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Valuing Environmental Outcomes: Preferences for Constant or Improving Sequences

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Experimental results on individuals' preferences for temporal sequences of environmental outcomes related to air quality and near-shore ocean water quality are compared with preferences for sequences of health and monetary outcomes. Generally, graduate business student participants gave significantly lower ratings to environmental and health sequences (with equal means) that worsened over time, relative to the ratings they gave to sequences that either remained the same or improved over time. This pattern was reversed by the participants when they faced sequences of monetary payments. This preference structure held for both short (5-year) and long (50-year) time horizons, and it was confirmed with choice data. A model proposed by Loewenstein and Prelec for the valuation of sequences of outcomes was applied to the current data set and compared to the traditional

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discounting model. In all cases, the model that incorporated "Gestalt" features of the sequence (slope and uniformity) performed better than the net present value discounting model at predicting the mean ratings for the sequences in the different domains.

Many decisions, especially those in the environmental domain, affect streams of consequences on multiple dimensions. For example, decisions to clean up nuclear waste determine health and environmental consequences over many decades and require the allocation of funds over a long period of time. Obviously, a coherent evaluation of such multidimensional, long-ranging, and sequential consequences is important for making sound decisions in this highly political context, with multiple stakeholders and tremendous public scrutiny. While decision analysis offers various techniques to model such situations, little empirical evidence exists in terms of how people actually evaluate such streams of consequences. This paper reviews the existing research, including different intertemporal modeling techniques, and presents the results of an empirical study where respondents evaluated and chose from sequences of consequences that were systematically manipulated across different domains and time frames.

The most commonly used approach to evaluate temporal streams of consequences on one particular dimension (e.g., money) is to apply a discount factor and calculate a net present value. In the monetary domain, the discount factor is usually positive, indicating that a given amount of money received at some point in the future is worth less than the same amount today. The discount factor is often determined by a savings interest rate that money could earn if it were to be invested. For nonmonetary consequences, decision analysts often "price them out" by determining their monetary equivalent before applying the discounting technique. However, little is known about whether such an approach matches people's actual preferences. There are some indications from prior studies that monetary and nonmonetary outcomes (such as health) may be treated differently.

The goal of this paper is to examine preferences for environmental and monetary consequences over time. In an experiment, participants expressed preferences for sequences of consequences from the environmental (air and near-shore ocean water quality), health, and income domains. Our investigation was motivated by societal decision contexts in which the outcomes are usually experienced as a *sequence*. Therefore, we chose to investigate preferences for these *sequences* rather than for a single *isolated future outcome*. Previous research showing that people can display different preferences when considering sequences or considering isolated outcomes has led to the development of new evaluation models (e.g., Loewenstein & Prelec, 1993). We were interested whether preferences for such sequences show domain-specific effects. In particular, we compared monetary vs nonmonetary consequences, since the justification of the traditional discounting approach relies heavily on the existence of a market where investments can earn interest over time. For consequences such as air, near-shore ocean water quality, or health it is far from obvious what the equivalent "market mechanism" would be that would justify a (positive) discount factor.

The paper is organized as follows. After this introduction we will review the existing research, including differences in the evaluation of isolated outcomes and sequences of consequences, domain-specific effects (e.g., health vs money), and models to evaluate such sequences. Based on this review, we will then describe the design of the experimental study before we discuss its main results and how different models can capture those results. The concluding section summarizes the main results and outlines their implications for future research and practical applications.

RESEARCH BACKGROUND

In this section we briefly review the experimental literature to show that temporal preferences may differ (1) for isolated outcomes versus sequences and (2) for health versus money. We then discuss the standard discounted utility model and Loewenstein and Prelec's model of temporal preferences.

Temporal Preferences May Differ for Isolated Outcomes versus Sequences

We chose to investigate sequences of environmental outcomes since that task matches the actual decision context. Research on how people implicitly discount future monetary outcomes or consumer commodities received as single isolated outcomes (Ahlbrecht & Weber, 1997; Benzion, Rapoport, & Yagil, 1989; Thaler, 1981) found, in general, that if acquisition is delayed, then a premium (in the form of an increase in the amount of the good) must be paid to the person to offset the disutility caused by the delay. This is known as *positive time discounting*, since the discount rate is positive. In contrast, when Loewenstein and Sicherman (1991) investigated implicit discount rates that museum-attending adults used for *sequences* of wage profiles and income from rental investments, they found that participants' preferences tended to display *negative time discounting*, preferring increasing sequences over decreasing sequences with equal means. The participants in their study generally gave higher rankings to sequences of income streams that increased in payoff over time than to sequences that decreased, even though the net present values of the latter streams were greater than the former. This preference for increasing sequences was stronger in the wage profile case than in the rental investment case. Further, particularly for rental investments, those participants who were older, were college graduates, and had higher incomes tended to prefer decreasing sequences. When Schmitt and Kemper (1996) employed an experimental design that incorporated real money outcomes over time, they also found preferences for increasing sequences. Both of these studies involving sequences are in contrast to the previous work with isolated outcomes, since delayed acquisition is actually preferred over instant acquisition (of the same amount). Furthermore, a parallel stream of research has shown that when individuals evaluate sequences of outcomes, factors which are seldom observed when presented as isolated outcomes may be influencing preferences. Peaks, trends, and end points of experiences appear to be good predictors of retrospective evaluations of events which occur over time (Ariely, 1998; Fredrickson & Kahneman, 1993; Kahneman, Fredrickson, Schreiber, & Redelmeier, 1993; Redelmeier & Kahneman, 1996; Ross & Simonson, 1991; Varey & Kahneman, 1992). For more information on anomalies of intertemporal choice see Loewenstein and Elster (1992).

Temporal Preferences Differ for Health vs Money

Individuals may treat monetary income differently from other, nonmonetary outcomes since they may imagine how the money will be saved or invested as they make their choices (among other reasons). With respect to isolated outcomes, there have been some findings of differences between discounting health and monetary outcomes (Chapman & Elstein, 1995; Cropper, Aydede, & Portney, 1994; Olsen, 1993). For example, Rose and Weeks (1988) found that discount rates for health states isolated to one time period were quite high (more than 40% annually) and were higher than those for monetary outcomes. Chapman and Elstein (1995) also found that discount rates were generally higher (more present-oriented) for health than for money.

When looking at sequences of outcomes, Chapman (1996) extended Loewenstein and Sicherman's work (on preferences between sequences with different shapes but equal means) into the health domain. When the time horizon was long (60 years), she found that her undergraduate student participants displayed positive time discounting (decreasing sequences were preferred) for health outcomes in three consecutive experiments. In contrast, monetary outcomes over the same time horizon were discounted positively (decreasing sequences slightly preferred), not at all (increasing and decreasing equally preferred), and negatively (increasing sequences were preferred) in the same three experiments. Thus, in general, discount rates for health were positive and higher than for money in the 60-year time horizon, since implicit monetary discount rates were sometimes negative. When the time horizon was shorter (12 days or 1 year) though, all three experiments indicated that both income and health during a medical treatment were discounted negatively. Thus, the preference for increasing sequences was stronger in the short time horizon than it was in the long time horizon.

Read and Powell (2000) collected written protocols from participants explaining how they thought about and made choices between pairs of health and pairs of monetary sequences similar to those used in Chapman (1996). "Maximizers," who showed a desire to take money up front for economic maximization reasons, were more likely to prefer decreasing sequences of money. Individuals who talked about savoring and dread, local reference points, self-control, or motivation were more likely to prefer increasing sequences. A major factor that influenced choice for the participants in their study was the subjective "appropriateness" of the sequence, how well it matched the individual's consumption needs due to time-of-life, personal, and seasonal circumstances.

For example, wanting better health when young was often given as a reason for choice, although some people thought it would be good to have better health when older. Others gave a personal reason such as being healthier while children were young.

Environmental outcomes have the potential of being treated by stakeholders in decisions involving effects on the environment as being similar to either monetary outcomes or health outcomes. For example, air quality could impact economic well-being through monetary effects on land values or restrictions on business activities. It also is potentially related to adverse health effects resulting from polluted air in people with certain health conditions such as breathing or cardiac problems. Since environmental outcomes have features that are similar to both health and monetary outcomes, we chose to compare all three types.

Models of Temporal Preferences for Sequences of Outcomes

Discounted utility theory would compute the net present value today of $110 in t years by the formula net present value $= 1/(1 + r)^t$ ($110). The annual discount rate r is positive in this standard discounting model since the discounting function, which is equal to $1/(1 + r)$, must lie between zero and one (Fishburn & Rubenstein, 1982; Koopmans, 1960; Samuelson, 1937). (Note here that the utility of money is taken to be linear in money; a more general model would replace the monetary amount $110 with the utility of $110.) Figure 1 displays the effect of the discount rate on the net present value of a sequence of outcomes over time. If an increasing sequence (such as Increasing Sequence I) is preferred to a constant or decreasing sequence (Constant Sequence C and Decreasing Sequence D, respectively) with the same mean over the time horizon, then the implicit discount rate is negative ($r < 0$), given the criterion that individuals choose the sequence that rewards them with the highest net present value. This would violate the discounted utility model.

Loewenstein and Prelec (1993) proposed an alternative model that incorporates a weight on the direction and a weight on the uniformity of the sequence (this model will be explained in detail in a later section of this article). When considering sequences with equal means but different slopes, the discounted utility model and the model presented by Loewenstein and Prelec can make different predictions. Loewenstein and Prelec's model can predict preferences for increasing or decreasing sequences, as well as preferences for moderate slopes (since they are nearer to uniform), depending on the signs and magnitudes of the parameters. Discounted utility can only predict preferences for steeply decreasing sequences (if the discount rate is positive, as required) or steeply increasing sequences (if the requirement of a positive discount rate is relaxed). Other discounting models exist, such as hyperbolic discounting (Ainslie, 1991; Herrnstein, 1997; Loewenstein & Elster, 1992). When valuing sequences of outcomes, these models will make predictions similar to those of the traditional discounting model, and therefore they will not be considered

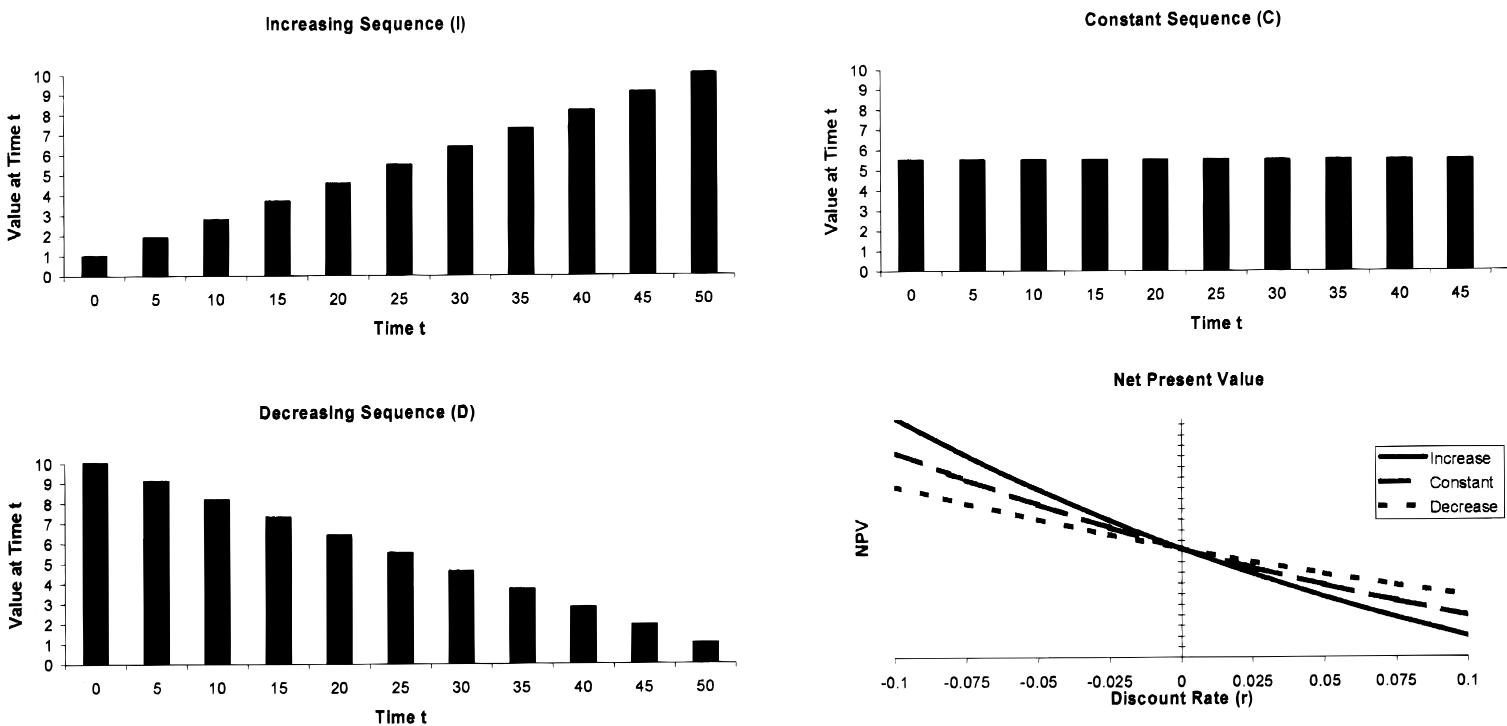

FIG. 1. Three sequences that have equal averages over the time horizon. Increasing Sequence I shows a sequence that is increasing at a constant rate over a 50-year time horizon. Constant Sequence C shows a sequence that is constant over the time horizon. Decreasing Sequence D depicts a sequence that is decreasing at a constant rate. The last graph shows the net present value of these three respective sequences for discount rates (r) between ±0.010. Notice that the decreasing sequence in D has the highest net present value if $r < 0$, the increasing sequence in I has the highest net present value if $r < 0$, and they all have the same net present value at $r = 0$.

here. Keller and Strazzera (in press) discuss some of the different models and present a method for examining their respective predictive accuracy.

METHOD

The current experiment elicited and compared preferences for sequences of environmental outcomes, health outcomes, and income streams. An experimental design for sequences of income streams and qualities of health was adapted from Loewenstein and Sicherman (1991) and Chapman (1996), respectively. However, the current study changed the time horizons explored and added the additional environmental domains. The research question addressed is whether or not participants will display differences in preferences for sequences of outcomes in the environmental, health, and monetary domains.

Participants

The participants were 48 graduate business students at the University of California, Irvine, who volunteered to participate in this study. Their ages ranged from 22 to 49, with a mean of about 30 (median age 29). Participants were recruited through an advertisement that was posted on campus. They were compensated with $5.00 for their participation in the experiment that lasted from 20 to 45 min. When the participants turned in the questionnaire, they received payment.

Procedure

Participants were asked to complete a paper-and-pencil questionnaire with four parts, two environmental, one health, and one income. The order of the four sections was randomized across participants. Each section consisted of two sets (5-year and 50-year) of seven temporal sequences, labeled with a letter (from A to G), which were counterbalanced across participants. Participants evaluated seven bar graphs depicting 5-year and 50-year sequences of air quality, near-shore ocean water quality, quality of health, and income streams. The total of each of the levels across all time periods (and thus the average) of the attribute was held constant; the graphs differed only in the shape of the distribution over the time horizon.

The seven distributions used in all four sections are illustrated in Fig. 2. The only differences between the sections were the labeling on the respective axes (either time horizon of 5 or 50 years, and *y*-axis of air quality, water quality, quality of health, or total payment) and the use of the “current level” line (only used in air and water quality scenarios). Figure 2 includes the graphs associated with environmental quality (either air or water) over a 5-year time horizon. For the long time horizon, the *x*-axis was rescaled to 50 years, giving a total of eight (four attributes by two time horizons) different sets of sequences. The first graph in Fig. 2 (Graph A), was used to display an air quality level that starts off better than current air quality, but decreases at a constant rate

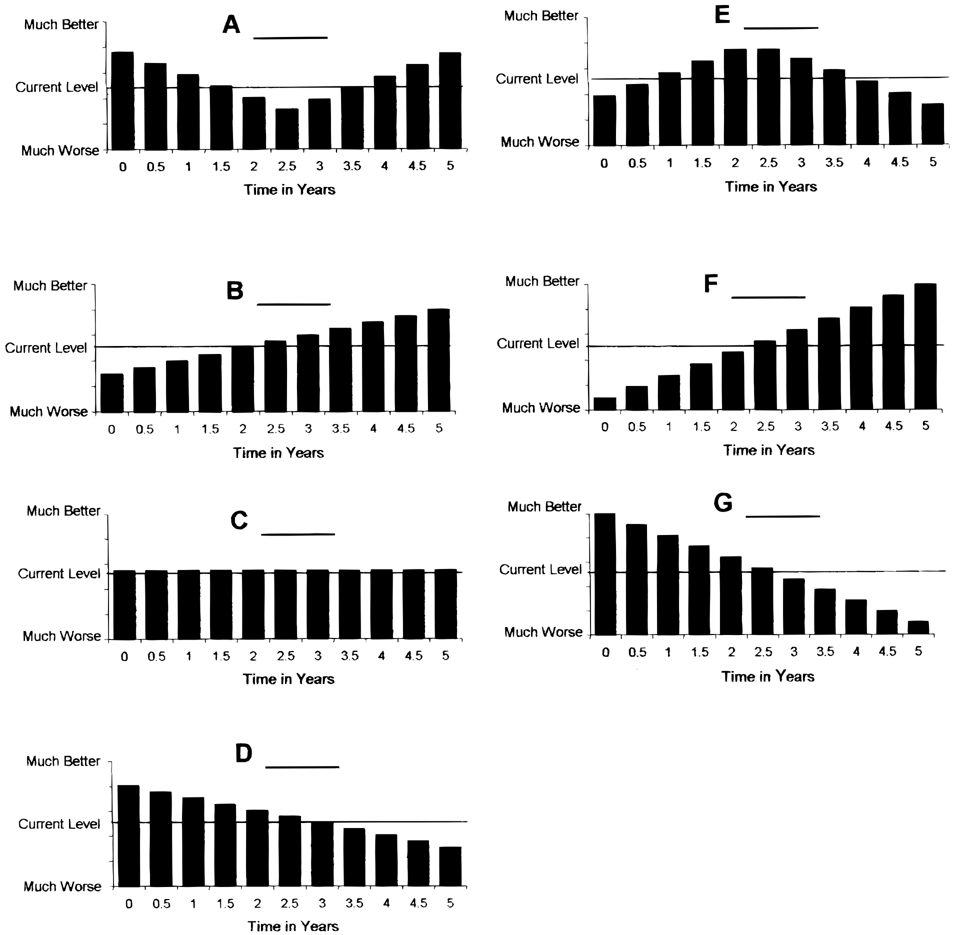

FIG. 2. The Seven graphs used in the experiment. This figure depicts the 5-year scenario for either air quality or near-shore ocean water quality. The same graphs were used (without the "current level" line) for quality of health, with the *y*-axis being relabeled with a qualitative health scale or a total payment scale. The *x*-axis was also rescaled to 50 years in all four scenarios.

over the next two and one-half years to an air quality level below the current level and then increases back up to a better than current level. All other graphs in Fig. 2 have similar explanations. The level of the environmental attributes (air and near-shore ocean water quality) was relative to the current level, placed in the midpoint of the *y*-axis. The extreme points were "much better" and "much worse." The "current level" reference line was inserted to ensure that the participants could see that these seven different sequences did not necessarily start at the same point, that some sequences had an immediate improvement and others had an immediate deterioration of the environmental attribute level. Without this line, the participants may have thought that the improving sequence started at the current levels and improved from there, whereas the declining sequences started at the current levels and then deteriorated. Such an interpretation would cause the participants to see the means of the distributions of environmental qualities to be unequal, with the increasing sequences having a much higher (better) mean than the decreasing ones.

The survey elicited three dependent measures, preference rating, preferred choice, and expectation. The ratings were done on a 0 ("extremely unfavorable") to 100 ("perfect") scale, and they were placed on the appropriate line next to each graph. The participants were then asked to fill in the graph label (A through G) of the sequence that "was closest to your ideal" sequence, and this response was regarded as their preferred choice. Finally, expectation was measured by the participants indicating the graph label (A through G) of the sequence which "regardless of your preference, is most likely to happen."

In the environmental sections, participants were asked to read selected excerpts from some local newspapers dealing with the on-going discussion of air and near-shore ocean water quality in the region.[1] For example, an excerpt from the *Los Angeles Times* (March 1, 1999) described a recent study (Waxman, 1999) which dealt with the exposure to hazardous air pollutants in Los Angeles. After reading the excerpts, the participants were then instructed to imagine that their local congressional representative had contacted them and asked them for their opinion on seven different air quality policies. These policies were to be carried out over a 5-year (or 50-year) period. To control for uncertainty, the participants were told that researchers believed that no technological advance would occur within the time period that could alter the policy once it was enacted. To ensure that the participants did not see the sequence continuing beyond the time horizon given, thus possibly not having the same mean, they were also instructed that only one policy could be enacted and at the end of the time horizon, a new policy would be voted on and enacted; the current policy would have no influence on this future decision. They were then instructed that each of the seven policies had an equal average change in the environmental level over the time period, relative to the current level, but the way this change was distributed differed between the policies. Also, a change in air quality meant the same thing regardless of when it occured. For example, a "much better" change in air quality near the beginning of the time horizon meant the same thing as a "much better" change near the end of the time horizon. The same graphs were used for both the air and the near-shore ocean water quality sections.

In the health sections the bar heights represented quality of health and the "current level" line was not included in order to replicate previous similar research that this paper is building on (Chapman, 1996). Participants considered qualities of health that ranged from 10 (perfect health, the best you could imagine) to 1 (very poor health, just barely better than death). The bars had an average of 5.5. The participants were explicitly instructed that a health

[1] "Cancer Risk From Air Pollution Still High, Study Says," *Los Angeles Times*, March 1, 1999; "More Smoke Than Fire in Smog Report," *Orange County Business Journal*, March 22, 1999; "Ocean Testing Tangled in Red Tape," *Los Angeles Times*, April 8, 1999; and "Good News for Beachgoers—With a Caveat," *Los Angeles Times*, April 9, 1999.

unit meant the same thing regardless of where it occurred in the sequence. They were asked to assume that they needed to undergo a medical treatment that took exactly 5 years to complete. The participants were presented with the seven graphs, this time representing seven different treatment options, and were told that their health would return to its current state in year 6. When the time horizon was 50 years, participants were instructed to assume that they were currently 25 years old and that the distributions represented different health profiles that they could experience over the next 50 years.

In the income stream sections, the *y*-axis was relabeled "Total Payment" and the values ranged from $0 to $100,000. In the 5-year (50-year) income stream section, participants considered annual after-tax incomes of $10,000 to $100,000. Like the health scenarios, these graphs did not include the "current level" reference line in order to be more similar to previous research (Chapman, 1996; Loewenstein & Sicherman, 1991). Participants were instructed that they had inherited part ownership in a small restaurant (or an apartment building) that was expected to be profitable for the next 5 years (or 50 years). They had decided to let the other part owner make payments to the participants in both scenarios, and that these payments would be the sole source of their income. The payment streams could follow any of the seven distributions used in the other sections.

RESULTS

The survey elicited ratings (a continuous quantitative variable), choices of sequence closest to their ideal sequence (a dichotomous qualitative variable), and the selection of the sequence that they felt was most likely to occur (a dichotomous qualitative variable) for the seven different sequences in the eight scenarios. Since there were 48 participants and four domains, there were 384 potential choices across all the scenarios in the two time horizons.[2] Looking at the total number of choices that participants made, out of the 384 choices, there were only 20 instances (5.2%) in which the preferred choice was either the "hill" (Graph E of Fig. 2) or the "valley" (Graph A) sequence. The remaining 94.8% of the choices were for one of the five monotonic sequences (sharply increasing, increasing, constant, decreasing, or sharply decreasing). For this reason, the "hill" and the "valley" graphs were not analyzed further. The analysis of ratings, choices, and expectations focused on the five other graphs.

Mean ratings were used as summary statistics for the strength of preference across the 48 participants for each of the five graph shapes. Ratings were good predictors of choice across participants according to a logistic regression model with ratings as a single independent variable (Wald = 270.79, $p = .000$). Figure

[2] The highest rated graph was inferred to be the ideal choice for one response (that was left blank) in the 5-year time horizon and four responses in the 50-year time horizon. This inference was consistent with the respective participant's choices in the other completed scenarios.

3 shows a graphical representation of these mean ratings. One will quickly notice that the environmental domains (air and near-shore ocean water) and the health domain have similar mean ratings per scenario, but the mean ratings in the monetary domain appear to be different. For environmental sequences, participants preferred the constant or improving sequences. For health, constant health over 50 years and moderately increasing over 5 years got the highest mean ratings. In contrast, for income the decreasing sequences were rated highest. Also there seems to be a distinct difference in the pattern of mean ratings between the two time horizons. In all four scenarios, increasing sequences were rated higher (on average) in the 5-year time horizon than they were in the 50-year time horizon. Likewise, decreasing sequences received higher ratings on average in the 50-year time horizon than they did in the 5-year time horizon.

To test these visually observed similarities (and differences) in the mean ratings, we analyzed the preference ratings using a 5 (sequence shapes) $\times$ 4 (domains) $\times$ 2 (time horizons) ANOVA. The sequence ratings were used as the dependent variable. The independent variables included the counterbalance condition (a between-subjects factor), the sequence shape (sharply increasing, increasing, constant, decreasing, or sharply decreasing), the domain (air, water, health, or income), and the sequence length (5 or 50 years), which are all within-subject factors. Interactions between the within-subject factors were also included. Table 1 shows the results of the ANOVA.

As expected from Fig. 3, the ANOVA revealed that the interaction between Domain and Shape was significant. This indicates that these two attributes together affect the ratings that participants gave; that is, the participants rated the graphs differently across domains. Looking back at Fig. 3, it seems that participants gave very similar ratings to air, water, and health with respect to Shape, but they gave different ratings to income. A second analysis was done by filtering the data to exclude income. Table 1 also displays the results of the second ANOVA. Comparing the results of the second analysis with the first one, we can see that the interaction between Domain and Shape disappears. The main effect of Shape is still highly significant. This second analysis indicates that the mean ratings for the five sequence shapes in the air, water, and health domain depend on the shape of the sequence, but not on the three different domains. Since the interaction between Shape and Domain was significant in the first analysis, the difference must be attributed to the monetary domain.

The two-way interaction between Time Length and Shape indicates a significant difference between the average ratings in the two time horizons with respect to sequence shape. The increasing sequences were rated higher with the 5-year time horizon than they were with the 50-year time horizon, and decreasing sequences were rated higher with 50 year than with 5 years.

Table 2 displays the frequency of choice of ideal sequence for the different shapes across domains, combining both time horizons. The choice of ideal sequence data were aggregated to find out if the proportion of choices for decreasing sequences in the environmental or health domains differed from

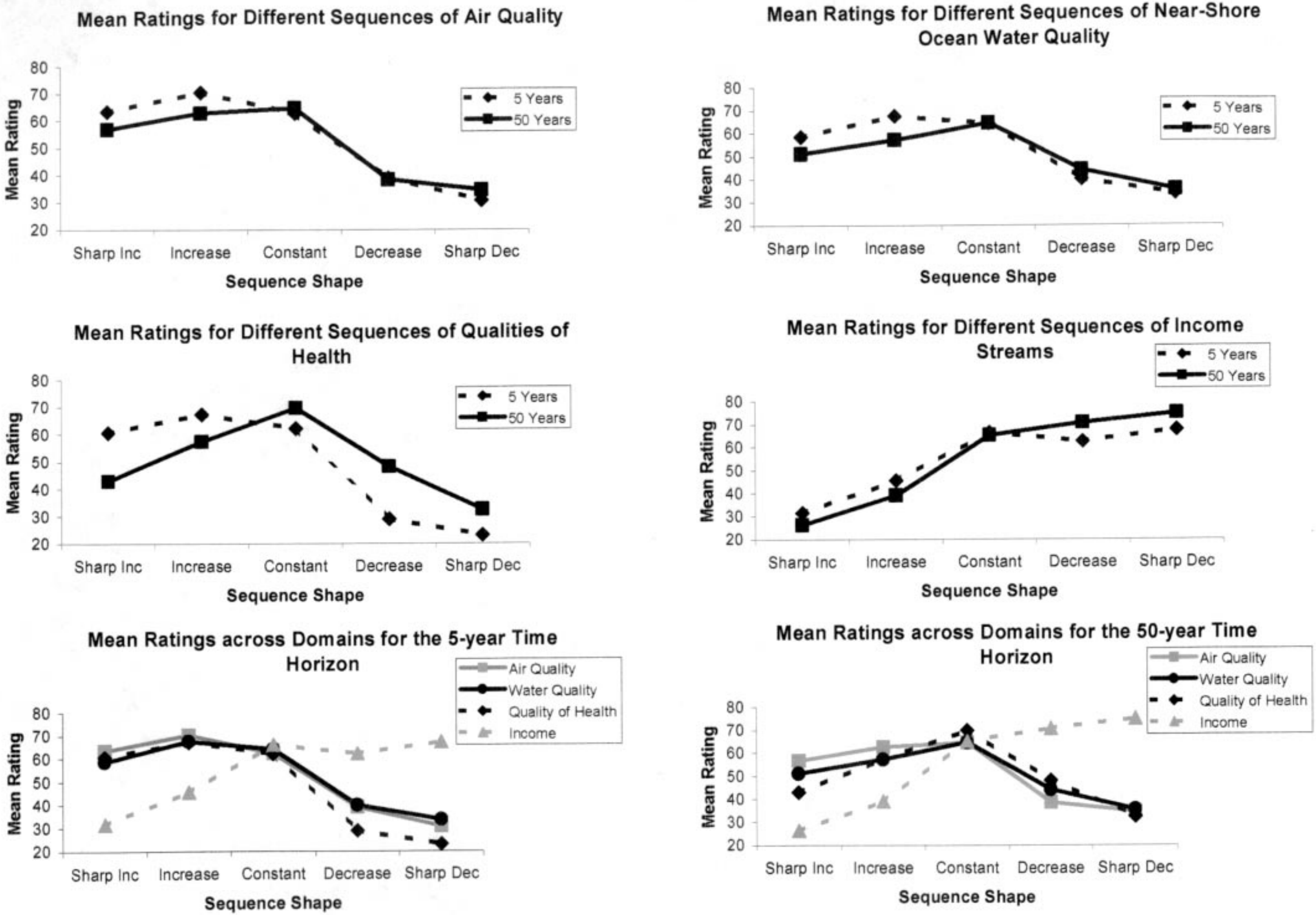
Mean Ratings for Different Sequences of Air Quality
Mean Rating
80
70
60
50
40
30
20
5 Years
50 Years
Sharp Inc
Increase
Constant
Decrease
Sharp Dec
Sequence Shape
Mean Ratings for Different Sequences of Near-Shore Ocean Water Quality
Mean Rating
80
70
60
50
40
30
20
5 Years
50 Years
Sharp Inc
Increase
Constant
Decrease
Sharp Dec
Sequence Shape
Mean Ratings for Different Sequences of Qualities of Health
Mean Rating
80
70
60
50
40
30
20
5 Years
50 Years
Sharp Inc
Increase
Constant
Decrease
Sharp Dec
Sequence Shape
Mean Ratings for Different Sequences of Income Streams
5 Years
50 Years
Mean Rating
80
70
60
50
40
30
20
Sharp Inc
Increase
Constant
Decrease
Sharp Dec
Sequence Shape
Mean Ratings across Domains for the 5-year Time Horizon
Air Quality
Water Quality
Quality of Health
Income
Mean Rating
80
70
60
50
40
30
20
Sharp Inc
Increase
Constant
Decrease
Sharp Dec
Sequence Shape
Mean Ratings across Domains for the 50-year Time Horizon
Air Quality
Water Quality
Quality of Health
Income
Mean Rating
80
70
60
50
40
30
20
Sharp Inc
Increase
Constant
Decrease
Sharp Dec
Sequence Shape

TABLE 1

ANOVA Results for Comparisons of Mean Ratings across Time, Domains, and Sequence Shapes

Factor	*df1*	*df2*	*F*	MS_e
First analysis (with all 4 domains)				
Counterbalance	1	46	0.90	844
Time Length	1	46	0.13	120
Domain	3	138	2.79*	2622
Shape	4	184	36.57***	34368
Time Length * Domain	3	138	0.46	434
Time Length * Shape	4	184	6.46***	6066
Domain * Shape	12	552	22.00***	20676
Time Length * Domain * Shape	12	552	0.73	685
Second analysis (without monetary domain)				
Counterbalance	1	46	0.51	493
Time Length	1	46	0.27	254
Domain	2	92	1.27	1218
Shape	4	184	65.34***	62683
Time Length * Domain	2	92	0.59	566
Time Length * Shape	4	184	5.38***	5159
Domain * Shape	8	368	0.71	676
Time Length * Domain * Shape	8	368	0.95	914

* $p < .05$.
*** $p < .001$.

TABLE 2

Frequency of the Different Sequence Shapes Being Chosen as Ideal Sequence in the Different Domains

Shape of sequence	Air quality	Water quality	Quality of health	Income stream
Sharply increasing	21	20	21	*7*
Increasing	25	18	19	8
Constant	**28**	**28**	**31**	17
Decreasing	*2*	*6*	10	8
Sharply decreasing	16	18	*6*	**55**

Proportion of Ideal and Expected Sequences that Were Decreasing

	Environmental or health	Income	χ^2
Choice	22%	66%	63.37****
Expectation	37%	10%	23.09****
χ^2	13.86****	63.09****	

Note. Bold numbers indicate the most frequently chosen sequence shape (the modal choice). Italicized numbers indicate the least frequently chosen sequence shape.
**** $p < .0001$.

FIG. 3. Comparison of mean ratings for 5- and 50-year time horizons across the environmental, health and income domains.

the proportion in the monetary domain. The bottom of Table 2 displays the results. Notice that, in general, the proportion of choices for decreasing sequences was greater for the monetary domain than for the other domains. This supports the results from the analysis on mean rating data, which indicates that, on average, decreasing sequences are preferred in the monetary domain, but not in the environmental or health domains.

The expected sequence data were aggregated like the choice data to find out if the proportion who expected decreasing sequences in the environment or health domains differed from the proportion who expected decreasing sequences in the monetary domain. Table 2B also displays these results. Notice that, in general, the proportion who expected decreasing sequences was greater for the environmental and health domains (37%) than for the monetary domain (10%). Contrasting between the expected and ideal sequences, there is a significant difference between the proportion who chose decreasing sequences as ideal and the proportion who expected a decreasing sequence as most likely in both the monetary and the environmental/health domains. The results indicate that in the monetary domain, most participants (90%) expected nondecreasing sequences, but most chose (66%) decreasing sequences as ideal.

We can see from Table 2 that the proportion (22%) choosing a decreasing sequence is closer to the proportion (37%) selecting a decreasing sequence as the expected most likely sequence in the environmental and health domains, as opposed to in the monetary domain where the proportions are 66% and 10%. To investigate whether participants in this study chose and expected sequences with similar slopes, the five sequence shapes were numerically coded from -2 (sharp decrease) to $+2$ (sharp increase). The Spearman Rank Correlation between the chosen and expected sequences was only significant in the health domain, with a coefficient of 0.41 ($p = .001$). All other coefficients were insignificant ($p > .17$).

In summary, for our graduate business student participants, the preference patterns for air quality, near-shore ocean water quality, and quality of health were not statistically different from each other. The results from both the ratings and the choice data indicate that these outcomes display a different preference pattern than that seen for income. In general, preferences for the income streams seem to follow the traditional discounting models (a preference for decreasing sequences) while preferences for the environmental and health outcomes do not (showing preferences for increasing or constant sequences).

Table 3 contrasts our results with those of the previous studies. In the monetary income domain we found that the majority of our graduate business student participants preferred decreasing sequences. Some previous experimental work has found similar preferences in favor of decreasing sequences. Read and Powell (2000) found a preference among University of Leeds students, staff, and academics for a special kind of decreasing sequence of lottery winnings over a year, which had a large payment in period 1, followed by a lower flat pattern in subsequent periods. They also found the same kind of decreasing sequence of 1-year salary income to be popular, along with a constant sequence and one with a flat amount until a peak in the final period. Chapman (1996) found decreasing sequences of lifetime after-tax salary income slightly preferred over increasing sequences in her Experiment 1 and found decreasing and increasing sequences equally rated in Experiment 2.

In contrast, the majority of museum-visiting adults (Loewenstein & Sicherman, 1991), undergraduate students (Schmitt & Kemper, 1996), Illinois undergraduates (Chapman, 1996; Experiment 2 (1-year horizon) and Experiment 3), and University of Leeds participants (Read & Powell, 2000 (lifetime income)) preferred increasing sequences of investment or wage income. Results in the current study may differ from this latter work because our participants were graduate business students, who might be more likely to be familiar with traditional net present value calculations for money and therefore might prefer decreasing sequences in the monetary domain. It could be that they wanted to give the "right" answer, realizing that they were dealing with money. In the terminology of Read and Powell (2000), the majority of our college graduate participants may have been reasoning as "maximizers" for the apartment and restaurant income scenarios. (We did not present a wage income scenario.) In fact, when examining preference for sequences of rental income, Loewenstein and Sicherman (1991, p. 77) found that "older individuals, college graduates, and people with higher incomes are more likely to be [decreasing sequence preferring] present-value maximizers" and that "the effects are far more significant for rental income than for wages." Relatedly, for their rental income scenarios (rather than wage income), the preference (across all subjects) for increasing sequences was not as strong. Other research (Keller & Sarin, 1995) has found differences between graduate business students and undergraduate psychology students when making choices in scenarios involving allocation of risks and economic benefits to different communities.

Next consider differences between short and long time horizons involving monetary outcomes. Figure 3 shows (significantly) higher ratings for increasing sequences in the short run than in the long-run time horizon. A similar pattern shows up in Table 3 when we look at some of the earlier results, such as Chapman's Experiment 2, where the preference for an increasing sequence was more dominant in the short run than in the long run.

In the health domain, our 5-year problem dealt with medical treatment options, in which one might demand increasing (or at least not worsening) health over time. Our graduate business student results show that this is the case, displaying a preference for constant or increasing sequences of health. Likewise, Chapman's somewhat younger undergraduate participants preferred increasing sequences for similar 1-year or 12-day medical treatment scenarios.

The 50-year time horizon scenario in our study investigated quality of health over a lifetime, from age 25 to 75. The pattern observed here was a preference for constant sequences (see Fig. 3). While our results differ from those of Chapman (1996), who found preferences for decreasing sequences in her "Lifetime" health time horizon, our participants moved in the same direction (from preference for increasing or constant in the short horizon to preference for constant) as did Chapman's (from increasing in the short horizon to decreasing). Further, unlike in Chapman's study, our results included the possibility that

TABLE 3

Summary of Current Previous Research on Preferences for Sequences of Outcomes

Study	Participants	Domain	Time horizon	Results of sequences preferred by majority
Loewenstein & Sicherman (1991)	80 adults (ages 17 to 77, median of 32) visiting the Museum of Science and Industry in Chicago	Income streams	Six-year rental income or wage income	Increasing (Those with higher income, greater age, and college degree were more likely to prefer decreasing. For rent rather than wages, preference for increasing was substantially lower.)
Schmitt & Kemper (1996)	20 undergrad. students	Income streams	Real experimental sequential outcomes during 50-min work sessions over 5 days	Increasing for rewards, and decreasing rate of loss for losses
Chapman (1996)	Experiment 1: 40 undergrad. students at U of I at Chicago	Quality of health	Lifetime (60 years) health	Decreasing
		Income streams	Lifetime (60 years) after-tax income	Decreasing slightly preferred
	Experiment 2: 50 undergrad. students at U of I at Chicago (ages 17 to 26, mean of 19)	Quality of health	Lifetime (60 years) health	Decreasing
			One-year medical treatment	Increasing
		Income streams	Lifetime (60 years) after-tax income	Increasing or decreasing equally preferred
			One-year income	Increasing
	Experiment 3: 79 undergrad. students at U of I at Chicago	Quality of health	Lifetime (60 years) health	Decreasing
			12-day medical treatment	Increasing
		Income streams	Lifetime (60 years) after-tax income	Increasing
			12-day income	Increasing

Read & Powell (2000)	34 staff, students, and academics at Univ. of Leeds (ages 22–40, median of 22)	Quality of health	Lifetime (60 years) health	Decreasing chosen most often in paired choices
		Income streams	Lifetime (60 years) income	Increasing (until retirement, then flat)
			One-year lottery winnings	Decreasing (large period-1 payment, then flat)
			One-year salary	Decreasing (large period-1 payment, then flat) slightly more than constant or flat with peak in final period
Guyse, Keller, & Eppel (current study)	48 graduate business students at the Univ. of California, Irvine (ages 22 to 49, mean of 30)	Quality of health	Lifetime (50 years) health	Constant
			5-year medical treatment	Increasing or constant
		Air Quality	50 years	Increasing or constant
			5 years	Increasing or constant
		Near-shore ocean	50 years	Increasing or constant
		Water quality	5 years	Increasing or constant
		Income streams	50-year apartment investment income	Decreasing
			5-year restaurant investment income	Decreasing

participants could choose the constant sequence. (Chapman did not include the possibility to choose a constant sequence (in Experiments 2 and 3) and did not analyze the ratings of the constant sequence in her Experiment 1.) Also, our graduate business student participants were somewhat older than Chapman's subjects (mean of 30 versus 19 years of age), which could help explain the difference.

In the current study, a positive relationship between the shape of the sequence expected as most likely and the shape of the ideal sequence was found in the health domain (correlation of 0.41) but not in the environmental or monetary domain. This result is close in magnitude to the result reported by Chapman (1996), who reported a correlation of .49 between preferences and expectations for qualities of health. The difference between the current study and that performed by Chapman (1996) is that Chapman found expectations to mediate choice and we did not.[3]

Since our aim was to investigate whether or not differences appear in preferences for sequences in environmental, health, and income domains, we have primarily analyzed mean ratings and majority choice data. Discounting models (with positive non-zero discount rates) cannot capture the preferences for increasing (or constant) sequences which many participants displayed. Furthermore, the discounting model would also predict that if an individual had a positive discount rate and maximized net present value (or net present utility), then he/she should prefer the sequence with the highest reward in the first period (such as the sharply decreasing sequence in Graph G of Fig. 2), regardless of the magnitude of the individual's implicit discount rate. That is, the traditional discounting model would predict a preference for the graph with the steepest descending slope leading to the most extreme outcomes. Since our data reveals that many individuals rated highly and chose as ideal sequences that were constant or moderately increasing, the traditional discounting model would not reflect these participants' preferences. Loewenstein and Prelec's (1993) model, in which the value of a sequence can be determined by an individual's desire to spread utility evenly over a time period and end with a positive event, may fare better than the traditional discounting model with the data that we have collected. Such a model may explain our results for the environmental and health outcomes better than the traditional discounting model.

Application of Intertemporal Preference Models

We fit the traditional discounting model and Loewenstein and Prelec's (1993) model to the mean rating judgments made by our group of participants, since when considering sequences with equal means but different slopes, the two models can make different predictions. Loewenstein and Prelec's model can predict preferences (expressed as high ratings) for increasing or decreasing sequences, as well as preferences for moderate slopes (since they are nearer

[3] A mediational analysis was performed on the domains of health and income alone, and the domain effect on choice could not be explained by the domain effect on expectations.

to uniform). The traditional discounting model with a positive (non-zero) discount rate will predict preferences for steeply decreasing sequences. (If a negative discount rate is allowed, it will predict preferences for a steeply increasing sequence.) Fitting an intertemporal preference model to the mean judgments of a group would be appropriate in cases when it is important to characterize the opinions of a stakeholder group as a whole. An identical process would be followed to fit the models to individual participant's judgments.

Loewenstein and Prelec's model for preferences over outcome sequences is[4]

$$Sequence \cdot Value = \sum_{t=1}^{n} u_t + \beta \sum_{t=1}^{n} d_t + \sigma \sum_{t=1}^{n} |d_t|, \tag{1}$$

where the parameter $\underline{\beta}$ signals whether an individual prefers sequences that increase (improve) over time ($\underline{\beta} > 0$) or decrease (get worse) over time ($\underline{\beta} < 0$). The parameter $\underline{\sigma}$ helps determine whether an individual prefers sequences that are relatively uniform, showing a small deviation from time unit to time unit ($\underline{\sigma} < 0$), or prefers nonuniform sequences ($\underline{\sigma} > 0$). For each period t, u_t is the utility of receiving the outcome in time t. The term d_t is the difference between the cumulated utility received up to time t and the cumulated utility that should have been received had the total utility been allocated in a constant sequence across the n periods. This term is formulated as follows:

$$d_t = \frac{t}{n} \sum_{i=1}^{n} u_t - \sum_{i=1}^{t} u_i. \tag{2}$$

Loewenstein and Prelec applied their model by first measuring the cumulative deviations of each sequence from the constant sequence. The utility of the outcome at time t was also recorded. The information was then inserted into the model (1) and predictions were recorded.

[4] This model can be rewritten as

$$Sequence \cdot Value = \sum_{t=1}^{n} u_t + (\beta + \sigma) \sum_{t=1}^{n} d_t^{+} - (\beta - \sigma) \sum_{t=1}^{n} d_t^{-}. \tag{1'}$$

The first term is the sum of the utilities over all n periods. The second term adds the weighted utility from global improvement, by the weight $(\beta + \sigma)$. The third term subtracts the weighted disutility from global deterioration, weighted by $(\beta - \sigma)$. This equation was derived algebraically from Eq. (1). It differs from the equation in Loewenstein and Prelec (1993) by the negative sign in front of the third term in the equation $(\beta - \sigma)$. The authors of the original paper had a positive sign, which must have been a type-setting error. The term d_t from (1) has been split into two terms, the positive and the negative deviation, since previous research has shown that individuals react differently to gains and losses relative to a reference point (Kahneman & Tversky, 1979).

$$d_t^{+} \equiv \frac{|d_t| + d_t}{2}, \qquad d_t^{-} \equiv \frac{|d|_t - d_t}{2}, \quad \text{where } d_t = d_t^{+} - d_t^{-}$$

This splitting of the deviation relative to a constant sequence allows the model to record the net impact of improvement and deterioration on the value of the sequence separately.

In the current study, the "Sequence Value" in Eq. (1) was used as a predictor of the mean rating for the different sequences in the eight scenarios (domains of air, water, health, and income by each time period, 5 and 50 years), where the only free parameters were β and σ. All of the sequences have the same mean and time frame (per scenario), therefore the total value (or utility) of each sequence will be equal, so the first term in (1) became a constant (the sum of the bars of the sequence which is equal to 60.5). The cumulative deviations of the two increasing, one constant, and two decreasing graphs were recorded and used to determine the summations in the second and third terms in (1). Least-squares optimization was performed to come up with the parameters β and σ that fit the mean ratings data. Eight models were constructed, with different β and σ values for each of the eight scenarios.

Predictions of the Models

Loewenstein and Prelec applied their model in two different studies. Each study had the participants rate sequences in a single scenario, and the model was then fit to each individual. In the current study, the eight different scenarios were fit individually, but instead of fitting the model to each participant, the model was fit to the participants' mean rating data. Such an approach, fitting aggregate parameters, might be used in decision making involving environmental outcomes, since consumer preferences must be met on an aggregate level. Figure 4 displays the partitioning of the (β, σ) parameter space. (The partitioning in this figure is similar to Loewenstein & Prelec's (1993) Fig. 3 (p. 99)).

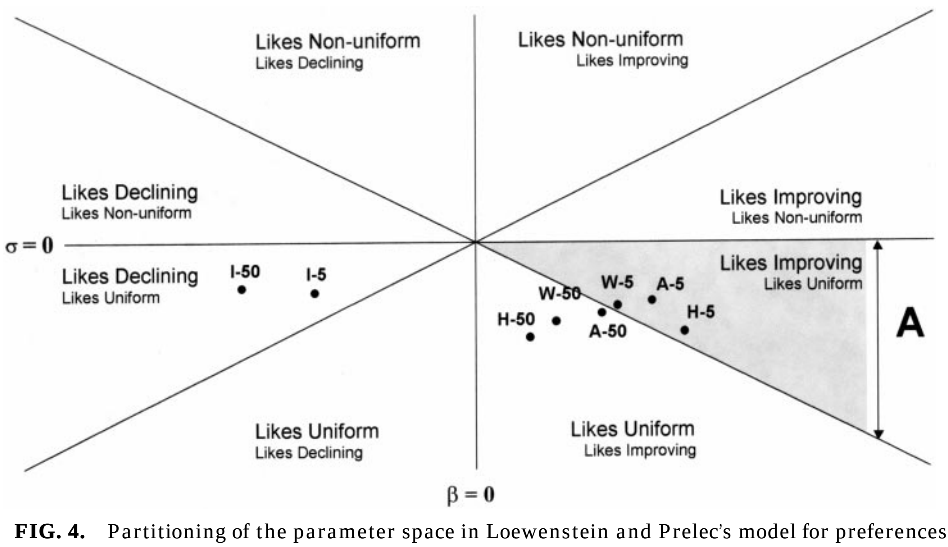

FIG. 4. Partitioning of the parameter space in Loewenstein and Prelec's model for preferences over outcome sequences into eight possible sign-magnitude combinations. The pair labels in each segment identify the major [top] and minor [bottom] motive associated with parameter values in that segment. The partitioning in this figure is similar to that used by Loewenstein and Prelec (1993, Figure 3 p. 99). The least-squares best-fitting (β, σ) pairs for the mean ratings data in the eight scenarios appear in the parameter space with the codings: A = Air Quality, W = Near-Shore Ocean Water Quality, H = Quality of Health, M = Monetary Income, 5 = Five-year time horizon, and 50 = Fifty-year time horizon.

The values of the (β, σ) pair determine the preference patterns. The large label (on top) in each section of Fig. 4 represents the dominant feature of the sequence. For example, if an individual's (β, σ) pair fell into Area A, then that person would like sequences that both improved and were uniform, but would find the improvement to be more important (higher weight) than the uniformity.

Figure 4 also plots the best fitting (β, σ) pairs for each sequence in the eight scenarios. These pairs, when used in Eq. (1), resulted in a predicted sequence value that minimized the sum of squared errors when compared with the actual mean values reported by the participants. These predicted values were then used as the independent variable in a regression to predict the actual mean ratings for the given scenario. A strong significant relationship exists between the sequence value given by Eq. (1) and the mean ratings ($F_{1,38} = 604.08$, $p = .000$, $R^2 = 94.08\%$).

Upon examining Fig. 4, for the environmental (points A-5, A-50, W-5, and W-50) and health domains (points H-5 and H-50), three out of six of the pairs lie in Area A. The remaining three pairs (A-50, W-50, and H-50) lie close to Area A, but closer to the β-axis, indicating a greater desire for uniformity than for improvement. This difference between the 5-year and the 50-year time horizons reveals that the participants (on average) put more weight on the increasing aspect than on uniformity in the short run, but they have a strong preference for uniformity in the long run. Looking back at the mean rating data in Fig. 3, we can see that the constant sequence shape was rated highest (on average) for these three domains in the 50-year time horizon, while the moderately increasing sequence shape had the highest mean rating in the 5-year time horizon. This is also in accordance with Fig. 3, which shows that the preference for increasing sequences is stronger in the short run than in the long run. In strong contrast, the best fitting (β, σ) pairs associated with the monetary sequences (I-5 and I-50) do not fall into the same areas as the other domains. The area that these pairs lie in shows a preference for sequences that both deteriorate and are uniform, but the deterioration of the sequence has a higher weight than the uniformity. The data point for the short-run income parameter pair (I-5) lies to the left of the (I-50) point. This once again shows that even in the monetary domain increasing sequences received a higher weight in the short run than in the long run. It appears that for both the monetary and nonmonetary domains, the mean rating data indicates a preference for more uniform over less uniform sequences, revealed by the best fitting $\sigma < 0$ in all cases. This goes against the traditional discounting model, which would predict a preference for a sharply decreasing sequence (which is the least uniform along with the sharply increasing one).

To contrast the results given by Loewenstein and Prelec's model, the data were also fitted to the traditional discounting model. Least-squares optimization was performed to find the best fitting discount rate (r) that minimized the difference between the mean rating and the net present value of the sequence across all sequences per scenario. Equation (3) displays the linear equation that was developed to best fit the data to the mean ratings,

$$Discounted \cdot Value = c + \alpha \sum_{t=1}^{n} \delta^t u_t, \tag{3}$$

where the parameters $\underline{c}$ and $\underline{\alpha}$ scale the discounted utility into the 0 to 100 rating interval where the current data resides. The parameter δ is the net present value discount function equal to $(1 + r)^{-1}$. The discounted values were used as the single independent variable in a regression to predict the mean ratings of the participants. A significant relationship exists between the discounted sequence value given by Eq. (3) and the mean ratings ($F_{1,38} = 93.29$, $p = .000$, $R^2 = 71.06\%$). Table 4 displays the results from the application of the traditional discounting model. As expected, the best-fitting discount rate associated with the environmental and health domains is negative, and the discount rate associated with the monetary domain is positive. Looking at Table 4, it is easy to see that, although both models are good predictors of the mean ratings, the model developed by Loewenstein and Prelec fits the mean ratings data from the current study better than the traditional discounting model, even when allowing for negative discount rates. Comparing the Sum of Squared Errors (SSE) measure per scenario, the model developed by Loewenstein and Prelec produces a lower SSE in all cases, even in the monetary domain. This is an indication that individuals use other features, besides the net present value of a sequence, when evaluating sequences of outcomes. Restricting the discount rate to being nonnegative, as required in traditional discounting, would result in a worse fit ($F_{1,38} = 16.02$, $p = .000$, $R^2 = 29.66\%$).

TABLE 4

Parameter Values and Sum of Squared Errors from the Application of Loewenstein and Prelec's Model and the Traditional Discounting Model

		Loewenstein & Prelec			Traditional discounting			
Domain	Time horizon	β	σ	SSE	Discount rate r	Scaling c	Parameters α	SSE
Air quality	5	0.19	−0.13	73.50	−0.28	−21.89	0.48	233.52
	50	0.14	−0.16	71.34	−0.02	−21.87	0.63	287.62
Water quality	5	0.16	−0.14	89.67	−0.23	−21.89	0.59	298.21
	50	0.09	−0.18	24.51	−0.02	−21.87	0.80	307.78
Quality of health	5	0.23	−0.20	126.59	−0.35	−21.90	0.32	395.52
	50	0.06	−0.21	124.28	−0.01	−21.85	0.91	709.45
Income streams	5	−0.18	−0.11	37.79	0.33	−21.86	2.35	193.25
	50	−0.26	−0.10	30.03	0.05	−21.82	3.02	151.51

Model	$F_{1,38}$	R^2
Loewenstein & Prelec	604.08****	94.08%
Traditional discounting (discount rate r unrestricted)	93.29****	71.06%
Traditional discounting (discount rate $r > 0$)	16.02****	29.66%

**** $p < .0001$.

Note. Using fitted models' ratings of five sequence shapes to predict actual average ratings (in four domains and two time horizons).

CONCLUSION

Our experimental findings suggest that preferences for temporal sequences of consequences may show domain-specific effects, in particular that monetary streams of consequences may be treated very differently from environmental and health-related consequences. Generally, our participants (a) prefer constant or increasing sequences of air quality, near-shore ocean water quality, and qualities of health, but (b) they prefer decreasing sequences of income. They gave significantly lower ratings to environmental sequences (with equal means) that worsened over time, relative to the ratings they gave to sequences that either remained the same or improved over time. This pattern is reversed when participants face sequences of monetary outcomes. This preference structure held for both short (5-year) and long (50-year) time horizons, and it was confirmed with the choice data. A positive relationship between the shape of the expectation of the most likely sequence and the shape of the ideal sequence was also found in the health domain, but not in the environmental or monetary domain.

Our findings have important implications for the application of traditional decision-analytic models to decisions involving sequences of environmental and monetary outcomes over time with effects on multiple stakeholders. For example, methods that "price-out" environmental consequences and discount their monetary equivalents may not reflect the true preferences of a stakeholder. Furthermore, even using different discount rates for each attribute in a traditional discounting model may not be sufficient, since the standard model cannot represent preferences for "configural" aspects of consequence sequences (e.g., preference for uniformity of sequence patterns). We found that Loewenstein and Prelec's model of temporal preferences (which can incorporate such configural aspects) outperformed the traditional discounting model in representing the responses of our participants.

More research is needed to analyze temporal preferences for consequences such as environmental events where there is no market mechanism that would justify a traditional discounting model. For example, it would be interesting to find out whether biases observed in the monetary domain (e.g., gain/loss asymmetries) occur in the environmental and health domain as well. Such studies will enhance our understanding of how people form and express preferences in realistic decision contexts with temporal streams of consequences on a variety of dimensions. Furthermore, these empirical results would form the basis for developing appropriate models that can then support societal decision makers in their difficult and often controversial endeavors.

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