.4
4	45	40	35	0.888	0.875	0.4
5	45	40	40	0.888	1	0.4
6	45	40	40	0.888	1	0.4
7	50	40	35	0.8	0.875	0.333
8	50	40	40	0.8	1	0.333
9	50	45	40	0.9	0.889	0.333
10	50	45	40	0.9	0.889	0.333
11	50	45	40	0.9	0.889	0.333
12	50	45	40	0.9	0.889	0.333
13	50	47	45	0.94	0.957	0.333
14	50	50	50	1	1	0.333
15	50	50	50	1	1	0.333
16	50	50	50	1	1	0.333
17	50	50	50	1	1	0.333
18	50	50	50	1	1	0.333
19	50	50	50	1	1	0.333
20	50	50	50	1	1	0.333
21	50	50	50	1	1	0.333
22	50	50	50	1	1	0.333
23	50	50	50	1	1	0.333
24	60	50	50	0.833	1	0.2
25	65	65	65	1	1	0.133
26	70	70	70	1	1	0.067
27	75	75	75	1	1	0

A-treatment	L_0	L_4	L_8	δ_1	δ_2	r_0
1	50	40	30	0.8	0.75	0.333
2	50	45	40	0.9	0.888	0.333
3	50	47	45	0.94	0.957	0.333
4	60	40	35	0.666	0.875	0.2
5	60	50	40	0.833	0.8	0.2
6	60	50	40	0.833	0.8	0.2
7	60	55	50	0.916	0.909	0.2
8	60	55	50	0.916	0.909	0.2
9	65	55	40	0.846	0.727	0.133
10	65	55	45	0.846	0.818	0.133
11	70	60	60	0.857	1	0.067
12	70	67	65	0.957	0.97	0.067
13	72	70	70	0.972	1	0.04
14	75	70	68	0.933	0.971	0
15	75	50	50	0.667	1	0
16	75	60	40	0.8	0.667	0
17	75	60	50	0.8	0.833	0
18	75	65	50	0.867	0.769	0
19	75	67.5	60	0.9	0.889	0
20	75	68	60	0.906	0.882	0
21	75	70	65	0.933	0.928	0
22	75	70	70	0.933	1	0
23	75	75	75	1	1	0
24	75	75	75	1	1	0
25	75	75	75	1	1	0
26	75	75	75	1	1	0
27	75	75	75	1	1	0
28	75	75	75	1	1	0
29	75	75	75	1	1	0
30	75	75	75	1	1	0
31	75	75	75	1	1	0
32	75	80	85	1.066	1.062	0
33	100	80	70	0.8	0.875	-0.33
34	100	95	90	0.95	0.947	-0.33

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REFERENCES

- Ainslie, G. and N. Haslam (1992), 'Hyperbolic Discounting', in: G. Loewenstein and J. Elster (eds.), *Choice Over Time*, Russell Sage Foundation, New York.
- Anderhub, V. and W. Güth (1999), 'On Intertemporal Allocation Behavior – A Selective Survey of Saving Experiments', *ifo Studien* 45(3), 303–333.
- Becker, G. M., M. H. DeGroot and J. Marshak (1964), 'Measuring Utility by a Single-Response Sequential Method', *Behavioral Science* 8, 41–55.
- Camerer, C. (1995), 'Individual Decision Making', in: J. H. Kagel and A. E. Roth (eds.), *The Handbook of Experimental Economics*, Princeton University Press, Princeton, NJ.
- Chapman, G. B. (1997), 'Risk Attitude and Time Discounting', *Medical Decision Making* 17, 355–356.
- Gafni, A. and G. W. Torrance (1984), 'Risk Attitude and Time Preference in Health', *Management Science* 30, 440–510.
- Hey, J. D. and V. Dardanoni (1987), 'Optimal Consumption under Uncertainty: An Experimental Investigation', *Economic Journal* 98, 105–116.
- Keren, G. and P. Roelofsma (1995), 'Immediacy and Certainty in Intertemporal Choice', *Organizational Behavior and Human Decision Processes* 63, 287–297.
- Laibson, D. (1996), 'Hyperbolic Discount Functions, Undersaving, and Savings Policy', NBER Working Paper No. 5635.
- Loewenstein, G. and J. Elster (eds.) (1992), *Choice over Time*, Russell Sage Foundation, New York.
- Loewenstein, G. and D. Prelec (1992), 'Anomalies in Intertemporal Choice: Evidence and an Interpretation', *Quarterly Journal of Economics*, 107, 573–597.
- Prelec, D. and G. Loewenstein (1991), 'Decision Making over Time and Under Uncertainty', *Management Science* 37, 770–786.
- Rachlin, H., A. Raineri and C. Cross (1991), 'Subjective Probability and Delay', *Journal of the Experimental Analysis of Behaviour* 55, 233–244.
- Rachlin, H., J. Brown and D. Cross (2000), 'Discounting in Judgments of Delay and Probability', *Journal of Behavioral Decision Making* 13, 145–159.
- Richards, J. B., L. Zhang, S. H. Mitchell and H. de Wit (1999), 'Delay or Probability Discounting in a Model of Impulsive Behavior: Effects of Alcohol', *Journal of the Experimental Analysis of Behaviour* 71, 121–143.
- Samuelson, W. and R. Zeckhauser (1988), 'Status Quo Bias in Decision Making', *Journal of Risk and Uncertainty* 1, 7–59.
- Shavit, T., D. Sonsino and U. Benzion (2000), 'On the Evaluations of Lotteries and Options on Lotteries', Working Paper, Technion.
- Thaler, R. (1980), 'Toward a Positive Theory of Consumer Choice', *Journal of Economic Behavior and Organization* 1, 39–60.
- Thaler, R. (1981), 'Some Empirical Evidence on Dynamic Inconsistency', *Economic Letters* 8, 201–207.
- Tietz, R. (1992), 'An Endowment Effect in Market Experiments?', in: S. E. G. Lea, P. Webley and B. M. Young (eds.), *New Directions in Economic Psychology: Theory, Experiment and Application*, Edward Elgar, Aldershot.