Journal of Mathematical Psychology **45**, 265–282 (2001)
doi:10.1006/jmps.2000.1312, available online at http://www.idealibrary.com on IDEAL®

Time Preference for Health: A Test of Stationarity versus Decreasing Timing Aversion

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This paper provides a new and more robust test of the descriptive validity of the constant rate discounted utility model in medical decision analysis. The constant rate discounted utility model is compared with two competing theories, Harvey's (1986) proportional discounting model and Loewenstein and Prelec's (1992) hyperbolic discounting model. To compare the various intertemporal models, previous studies on intertemporal preferences for health assumed a specific parametric form of the utility function for life-years and no discounting within the time periods that health states are experienced. The present study avoids such confounding assumptions by focusing on the axiomatic structure of the discounting models. The present study further differs by using choices instead of matching to elicit intertemporal preferences. The experimental results provide support for decreasing timing aversion, the condition underlying the proportional and the hyperbolic discounting model, but they violate stationarity, the central condition of the constant rate discounted utility model. There is some ambiguity whether the violations of stationarity are primarily caused by an immediacy effect. The results confirm violations of stationarity in choice-based elicitations tasks, in contrast with the results from Ahlbrecht and Weber (1997) which supported stationarity in choices over monetary outcomes.

Key Words: time preference; medical decision making; utility theory.

We are grateful to Daniel Read, Peter Wakker, an associate editor, and two referees for their comments on previous drafts. Han Bleichrodt's research was made possible by a fellowship from the Royal Netherlands Academy of Arts and Sciences. Financial support was received from the National Corporation of Swedish Pharmacies and from Merck, Sharp, and Dohme.

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0022-2496/01 $35.00

This paper studies individual intertemporal preferences for health. The common way to model the impact of time on the valuation of health is by the constant rate discounted utility model. Empirical evidence has shown that the constant rate discounted utility model is a poor description of individual intertemporal preferences (Thaler, 1981; Loewenstein, 1987; Loewenstein, 1988; Benzion, Rapoport, & Yagil, 1989; Loewenstein & Prelec, 1992; Shelley, 1993; Kirby, 1997). The evidence suggests that individual intertemporal preferences are more in line with a discount rate that decreases over time. Alternative models have been proposed that incorporate this empirical finding, e.g., Harvey's (1986) proportional discounting model and Loewenstein and Prelec's (1992) hyperbolic discounting model.

Most violations of the constant rate discounted utility model have been elicited for preferences over monetary outcomes. It is not a priori clear that these results are also valid for health outcomes. There is no arguing that health is special as an outcome in decision analyses. An important difference between health and money is that health is not readily transferable through time. Consequently, intertemporal preferences for health are not distorted by investment and savings considerations and thus by interest rates, and studies using health outcomes may more accurately reflect individual intertemporal preferences than studies using monetary outcomes. Chapman & Elstein (1995) and Chapman (1996a, 1996b) present empirical evidence that intertemporal preferences for money and health are different and that what is true for monetary outcomes need not hold for health outcomes.

Several studies have examined the validity of the constant rate discounted utility model for medical decision making. The common procedure in these studies is to infer discount rates from people's preferences and to test whether these discount rates are constant over time. These studies generally display a discounting pattern that is at variance with the constant rate discounted utility model (Cairns, 1992; Redelmeier & Heller, 1993; Cropper, Aydede & Portney, 1994; Chapman & Elstein, 1995; Chapman, 1996a; Viscusi, Hakes & Carlin, 1997). Unfortunately, these studies have three important problems. First, they have to make specific assumptions about the shape of the utility function for life-years to be able to estimate implied discount rates. Most studies assume that the utility function for life-years is either linear or power. Empirical results support neither the linear nor the power specification for the utility function for life-years (e.g., Miyamoto & Eraker, 1989). Therefore, the possibility cannot be ruled out that the observed violations of constant rate discounting are primarily due to misspecification of the utility function for life-years. More definite conclusions that are independent of the specification of the utility function for life-years can be obtained by looking into the axiomatic structure of the constant rate discounted utility model and its two main alternatives, proportional discounting and hyperbolic discounting, and by testing the axioms that distinguish the models.

Second, previous studies have problems in incorporating the time dimension of health. To be able to estimate discount rates for health, these studies implicitly assume that health states occur at one point in time, thereby ignoring that health states need a duration to be experienced. For example, Chapman (1996a) assumes that in the evaluation of 1 year in a given health state now and x years in the same health state with some delay, only the delay is discounted but no discounting occurs within the 1 year and and the x years that the health state is experienced. This assumption introduces some bias, and it would be preferable to take the time component of health into account in testing hypotheses about individual intertemporal preferences for health.

Finally, the above studies used either matching or rating tasks to elicit intertemporal preferences for health. It is well known that different elicitation procedures lead to different assessments. Tversky, Sattath, and Slovic (1988) have emphasized the difference between choice-based elicitation procedures and matching tasks. Bostic, Herrnstein, and Luce (1990) have shown that the use of choice-based elicitation procedures significantly reduces the number of inconsistencies in individual preferences compared to matching and rating. Interestingly, a recent study by Ahlbrecht and Weber (1997) only displayed violations of constant rate discounting in matching tasks; no violations were observed in choice tasks. Because choice is the basic primitive of decision theory, the findings of Ahlbrecht and Weber suggest that previously found deviations from the constant rate discounted utility model are primarily caused by distorted elicitations.

This paper contains a test of the descriptive validity of constant rate discounting versus proportional and hyperbolic discounting that avoids the above three problems. The first part of the paper contains an axiomatic analysis of the models. We describe the axioms that distinguish the constant rate discounted utility model from the proportional and hyperbolic discounted utility models, and we derive a test of these axioms that takes into account the time dimension of health. In the second part of the paper, we use this test in an experiment where preferences are elicited by choice to reduce the possibility of distorted elicitations.

The structure of the paper is as follows. Section 1 describes the axiomatic differences between constant rate discounting and proportional and hyperbolic discounting. Section 2 contains the derivation of the test of the axioms. Section 3 describes the experimental design used to perform the test derived in Section 2. Section 4 contains the results of the experiment. Section 5 concludes.

1. THEORY

Consider a preference relation $\succcurlyeq$ meaning "at least as preferred as." The preference relation is defined over a set of health profiles Q^T, where T stands for the individual's remaining lifetime. The set of health profiles is a Cartesian product of the single-period sets of health outcomes Q, which are assumed identical. Health profiles are denoted by Roman letters (q, r, etc.) and health outcomes by Greek letters (α, β, etc.). As usual, $\succ$ denotes the asymmetric part of $\succcurlyeq$ (strict preference) and $\sim$ denotes the symmetric part of $\succcurlyeq$ (indifference). The preference $q \preccurlyeq r$ is equivalent to $r \succcurlyeq q$. A preference relation over health outcomes is defined from preferences over constant health profiles: $\alpha \succcurlyeq \beta$ only if $(\alpha, ..., \alpha) \succcurlyeq (\beta,, \beta)$. Let $\alpha_t q$ denote the profile q with the outcome at point in time t, q_t, replaced by $\alpha : \alpha_t q = (q_1, ..., q_{t-1}, \alpha, q_{t+1}, ..., q_T)$. Let A be a subset of the set of time points S.

Denote by $\alpha_A q$ the profile q with the outcomes that occur at points in time that are elements of the set A replaced by α. For example, if $A = \{2, 3\}$ then $\alpha_A q = (q_1, \alpha, \alpha, q_4, ..., q_T)$. Finally, $\{\alpha, ..., \varphi\}_A\, q$ with $A = \{t, ..., t+s\}$ denotes the profile $(q_1, ..., q_{t-1}, \alpha, ..., \varphi, q_{t+s+1}, ..., q_T)$ in which the outcomes can differ over the elements of A.

Throughout the paper, the following structural assumption is made:

Structural assumption. The preference relation $\succcurlyeq$ over the set Q^T can be represented by an additive representation $\sum_{t=1}^{T} \lambda_t U(q_t)$, with U a continuous utility function that is unique up to positive linear transformations, and the λ_t unique positive period-specific decision weights.

Necessary and sufficient conditions for this representation have been given by Krantz, Luce, Suppes, and Tversky (1971), Wakker (1989), and Fishburn & Edwards (1997).

The additive representation is characteristic of a wide class of utility models for denumerable time streams, special cases of which are the constant rate discounted utility model, Harvey's (1986) proportional discounting model, and Loewenstein and Prelec's (1992) hyperbolic discounting model. These three models differ in the assumptions they impose on the period-specific decision weights λ_t, but not in the underlying utility structure. This paper tests the assumptions that are made about the λ_t and not the underlying utility structure. This does not mean that the additive representation is uncontroversial: it requires restrictive assumptions like interperiod independence (Fisher, 1930; Lucas & Stokey, 1984). Loewenstein and Prelec (1993) present empirical evidence that people's preferences violate interperiod independence. Gilboa (1989) and Loewenstein and Prelec (1993) describe more general intertemporal models in which interperiod independence is relaxed.

The constant rate discounted utility model is characterized by imposing *stationarity* on top of the additive representation. The following formulation was used by Fishburn (1970).

DEFINITION 1. The preference relation $\succcurlyeq$ satisfies *stationarity* if there exists an outcome $\alpha \in Q$ such that for all $q, r \in Q^T: (r_1, ..., r_{T-1}, \alpha) \succcurlyeq (s_1, ..., s_{T-1}, \alpha)$ if and only if $(\alpha, r_1, ..., r_{T-1}) \succcurlyeq (\alpha, s_1, ..., s_{T-1})$.

In words, stationarity says that if a particular common outcome α is shifted from the last to the first period and all other outcomes are shifted one period ahead in time, then preferences are unaffected. Definition 1 says that stationarity holds for one particular outcome α. The following result establishes that if the additive representation holds then the choice of the common outcome in the definition of stationarity is irrelevant. If stationarity holds for one common outcome, it holds for all common outcomes.

RESULT 2. *If the additive representation and stationarity hold, then for all outcomes $\alpha \in Q$ and for all $q, r \in Q^T: (r_1, ..., r_{T-1}, \alpha) \succcurlyeq (s_1, ..., s_{T-1}, \alpha)$ if and only if $(\alpha, r_1, ..., r_{T-1}) \succcurlyeq (\alpha, s_1, ..., s_{T-1})$.*

Proof. Let α be the common outcome for which stationarity holds. Substitution of stationarity in the additive representation gives

$$\begin{aligned} \sum_{t=1}^{T-1} \lambda_t U(r_t) + \lambda_T U(\alpha) &\geqslant \sum_{t=1}^{T-1} \lambda_t U(s_t) + \lambda_T U(\alpha) \qquad \text{iff} \\ \lambda_1 U(\alpha) + \sum_{t=2}^{T} \lambda_t U(r_{t-1}) &\geqslant \lambda_1 U(\alpha) + \sum_{t=2}^{T} \lambda_t U(s_{t-1}), \end{aligned} \tag{1}$$

which is equivalent to

$$\begin{aligned} \sum_{t=1}^{T-1} \lambda_t U(r_t) &\geqslant \sum_{t=1}^{T-1} \lambda_t U(s_t) \qquad \text{iff} \\ \sum_{t=2}^{T} \lambda_t U(r_{t-1}) &\geqslant \sum_{t=2}^{T} \lambda_t U(s_{t-1}), \end{aligned} \tag{2}$$

which holds for all common outcomes. ∎

The next result applies stationarity to shifts in time of more than one period and to general subsets of S.

RESULT 3. *Let $A = \{s, ..., t\}$ and $B = \{v, ..., w\}$ be subsets of S. If the additive representation holds, then stationarity implies that for all $\alpha, ..., \varphi, \beta, ..., \mu \in Q$, for all $q \in Q^T$, and for all $e \in \mathbb{Z}$ such that $A + e = \{s + e, ..., t + e\}$ and $B + e = \{v + e, ..., w + e\}$ are also subsets of S,*

$$\{\alpha, ..., \varphi\}_A\, q \succcurlyeq \{\beta, ..., \mu\}_B\, q \qquad \textit{iff} \quad \{\alpha, ..., \varphi\}_{A+e}\, q \succcurlyeq \{\beta, ..., \mu\}_{B+e}\, q.$$

Proof. By Result 2, stationarity holds for all common outcomes. Let $s \leqslant v$ (the case $s > v$ is proved analogously). If s is equal to the first period and t or w is equal to the last period, then e can only be equal to zero and the Result trivially follows. So let us assume that either s is not equal to the first period or both t and w are not equal to the last period. Suppose the latter holds (the other case is proved analogously). We prove the implication if $\{\alpha, ..., \varphi\}_A\, q \succcurlyeq \{\beta, ..., \mu\}_B\, q$, then $\{\alpha, ..., \varphi\}_{A+e}\, q \succcurlyeq \{\beta, ..., \mu\}_{B+e}\, q$. From $\{\alpha, ..., \varphi\}_A\, q \succcurlyeq \{\beta, ..., \mu\}_B\, q$ we obtain by application of stationarity and Result 2 $\{\alpha, ..., \varphi\}_{A+1}\, q \succcurlyeq \{\beta, ..., \mu\}_{B+1}\, q$. If $A + 2$ and $B + 2$ are subsets of S then applying stationarity again gives $\{\alpha, ..., \varphi\}_{A+2}\, q \succcurlyeq \{\beta, ..., \mu\}_{B+2}\, q$. As long as $A + e$ and $B + e$ are subsets of S, repeated application of stationarity and Result 2 then gives $\{\alpha, ..., \varphi\}_{A+e}\, q \succcurlyeq \{\beta, ..., \mu\}_{B+e}\, q$. The reverse implication follows along the same lines of proof. ∎

COROLLARY 4. *If the additive representation holds, then stationarity implies that for all $\alpha, \beta \in Q$, for all $q \in Q^T$, and for all $e \in \mathbb{Z}$ such that $t + e$, $v + e \in S$,*

$$\alpha_t q \succcurlyeq \beta_v q \qquad \textit{iff} \quad \alpha_{t+e} q \succcurlyeq \beta_{v+e} q.$$

In words, Result 3 says that preferences between profiles are unaffected if the timing of all outcomes that differ between the profiles is shifted by e periods.

Corollary 4 asserts the same for *single outcomes*, profiles that differ at only two points in time, which is the case most frequently studied in the literature. Equivalently, Result 3 and Corollary 4 say that preferences between outcomes that are realized at different points in time depend only on the difference in timing and not on the passage of time. Stationarity, which says that intertemporal preferences are not affected if a common delay is added to all outcomes, is similar in spirit to constant absolute risk aversion in decision under risk, which says that preferences over lotteries are not affected if a common constant is added to all outcomes. Stationarity can only hold if the discount function satisfies either $\lambda_{t+e} = \lambda_t \lambda_e$ or $\lambda_{t+e} = \lambda_t + \lambda_e$, which implies that the discount function must be of the exponential family (Aczél, 1966).

Empirical evidence on intertemporal preferences has generally shown that preferences are not insensitive to the passage of time. The typical pattern is that differences in timing become less important with the passage of time. Harvey (1994) refers to this pattern as *decreasing timing aversion*. The displayed empirical violations of the constant rate discounted utility model have spurred the development of alternative intertemporal models in which stationarity is replaced by conditions that reflect decreasing timing aversion. Harvey (1986, 1994, 1995) replaces stationarity by *relative timing preference*, which says that for all $a, b \in Q$, for all $q \in Q^T$, and for all $k \in \mathbb{N}$ such that $ks, kt \in S : \alpha_s q \succcurlyeq \beta_t q$ iff $\alpha_{ks} q \succcurlyeq \beta_{kt} q$. Relative timing preference means that, contrary to stationarity, intertemporal preferences are not invariant with respect to common shifts in time, but are invariant with respect to multiplication of the time points by a common constant. Relative timing preference is comparable to constant proportional risk aversion in decision under risk, which says that preferences over lotteries are unaffected if all outcomes are multiplied by a common constant. Under relative timing preference, the discount function satisfies either $\lambda_{ks} = \lambda_k \lambda_s$ or $\lambda_{ks} = \lambda_k + \lambda_s$ and it follows that the discount function must be of the power family (Aczél, 1966). Loewenstein & Prelec (1992) employed another condition to derive their hyperbolic discounting model. Their condition is also consistent with decreasing timing aversion.

2. EMPIRICAL TESTS

A difficulty in testing intertemporal preferences for health is that duration is an integral part of any health state. Previous studies have assumed that individuals have no time preference within the duration that health states are experienced. An alternative approach, adopted in this paper, is to consider sequences of health states and to use the axiomatic analysis of Section 1 to derive empirical tests of stationarity and decreasing timing aversion for these sequences. By considering sequences of outcomes, the time periods can be made infinitesimally small, which ensures that the assumption of no discounting within time periods becomes innocuous.

We asked individuals to choose between profiles of the types $\alpha_A q$ and $\beta_B q$, with $A = \{s, ..., t\}$ and $B = \{s, ..., u\}$ subsets of the set of time periods, and we examined the impact of the passage of time on individual choice behavior. By Result 3, stationarity predicts that the passage of time has no effect on individual preferences: $\alpha_A q \succcurlyeq \beta_B q$ iff $\alpha_{A+e} q \succcurlyeq \beta_{B+e} q$. The conditions underlying the proportional discounting model and the hyperbolic discounting model were primarily selected to model intertemporal preferences for single outcomes, and it is not straightforward to test these conditions for sequences of outcomes. For example, suppose $A = B = \{1, 2, 3\}$ and $k = 2$. Then Harvey's model predicts that profile $(\alpha, \alpha', \alpha'', q_4, ..., q_T)$ is at least as preferred as profile $(\beta, \beta', \beta'', q_4, ..., q_T)$ if and only if profile $(q_1, \alpha, q_3, \alpha', q_5, \alpha'', q_7, ..., q_T)$ is at least as preferred as profile $(q_1, \beta, q_3, \beta', q_5, \beta'', q_7, ..., q_T)$. The latter types of profiles are highly unintuitive, and pilot testing showed that subjects found it hard to make choices between such profiles. To maximize the reliability of the data, an attempt was made to make the choices as realistic as possible. Therefore, decreasing timing aversion was reformulated in terms of sequences of outcomes to allow a more intuitive empirical test.

Definition 5. The preference relation $\succcurlyeq$ over the set Q^T satisfies *decreasing timing aversion* if for all $\alpha, \beta \in Q$ such that $\alpha \succ \beta$, for all $q \in Q^T$ such that for all $t \in S$ $q_t \succ \alpha \succ \beta$, and for all subsets $A = \{s, ..., t\}$ and $B = \{s, ..., u\}$ of S with $u < t < T$: $\alpha_A q \preccurlyeq \beta_B q$ implies $\alpha_{A+1} q \prec \beta_{B+1} q$.

An example may clarify that Definition 5 indeed reflects that differences in timing become less important with the passage of time. Suppose the vector q stands for T years in full health, α stands for a mild back problem, and β stands for a more severe back problem. Hence, the profile $\alpha_A q$ consists of a mild back problem from time point s up to time point t and full health for the remaining life duration, and the profile $\beta_B q$ consists of the more severe back problem from time point s up to time point u and full health for the remaining life duration. Let indifference hold between $\alpha_A q$ and $\beta_B q$. Substitution in the additive representation yields

$$\begin{aligned}\sum_{t=1}^{s-1} \lambda_t U(\text{full health}) + \sum_{t=s}^{t} \lambda_t U(\text{mild back pain}) + \sum_{t=t+1}^{T} \lambda_t U(\text{full health})\\ = \sum_{t=1}^{s-1} \lambda_t U(\text{full health}) + \sum_{t=s}^{u} \lambda_t U(\text{severe back pain}) + \sum_{t=u+1}^{T} \lambda_t U(\text{full health}),\end{aligned} \tag{3}$$

which gives after some rearrangement

$$\begin{aligned}&U(\text{mild back pain}) - U(\text{severe back pain})\\ &\quad = \left(\sum_{t=u+1}^{t} \lambda_t \Big/ \sum_{t=s}^{u} \lambda_t \right) (U(\text{full health}) - U(\text{mild back pain})).\end{aligned} \tag{4}$$

The preference $\alpha_{A+1} q \prec \beta_{B+1} q$ gives

$$\begin{aligned}&U(\text{mild back pain}) - U(\text{severe back pain})\\ &\quad < \left(\sum_{t=u+2}^{t+1} \lambda_t \Big/ \sum_{t=s+1}^{u+1} \lambda_t \right. (U(\text{full health}) - U(\text{mild back pain})).\end{aligned} \tag{5}$$

A comparison between Eqs. (4) and (5) shows that Definition 5 indeed implies that the relative weight given to the earlier points in time decreases with the passage of time.

Result 6 extends decreasing timing aversion to all delays e.

RESULT 6. *If the additive representation and decreasing timing aversion hold, then for all* $\alpha, \beta \in Q$ *such that* $\alpha \succ \beta$, *for all* $q \in Q^T$ *such that for all* $t \in S$ $q_t \succ \alpha \succ \beta$, *for all subsets* $A = \{s, ..., t\}$ *and* $B = \{s, ..., u\}$ *of* S *with* $u < t < T$, *and for all* $e \in \mathbb{N}$ *such that* $A + e$, $B + e \subset S$:

$$\text{if} \quad \alpha_A q \preccurlyeq \beta_B q \quad \text{then} \quad \alpha_{A+e} q \prec \beta_{B+e} q.$$

Proof. The proof is by induction. Result 6 is satisfied for $e = 1$ by decreasing timing aversion. Suppose it holds for $e = n$. Then by defining $A' = \{s+n, ..., t+n\}$ and $B' = \{s+n, ..., u+n\}$ all prerequisites for decreasing timing aversion are satisfied, and from $\alpha_{A'} q \preccurlyeq \beta_{B'} q$ we derive $\alpha_{A'+1} q \prec \beta_{B'+1} q$, which proves that Result 6 also holds for $n+1$ and, hence, holds in full generality. ∎

In the experiment described in the next section, the above results were used to test stationarity versus decreasing timing aversion. First, indifference was established between $\alpha_A q$ and $\beta_B q$ with $\alpha \succ \beta$. Then, some delay was introduced for the outcomes that differed between the profiles. By Result 3, stationarity predicts that preference will be unchanged and that indifference still holds. By Result 6, decreasing timing aversion predicts that preference will change from indifference to strict preference for the profile $\beta_B q$.

3. EXPERIMENT

3.1. Subjects

Eighty students at the Stockholm School of Economics and 92 students at Erasmus University, Rotterdam, participated in the experiment. The students were paid about \$15 in local currency for their participation. The experiment was carried out in sessions with approximately 10 subjects per session. Before administering the experiment, we tested the questionnaire in several pilot sessions using university staff as subjects.

3.2. Health States and Profiles

Two health states were selected in addition to full health. The selected health states correspond to common types of lower back pain. We selected a mild type of back pain and a more severe type of back pain. The health states were described by level of functioning on four attributes, general daily activities, self care, leisure activities, and pain. The health states were such that on each of the four attributes full health scores at least as good as mild back pain, which in turn scores at least as good as severe back pain. Hence, we expected the preference order full health $\succ$ mild back pain $\succ$ severe back pain. To avoid possible framing biases, subjects were only told that the health states correspond to common types of lower back pain,

TABLE 1

Health States

Mild back pain

- able to perform all tasks at home and/or at work without difficulties
- able to perform all self care activities (eating, washing, dressing) without help
- able to participate in all types of leisure activities albeit with some difficulties
- now and then light to moderate pain and/or other complaints

Severe back pain

- able to perform all tasks at home and/or at work albeit with some difficulties
- able to perform all self care activities (eating, washing, dressing) without help
- unable to participate in certain types of leisure activities
- often light to moderate pain and/or other complaints

Full health

- able to perform all tasks at home and/or at work without difficulties
- able to perform all self care activities (eating, washing, dressing) without help
- able to participate in all types of leisure activities
- no light to moderate pain and/or other complaints

and throughout the experiment mild back pain and severe back pain were referred to as health states A and B, respectively. Table 1 displays the description of the two types of back pain and full health.

Two types of health profiles were used. The first profile, which corresponds to $\alpha_A q$ in Section 2, consisted of 4 years with mild back pain and 16 years in full health. The second profile, which corresponds to $\beta_B q$ in Section 2, consisted of t^1 years with severe back pain and $20 - t^1$ years in full health. Subjects were told that both types of profiles were followed by death. Throughout the paper, we refer to the first profile as the "mild profile" and to the second profile as the "severe profile." To avoid framing biases, the profiles were described to the subjects as "profile 1" and "profile 2."

The time of onset of the 4 years with mild back pain varied across the questions, but it was always equal to the time of onset of the t^1 years with severe back pain. The pilot sessions had shown that subjects found choices between profiles easier when they had identical times of onset of the years with back pain. Referring back to Section 2, we set the distance between time points 1 and T equal to 20 years, the distance between time points s and t equal to 4 years, and the distance between time points s and u equal to t^1 years.

3.3. *Tasks*

To test the presupposed order full health $\succ$ mild back pain $\succ$ severe back pain, subjects were first asked to rank order the health states. Subjects were further asked to put the health states on a rating scale calibrated between 100 (full health) and 0 (death) to obtain insight into the strength of preference of one health state over another.

In the main part of the questionnaire, we asked subjects to choose between the health profiles. Each subject answered three choice questions, one question in which there was no delay and the years with back pain occurred at the beginning of the profiles, one question in which there was a delay of 1 year, and one question in which there was a delay of 3 years. In the notation of Section 2, s was set equal to the first point in time and two different values were used for e: $e=1$ year and $e=3$ years. There were five possible values for t^1: 1 year, 1.5 years, 2 years, 2.5 years, and 3 years. For each delay, a subject only faced one value of t^1. This value was determined by a random procedure under the restriction that the number of observations on each value of t^1 had to be equal. The procedure was repeated for each delay. A subject therefore generally faced a different value of t^1 in each question. The order in which the questions were asked was fixed: first the question with a delay of 0 years, then the question with a delay of 1 year, and finally the question with a delay of 3 years.

The profiles were represented by boxes in which each health state was displayed in a different color. Figure 1 displays the way in which the choice questions were presented. For ease of exposition, Fig. 1 displays the questions next to each other. In the actual experiment, subjects were handed three different cards with the questions printed on them.

At the end of the questionnaire, subjects were asked whether they found the questions hard to answer and the profiles realistic. This was done to get an impression of the reliability of the data. We learnt from the pilot sessions that subjects found the questions easy to answer and realistic, and we wanted to know whether the subjects in the actual sample shared this feeling.

3.4. Methods

Because a choice task was used, the observed variable is discrete. The following discrete choice model was estimated,

$$y_i^* = \beta_0 + \beta_1 * t_i^1 + \varepsilon_i, \tag{6}$$

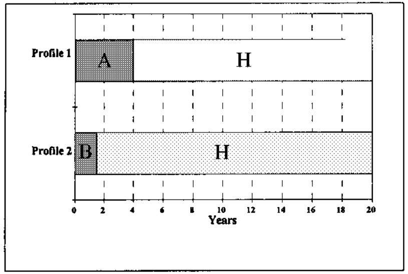
where y^* is a latent variable that can be interpreted as the strength of preference for the severe profile; $y^*=0$ corresponds to indifference. The variable t^1 denotes the time spent with severe back pain, and ε is an error term. Obviously, β_1 is expected to be negative.

Equation (6) was estimated by maximum likelihood under the assumption that the error terms are distributed normally. Yatchew & Griliches (1985) have shown that if the error terms are heteroskedastic, the maximum likelihood estimators will be inconsistent and the variance matrix is inappropriate. Two asymptotically equivalent test statistics were used to test for heteroskedasticity, a Likelihood Ratio test and a Lagrange Multiplier test developed by Davidson & MacKinnon (1984). Monte Carlo evidence has shown that the Likelihood Ratio test has higher power but that the Lagrange Multiplier test performs better under the null hypothesis of no heteroskedasticity. If heteroskedasticity was detected, we used the following correction: var $[\varepsilon_i] = \exp[\gamma^* t^1]$.

Question 1:

Profile 1: 4 years in health state A followed by 16 years in full health

Profile 2: 1.5 years in health state B followed by 18.5 years in full health

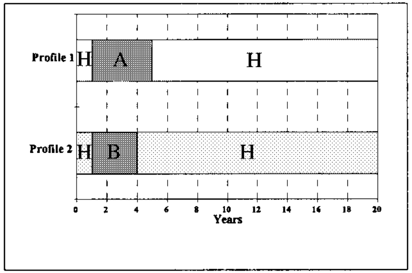


I prefer profile......

Question 2:

Profile 1: 1 year in full health, then 4 years in health state A, followed by 15 years in full health

Profile 2: 1 year in full health, then 3 years in health state B, followed by 16 years in full health

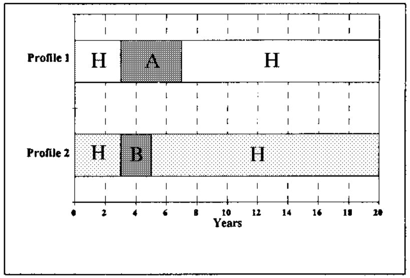


I prefer profile.......

Question 3:

Profile 1: 3 years in full health, then 4 years in health state A, followed by 13 years in full health

Profile 2: 3 years in full health, then 2 years in health state B, followed by 15 years in full health



I prefer profile.....

FIG. 1. The way of presenting the choice questions.

By a corollary to Proposition 1 in Kriström (1990a), the mean indifference value for t^1 can be calculated as $-\hat{\beta}_0/\hat{\beta}_1$, where $\hat{\beta}_0$ and $\hat{\beta}_1$ are the estimated values of β_0 and β_1, respectively. Because we assumed that the error terms are distributed normally, the mean is equal to the median by the symmetry property of the standard normal distribution.

The parameter estimates are not consistent if normality of the error terms does not hold. We therefore included a nonparametric estimator developed by Kriström (1990b). An empirical "survival" function with respect to time in severe back pain was constructed from the proportion of subjects who chose the severe back pain profile for each value of t^1. The mean indifference value of t^1 can be computed by integrating this function. The median indifference value is calculated as the value of t^1 for which the probability of choosing the severe profile is equal to 0.5. To be able to integrate the function, it was assumed that the probability of choosing the severe profile is zero if t^1 is equal to 4 and one if t^1 is equal to zero. The first assumption means that everyone prefers the profile that consists of 4 years with mild back pain and 16 years in full health to the profile that consists of 4 years with severe back pain and 16 years in full health if the 4 years with mild back pain and the 4 years with severe back pain are experienced during the same time period. The second assumption says that everyone prefers the profile that consists of 20 years in full health to the profile that consists of 4 years with mild back pain and 16 years in full health. Both assumptions are plausible if the presupposed ranking of the health states holds.

3.5. *Prediction*

The above procedure allows the calculation of the indifference values of t^1 for each of the three questions. If stationarity holds, then by Result 3 the indifference values are identical in the three questions, the only difference being due to random error. If decreasing timing aversion holds, then holding t^1 constant in the three questions leads to a stronger preference for the severe profile by Result 6. If the indifference value of t^1 from the first question is used in the second question then, by decreasing timing aversion, a majority of the subjects will prefer the severe profile in the second question. The severe profile has to become less attractive to restore indifference, which is achieved by increasing the time in severe back pain. Similarly, if the indifference value of t^1 from the second question is used in the third question, then, by decreasing timing aversion, a majority of the subjects will prefer the severe profile in the third question and t^1 has to be increased to restore indifference. Hence, if decreasing timing aversion holds, the indifference value of t^1 will increase with delay and thus over the three questions.

4. RESULTS

As expected, the rank order of the health states was full health $\succ$ mild back pain $\succ$ severe back pain for all subjects. The mean ratings of mild and severe back pain were 83 and 65, respectively (the rating of full health is equal to 100 by the construction of the scale). In response to the questions at the end of the questionnaire, subjects answered that they found the questions clear and easy to answer and the profiles realistic.

Table 2 displays the estimation results for the discrete choice model. The sign of β_1 is negative and significantly different from zero. This indicates that subjects took the time in severe back pain into account in answering the experimental questions. The parameter estimates vary across the three questions leading to differences in the estimated indifference values for t^1. The estimated indifference values increase with delay, in violation of stationarity but supportive of decreasing timing aversion. The indifference values differ significantly between questions 1 and 2 ($p < 0.001$) and between questions 1 and 3 ($p < 0.001$), but not between questions 2 and 3 ($p > 0.05$). This latter finding suggests that the main deviation from stationarity occurs in the transition from the immediate future to the more remote future, which is consistent with an explanation for violations of stationarity suggested by Benzion *et al.* (1989), the "one-period-realization-of-risk" hypothesis. Any delayed outcome carries a certain degree of risk that the outcome may never be experienced, for example, because there is a risk that people die prematurely and do not live up to the period that the outcome is due to be received. On the other hand, outcomes that are experienced immediately are certain. According to the one-period-realization-of-risk hypothesis, people expect a one-time premium to be compensated for the risk associated with delay, but they discount any additional delays by a constant rate after this premium has been incorporated. That is, there is an *immediacy effect* in intertemporal choice which is comparable to the certainty effect in choice under risk (Prelec & Loewenstein, 1991). Several studies have confirmed the

TABLE 2

Results of the Parametric Estimation

	Question 1	Question 2	Question 3
Parameter estimates (standard error)			
$\hat{\beta}_0$	1.764	2.454	2.224
	(0.329)	(0.363)	(0.343)
$\hat{\beta}_1$	−0.996	−1.276	−1.082
	(0.161)	(0.176)	(0.163)
Mean time in B (standard error)			
	1. 722	1.924	2.056
	(0.109)	(0.088)	(0.098)
After correction for heteroskedasticity	1.575		
	(0.083)		
Goodness of fit			
Likelihood Ratio index	0.188	0.280	0.217
% correctly predicted	73.1	78.1	72.1
Heteroskedasticity			
Lagrange Multiplier ($\chi^2(1)$)	3.955	0.881	0.062
	($p = 0.046$)	($p = 0.348$)	($p = 0.807$)
Likelihood Ratio ($\chi^2(1)$)	4.690	0.975	0.076
	($p = 0.030$)	($p = 0.323$)	($p = 0.786$)

TABLE 3

Results of the Nonparametric Estimation

	Question 1	Question 2	Question 3
Mean time in B	1.82	1.93	2.05
Median time in B	1.54	1.78	2.10

presence of an immediacy effect due to the presence of risk. Stevenson (1992) found a large difference between the discount function elicited from riskless intertemporal decisions and the discount function elicited from risky intertemporal decisions. The riskless discount function starts off very steep and then runs more smoothly after some delay. The risky discount function has no initial steep part and runs smoothly throughout. Keren & Roelofsma (1995) found that the introduction of uncertainty in intertemporal decision making, which makes all options uncertain regardless of whether they are delayed or not, removes the immediacy effect and leads to preferences that are more in line with the predictions of the constant rate discounted utility model. Finally, Kirby (1997) found that correction for the "one-period-realization-of-risk" hypothesis reduces the superiority of hyperbolic discounting over constant rate discounting to a large extent. The existence of an immediacy effect is also consistent with *present-biased preferences*, developed by Phelps & Pollak (1968) and recently employed by Laibson (1997, 1998) and O'Donoghue and Rabin (1999).

Table 3 displays the results of the nonparametric estimation. The elicited indifference value of t^1 increases with delay. Hence, the nonparametric estimation confirms the violation of stationarity and provides further support for decreasing timing aversion. Contrary to the parametric estimation, the nonparametric estimation does not endorse the one-period-realization-of-risk hypothesis: there is no initial jump in the indifference values of t^1, but a gradual increase.

5. DISCUSSION

This paper has provided the most robust test performed to date of the descriptive validity of the constant rate discounted utility model versus proportional discounting and hyperbolic discounting in medical decision making. We generalize previous findings in three respects. First, by focusing on the axiomatic differences between the theories, confounding assumptions about the utility function for life-years are avoided. Second, by studying preferences over sequences of outcomes, we take into account that duration is an integral part of health states, and we do not need the assumption that no discounting takes place during the time periods that the health states are experienced. Third, choices instead of matching or rating were used to elicit preferences. Previous research has shown that choice-based elicitations are less prone to inconsistencies.

The results violate stationarity and support decreasing timing aversion and are therefore consistent with the general pattern observed in previous studies on intertemporal preferences for health. This indicates that even though previous studies may have been biased by the three problems mentioned above, their main conclusion is robust. The results disagree with the finding of Ahlbrecht & Weber (1997) that violations of stationarity are only observed in matching tasks, but not in choice tasks. There is some ambiguity about the question of whether the violations of stationarity are primarily due to an immediacy effect. The parametric estimation supports this hypothesis, but the nonparametric estimation does not provide evidence for an immediacy effect.

The main implication of our study for general intertemporal choice theory is that violations of stationarity can be observed in choice tasks. This is an important finding because choice is the basic primitive of decision theory. One reason that our results differ from those of Ahlbrecht & Weber may be the difference in outcome domain, health instead of money. As observed in the Introduction, intertemporal preferences for health are not distorted by interest rates. If there is a distortion due to the interest rate in intertemporal studies with monetary outcomes, then this distortion will be in the direction of constant rate discounting and hence support for stationarity. An alternative explanation of the difference in findings between our study and Ahlbrecht & Weber's is that they tested stationarity at the individual subject level whereas we tested stationarity at the aggregate level. A disadvantage of using choices to test stationarity at the individual level is that the delay for which indifference holds between the options is unknown. A delay is selected in advance and choices are elicited for this fixed delay. If the fixed delay differs considerably from the delay for which indifference holds between the options, then it may be hard to detect violations of stationarity. Future research may examine these explanations by applying the test used in this paper to monetary outcomes.

Future research on intertemporal preferences for health should focus both on the causes of violations of stationarity and on the development and testing of alternative models for constant rate discounting that can explain these violations. Concerning the causes of violations of stationarity, it is particularly important to establish whether these violations are primarily caused by the presence of an immediacy effect. Medical decisions are often made under uncertainty, regardless of whether the outcomes occur immediately or with some delay. Hence, if the one-period-realization-of-risk hypothesis is true, then this would imply that in most medical decision contexts the steep part of the discount function, which is primarily responsible for violations of stationarity, is absent and that the constant rate discounted utility model may be a good approximation of individual intertemporal preferences for health.

There are two possible courses for future research on alternative theories that can accommodate the displayed violations of stationarity. One possible course is to retain the additive structure and to compare Harvey's (1986) proportional discounting model and Loewenstein & Prelec's (1992) hyperbolic discounting model. These models were primarily developed to model intertemporal preferences for single outcomes. However, when studying intertemporal preferences for health, it is more natural to consider preferences over sequences of outcomes. We used a condition for sequences of outcomes, decreasing timing aversion, which captures the essence of both proportional discounting and hyperbolic discounting, but which cannot distinguish between these two models. Future studies may seek to develop and perform tests that can distinguish between these models and that remain intuitive to experimental subjects. The preferred way to compare the models is to focus on their axiomatic structure. If it turns out to be impossible to develop intuitive tests of the distinguishing axioms, then an alternative way of testing the models is to elicit their parameters and to compare the predictions of the models in choice settings.

A second possible course for future research is to test whether additivity itself is a valid assumption to impose on individual intertemporal preferences. Empirical evidence suggests that people's preferences over sequences of outcomes violate additivity (Loewenstein & Sicherman, 1991; Loewenstein & Prelec, 1993; Krabbe & Bonsel, 1998). Alternative, nonadditive, models have been proposed (Gilboa, 1989; Loewenstein & Prelec, 1993) but have yet to be tested. The axiomatic structure of additive preference models is well-documented (Krantz *et al*., 1971; Wakker, 1989) and these axiomatizations can be used to design tests of additivity.

Regardless of the course taken, an important thing to keep in mind in the development of alternative discounting models is the trade-off between theoretical soundness and practical applicability. One reason that many researchers continue to use constant rate discounting in spite of the observed violations is its practical appeal. The danger of developing alternative intertemporal models is that they quickly become too complicated to be useful in practical research. The true challenge for future research is to develop models that strike a good balance between theoretical soundness and practical applicability.

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Received: November 10, 1998; published online February 16, 2001