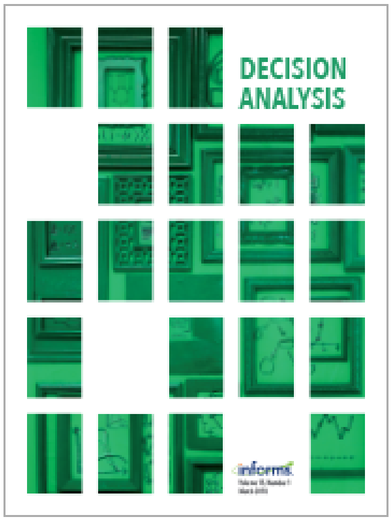

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Valuing Sequences of Lives Lost or Saved Over Time: Preference for Uniform Sequences

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Abstract. Policymakers often make decisions involving human-mortality risks and monetary outcomes that span across different time periods and horizons. Many projects or environmental-regulation policies involving risks to life, such as toxic exposures, are experienced over time. The preferences of individuals on lives lost or saved over time should be understood to implement effective policies. Using a within-subject survey design, we investigated our participants' elicited preferences (in the form of ratings) for sequences of lives saved or lost over time at the participant level. The design of our study allowed us to directly observe the possible preference patterns of negative time discounting or a preference for spreading from the responses. Additionally, we embedded factors associated with three other prevalent anomalies of intertemporal choice (gain/loss asymmetry, short/long asymmetry, and the absolute magnitude effect) into our study for control. We find that our participants exhibit three of the anomalies: preference for spreading, absolute magnitude effect, and short/long-term asymmetry. Furthermore, fitting the data collected, Loewenstein and Prelec's model for the valuation of sequences of outcomes allowed for a more thorough understanding of the factors influencing the individual participants' preferences. Based on the results, the standard discounting model does not accurately reflect the value that some people place on sequences of mortality outcomes. Preferences for uniform sequences should be considered in policymaking rather than applying the standard discounting model.

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Keywords: behavioral decision making • preference assessment • time preference

1. Introduction

Many societal policy decisions involve human-mortality risks and monetary outcomes that are experienced over time. Government agencies often face decisions on projects or environmental regulations involving risks to life, such as cancer risks from toxic exposures. To incorporate the time element into decision making, the concept of discounting monetary outcomes has become well accepted when performing a decision analysis (Clemen and Reilly 2014). Discounted utility theory,[1] introduced by Samuelson (1937) and derived axiomatically by Koopmans (1960) and Fishburn and Rubenstein (1982), has historically been the dominant model for intertemporal choice problems with a single monetary attribute when future monetary outcomes are known with certainty. If the level of the attribute is linear with the utility associated with it, then the standard discounting model takes the form

$$\textit{Discounted Value} = \sum_{t=0}^{T} \delta^t P_t, \quad (1)$$

where P_t is the monetary value at time t, and the parameter δ is the net present value discount function equal to $1/(1 + r)$ with the discount rate $r > 0$. Most research on how individuals implicitly discount future outcomes focuses primarily on monetary outcomes or consumer goods and services such as VCRs and restaurant meals (Thaler 1981; Loewenstein 1988; Benzion et al. 1989; Loewenstein and Prelec 1991, 1992). However, discounting of human lives (or years of life) saved (or lost) is much more controversial (Klarman et al. 1968, Roth et al. 1978, Eddy 1980). When merely considering now versus a single point in the future, rather than a sequence of time periods, there is evidence that people do discount a life saved in the future relative to a life saved today, indicating a positive discount rate for lives saved. Horowitz and Carson (1990) find that the average annual discount rates respondents placed when comparing lives saved now versus lives saved 3–5 years into the future is between 4.5% and 12.8%. Cropper et al. (1992) find that the majority attach a different discount rate to saving a life in the far future, with a larger discount rate (16.8%) for the nearer future such as 5 years compared with a distant future of 100 years (3.8%).

Use of the standard discounting model may not actually match the preferences of the public, though, based on evidence from prior studies on preference for sequences of monetary outcomes (Frederick and Loewenstein 2008), as well as evidence of the presence of other anomalies associated with intertemporal monetary choice (Loewenstein and Elster 1992, Frederick et al. 2002). Previous research in this area has predominately employed two different types of elicitation procedures when empirically testing the standard discounting model for predictive accuracy: (1) rating (or ranking) of sequences and (2) matching of quantity–timing pairs.

The studies that elicited the ratings (or rankings) of different sequences have revealed that participants are possibly using characteristics of the sequence such as peak, trend, endpoint, and uniformity when making value judgments. The associated deviations from the standard discounting model are negative time discounting and preference for spreading. Negative time discounting occurs when a person's preferences are consistent with a negative discount rate.[2] For example, people who prefer to receive an improving sequence of payments over a declining one with an equal mean are consistent with a negative discount rate (Loewenstein and Sicherman 1991, Schmitt and Kemper 1996, Read and Powell 2002). Preference for spreading is associated with a higher preference for stable moderate sequences relative to more extremely sloped sequences (with an equal mean). Individuals have shown a preference to spread outcomes over time rather than concentrate them (Loewenstein and Prelec 1993, Chapman 1996, Guyse et al. 2002). For a thorough review, see Frederick and Loewenstein (2008).

The literature using the matching elicitation procedure has revealed three anomalies that cause deviations from the predictions of the standard discounting model: gain/loss asymmetry, short/long-term asymmetry, and the absolute magnitude effect. Gain/loss asymmetry occurs when individuals implicitly use a higher subjective discount rate for gains than for losses (Thaler 1981, Loewenstein and Prelec 1991, Shelley 1993, Ahlbrecht and Weber 1997). Short/long-term asymmetry, also known as the *immediacy effect* (Read et al. 1999, Weber and Chapman 2005) or *present-biased preference* (O'Donoghue and Rabin 1999), occurs when an individual's implicit long-term subjective discount rate is lower than the short-term subjective discount rate (Thaler 1981, Benzion et al. 1989, Stevenson 1992, Kirby and Marakovic 1995, Chapman 1996, Ahlbrecht and Weber 1997). For example, a person's discount rate between 15 and 16 years from now may be lower than the rate between this year and next year. The absolute magnitude effect occurs when participants subjectively discount large monetary amounts less than smaller amounts (Thaler 1981, Benzion et al. 1989, Loewenstein and Prelec 1992, Chapman and Elstein 1995, Kirby and Marakovic 1995). See Frederick et al. (2002) for a comprehensive review of all three anomalies.

Guyse and Simon (2011) provide a detailed analysis of the consistency between the two elicitation methods discussed earlier for monetary outcomes in a within-subjects design. They observed significantly more consistency in the results between the two elicitation techniques when the outcome was a gain in the relatively far future than when it was a future loss. They propose that this may be due to the participants' inability to display a preference for spreading in a matching task.

In addition to the issues raised by these past studies, we question whether application of the standard discounting model would accurately reflect the preferences of the public when the outcomes are (nonmonetary) human lives. Descriptive studies have investigated whether individuals adhere to the standard discounting model for other types of nonmonetary outcomes.

Our earlier work (Guyse et al. 2002) on how people value sequences of nonmonetary outcomes of health level, air quality, and near-shore ocean water quality found that elicited preferences did not conform to those predicted by the standard discounting model. Many participants exhibited either a preference for spreading or negative time discounting in these domains. Keeler and Cretin (1983) present a normative argument in favor of using the same discount rate for monetary and nonmonetary outcomes when decisions are made by choosing the program that yields the highest cost-effectiveness (the highest discounted benefit per discounted monetary unit). In contrast, a recent study by Attema et al. (2018) found that individuals may actually discount monetary outcomes (an increase in purchasing power) at a higher rate than health (a decrease in back pain).

Sparse evidence has been reported on the public's preferences for temporal sequences of human lives. Frederick (2003) investigated preferences associated with the saving of human lives over time with respect to the elicitation procedure employed. In his study, two of the methodologies used sequences ("sequence" and "equity"), but his focus was on the influence of the elicitation procedure and not on characterizing the public's preferences in general. In these two tasks, the complementary case of losing lives was not investigated.

Frederick and Loewenstein (2008) found that different elicitation tasks lead to different results when evaluating sequences in between-subjects experiments. This inconsistency disappeared when they used a within-subjects design in Frederick and Loewenstein (2008, study 2b).

Our paper extends and synthesizes the breadth of differing results just discussed. We investigate whether the participants' elicited preferences (in the form of ratings) for sequences of human lives saved or lost over time are in accordance with the standard discounting model using a within-subjects experimental design to minimize these inconsistencies and additionally enable the subsequent modeling of preferences at the participant level. In addition to being able to observe a preference for spreading and/or negative time discounting explicitly through the ratings data collected, we embedded factors into the survey design that are associated with the other three anomalies of intertemporal choice (gain/loss asymmetry, short/long-term asymmetry, and the absolute magnitude effect). If deviations from the standard discounting model do exist, these embedded controls may help to identify whether the deviations are due to the influence of any of these three anomalies. We also fit an alternative intertemporal value model proposed by Loewenstein and Prelec (1993). This latter model (1) has the ability to consider "configural" aspects, such as the uniformity of the sequence, to capture a preference for spreading, and (2) places no restriction on sequence direction to capture negative time discounting and therefore may be a relatively better descriptive model to capture the importance of these factors at the participant level.

To summarize, our research investigates whether preferences for sequences of human lives are in accordance with the standard discounting model. If they are not, what preference pattern is observed in this domain, and could it be that the observed nonconformance is due to the factors associated with the anomalies of intertemporal choice? Finally, if the preferences are not in accordance with the standard discounting model, is there an alternative descriptive model that can be employed that captures and details the important factors associated with the preferences for sequences of lives lost or saved over time at the participant level?

In the next section, we detail our experimental design. We follow it with the analysis of the preference ratings and the subsequent fitting of a descriptive intertemporal preference model. This study concludes with a general discussion and possible directions for further research.

2.1. Method

2.1.1. Participants

This study uses a within-subjects design with 101 subjects. The participants are undergraduate students at a large public research university on the West Coast of the United States, and each received course credit for participating in the study. The median age of the participants is 21 years.

2.1.2. Procedure and Design

Participants were presented with eight scenarios involving sequences of lives lost or saved over time. They were asked to rate their preferences for the different sequences of mortality outcomes. Each of the scenarios consisted of three triples (all with the same yearly mean) that differed only in the distribution of the lives over the time horizon. The actual survey used can be found in the online supplement. An example scenario is as follows:

> Please rate (according to personal preference) from 1 (relatively poor distribution of lives) to 10 (relatively excellent distribution of lives) these sequences of different ways **24 lives** could be **saved** for sure for three consecutive years, **starting this year**.

	This year	Next year	2 years from now
Option A	0	0	24
Option B	8	8	8
Option C	24	0	0

> Rate (by filling in the blank) from 1 (relatively poor distribution of lives) to 10 (relatively excellent distribution of lives) for each option. Be sure to notice the timing of the events as labeled in the first row of the table.

Option A __________

Option B __________

Option C __________

A person following the standard discounting model with a positive discount rate would prefer (rate highly) the declining sequence {24, 0, 0}. A preference for spreading or negative time discounting is easily identified with the questionnaire design through high relative ratings reported for the uniform {8, 8, 8} or improving {0, 0, 24} sequences, respectively. To identify possible influences of the other three anomalies discussed, we constructed different scenarios that were based on factors associated with each of these anomalies. This ensures that the preferences have been assessed with scenarios varying on the control factors that have been shown to cause inconsistencies with the standard discounting models for monetary outcomes. Given the lives-saved scenario displayed above, a scenario to examine the possible presence of gain/loss asymmetry was designed by multiplying all outcomes by −1 and changing the instructions to read "lost" instead of "saved." Below is the scenario transformed into the lives-lost domain. Note that a person following the standard discounting model with a positive discount rate would prefer (rate highly) the declining sequence of {0, 0, −24}.

> Please rate (according to personal preference) from 1 (relatively poor distribution of lives) to 10 (relatively excellent distribution of lives) these sequences on different ways that **24 lives** could be **lost** for sure for three consecutive years, **starting this year**.

	This year	Next year	2 years from now
Option A	0	0	−24
Option B	−8	−8	−8
Option C	−24	0	0

> Rate (by filling in the blank) from 1 (relatively poor distribution of lives) to 10 (relatively excellent distribution of lives) for each option. Be sure to notice the timing of the events as labeled in the first row of the table.

Option A __________

Option B __________

Option C __________

A factor associated with short/long-term asymmetry was embedded in the design by adding a uniform 15 years to all outcome timings in the two scenarios presented above, thus changing the initial timing of the 3-year sequences from now to 15 years into the future. The wording was subsequently changed to "Please rate (according to personal preference) from 1 (relatively poor distribution of lives) to 10 (relatively excellent distribution of lives) these sequences on different ways that 24 lives could be saved (*or lost*) for sure for 3 consecutive years, starting 15 years from now."

Finally, a factor associated with the absolute magnitude effect was embedded in the design by multiplying all the outcomes in the four tasks described above by 25.

Therefore, the design incorporated a 2 (save lives versus lose lives) × 2 (short versus long initial timing of the sequences) × 2 (relatively small versus relatively large magnitude of lives) factorial design, creating eight possible combinations. Because we employed a within-subjects design in our experiment, we were also able to identify any significant interactions between these factors at the participant level, which has not been investigated in the domain of human-mortality outcomes. Scenarios were presented one at a time. All the participants eventually saw all eight scenarios. The order of the scenarios was randomized across the participants. Each scenario had a validation check added to ensure that the participants entered ratings between 1 and 10 for each of the three sequences presented before they were allowed to proceed to the next scenario. Ties in reported ratings were allowed. Backtracking was not permitted once the responses for a given scenario were submitted.

2.2. Results

2.2.1. Investigation into the Accordance with the Standard Discounting Model

The standard discounting model makes very precise predictions on how the sequences presented in this study shall be rated. A model that discounts the number of lives saved in each period with a positive discount rate would predict that the declining sequence shape receives the highest rating, followed by the uniform shape, with the improving sequence receiving the lowest rating of the three. Therefore, if a fixed number of lives were to be saved, the standard discounting model would require a person to give the highest rating to the sequence that has all these lives saved in the first year and has no lives saved in the ensuing two years. Similarly, in the case of lost lives, all the lives should be lost in the third year of the sequence to be highest rated.[3] This preference order should be independent of the magnitude and initial timing of the sequences.

To investigate whether the ratings elicited from our participants were in accordance with the predictions of the standard discounting model with a positive discount rate, an indicator variable was defined as follows for each scenario for each participant:

$$I_D = \begin{cases} 1 & \text{if the participant's ratings in a given} \\ & \text{scenario were in accordance with the} \\ & \text{standard discounting model,} \\ 0 & \text{otherwise.} \end{cases} \tag{2}$$

Participants who rated the declining sequence shape the highest (all lives saved in the first period or all lives lost in the last period), followed by the uniform sequence shape (equal number of lives saved and lost over the three time periods), with the improving sequence shape (all lives saved in the last period or all lives lost in the first period) receiving the lowest rating of the three are considered "in accordance with the standard discounting model." Any reported ties in ratings are not in accordance with the standard discounting model for a positive discount rate.

Per scenario across participants, ratings that were in accordance with the standard discounting model as defined above ranged from 10% to 17%. Participants themselves ranged between 0% and 100% across the eight scenarios they evaluated, with a median of 0% and a mean of 12.9%. Only 2% of the participants (2/101) gave ratings that were completely in accordance with the standard discounting model.

The number of scenarios in which a participant was in accordance with the standard discounting model was tabulated to further investigate the observed relatively low compliance. Table 1 displays the frequency and relative frequency distributions associated with the number of scenarios in which the participants rated the three sequences in accordance with the standard discounting model. Referring to Table 1, note that, as reported, only 2% of the participants (2/101) were in accordance across all eight scenarios presented to them. We found that 94% (95/101) of the participants were *not* in accordance in four or more of the eight scenarios. Based on our study, few participants actually rated these sequences of lives over time in accordance with the standard discounting model.

When looking into the ratings data for other patterns (aside from the standard discounting model with a positive discount rate, which requires a preference for the declining sequence), it was found that 3% (3/101) of the participants responded with ratings for all eight scenarios that preferred the improving sequence, which is in accordance with negative time discounting. Because each option within a scenario sums up to the same number of lives across the three time periods, a person who does not discount at all (zero discounting) would be indifferent between A, B, and C and would have given them all the same rating. No participant rated all the scenarios presented to him or her in accordance with zero discounting. Table 2 displays a

Table 1. Frequency and Relative Frequency Distributions Associated with Accordance of Participant's Ratings with the Standard Discounting Model with a Positive Discount Rate

Number of scenarios rated in accordance	Number of participants (N = 101)	Percentage of participants	Implications
0	67	66.3%	
1	11	10.9%	
2	7	6.9%	
3	2	2.0%	One or more violations of standard discounting
4	8	7.9%	
5	1	1.0%	
6	1	1.0%	
7	2	2.0%	
8	2	2.0%	Standard discounting

summary of the findings across the participants in this study.

Because the participants overwhelmingly did not assign ratings that were in accordance with the standard discounting model, the question then arises as to how these ratings were actually assigned. In the next section, we investigate how these ratings systematically differed from those predicted by the standard discounting model.

2.2.2. Investigation into the Observed Preference Patterns

The percentage of participants rating each sequence the best (highest numerical rating) is displayed[4] in Table 3. As detailed earlier, the standard discounting model would predict that the declining sequence shape would be rated the best by all participants in all scenarios because (1) the best outcome (saving lives) should occur at the earliest time in the saving-lives case, and (2) in the losing-lives case, the worst outcome should be at the latest time. Giving the best rating to any of the other sequence shapes is considered inconsistent with the standard discounting model. A quick inspection of Table 3 reveals that the majority of the participants did not rate the declining sequence shape the best, but, modally, the uniform sequence shape was the best rated across all eight scenarios (shown in bold font). A rating of the uniform shape as the best exhibits a preference for spreading that cannot be captured by the standard discounting model. The maximum percentage of participants in accordance with the standard discounting model (rating the declining sequence shape the best) was in the scenario involving the saving of the relatively larger number of lives in the later time horizon, but even there, only one in four participants rated the declining shape the best.

The percentage of participants rating each sequence shape the best indeed depends on the shape of the sequence in all scenarios, as indicated by the overall goodness of fit (uniform multinomial) χ^2 values reported in the last row of Table 3. The preference pattern for each sequence shape is also observed to depend on whether the lives are saved or lost. Notice that when the lives are saved, the declining sequence shape is generally the second-best-rated sequence shape. A preference for a declining sequence of lives saved would indicate a desire to save lives now rather than later and is consistent with the standard discounting model. However, when the domain changes to lives lost, the improving sequence shape becomes the

Table 2. Summary of Participants' Accordance with the Standard Discounting Model

Sign of discount rate	Actual number of the 101 participants consistent across all 8 scenarios	Average number of the 8 scenarios rated in accordance per participant	Implications
Negative	3	0.92	Discounting but sign differs from standard discounting
Zero	0	0.57	
Positive	2	1.03	Standard discounting

Table 3. Percentage of Participants Rating Each Sequence Shape as the Best

	Saved				Lost			
	Now		Later		Now		Later	
Shape	Small	Large	Small	Large	Small	Large	Small	Large
Declining	23%	21%	22%	25%	20%	22%	17%	18%
Uniform	**57%**	**57%**	**60%**	**58%**	**56%**	**55%**	**62%**	**58%**
Improving	20%	21%	19%	17%	23%	23%	20%	24%
Overall $\chi^2_{df=2}$	26.11****	25.66****	31.82****	29.05****	23.70*****	21.93****	37.60****	28.38****

Note. Boldface font indicates that the uniform sequence shape was the best rated across all eight scenarios.
****$p < 0.001$.

second-best-rated across scenarios. A preference for improving the sequence of lives lost would indicate a desire to lose lives now rather than later, which is associated with negative time discounting. In both instances, aside from the modal rating of a uniform sequence as the best, the second-best-rated sequence shape was the one that had immediate life outcomes rather than delayed ones. Future events are uncertain, and studies have shown a strong link between behavior associated with intertemporal choice and behavior when facing uncertainty (Prelec and Loewenstein 1991). This second-best rating of the immediate life outcomes rather than delayed ones may be attributed to an aversion of the participants to delaying the resolution of the events (Prelec and Loewenstein 1991, Wu 1999).

2.2.3. Do the Three Embedded Anomaly Factors Affect Observed Ratings?

To see whether any of the embedded factors associated with the anomalies of intertemporal choice had an influence on the raw mean ratings, we examined the mean ratings reported for each sequence at the participant level. A repeated-measures analysis of variance (ANOVA) model was employed that included the quantitative dependent variable of the *Rating* (1–10), the qualitative dichotomous independent variables of *Save/Lose*, *Magnitude* (relatively small or large), *Initial Timing* (sequences starting now or starting 15 years from now), and the categorical qualitative independent variable *Shape* (three levels of declining, uniform, or improving). The results on this ANOVA are displayed in Table 4, "Analysis 1."

The shape of the sequence and whether the lives were saved versus lost both had significant main effects ($F_2 = 44.35$, $p < 0.001$, and $F_1 = 66.75$, $p < 0.001$, respectively). In addition, there was a significant two-way interaction between the relative magnitude of lives involved and whether the lives were saved or lost ($F_1 = 5.99$, $p < 0.05$). Finally, a significant four-way interaction between *Shape* × *Magnitude* × *Save/Lose* × *Initial Timing* ($F_2 = 3.93$, $p < 0.05$) was present. These findings will be discussed individually in detail. All other main effects and interactions were insignificant ($p > 0.05$).

The main effect of *Shape* in "Analysis 1" of Table 4 indicates that at least one of the three different sequence shapes (declining, uniform, or improving) received a different mean rating than the others. Figure 1 graphically displays the effect that the shape of the sequence had on the mean ratings.

The participants in this study gave the uniform sequence shape the best mean rating. This result is consistent with the analysis in the preceding section and once more displays a consistent preference for spreading across both lives saved and lives lost. In addition, Figure 1 displays the main effect associated with the lives being saved versus lost, evidenced by the falling of the three sets of mean rating lines from lives saved to lives lost. On average, the participants rated sequences of lives saved higher than sequences of lives lost for all the scenarios presented to them. This behavior may be considered logical because losing lives is definitely less desirable than saving lives. Because the task asked the participants to give higher ratings to sequences that displayed "relatively excellent distribution of lives," participants may have been wary to subjectively judge such sequences of lives being lost as "excellent," even if a sequence were the best among the three being compared within a single scenario. This aversion would result in the observed lower mean

Table 4. Repeated-Measures ANOVA Results on Ratings for Sequences of Lives

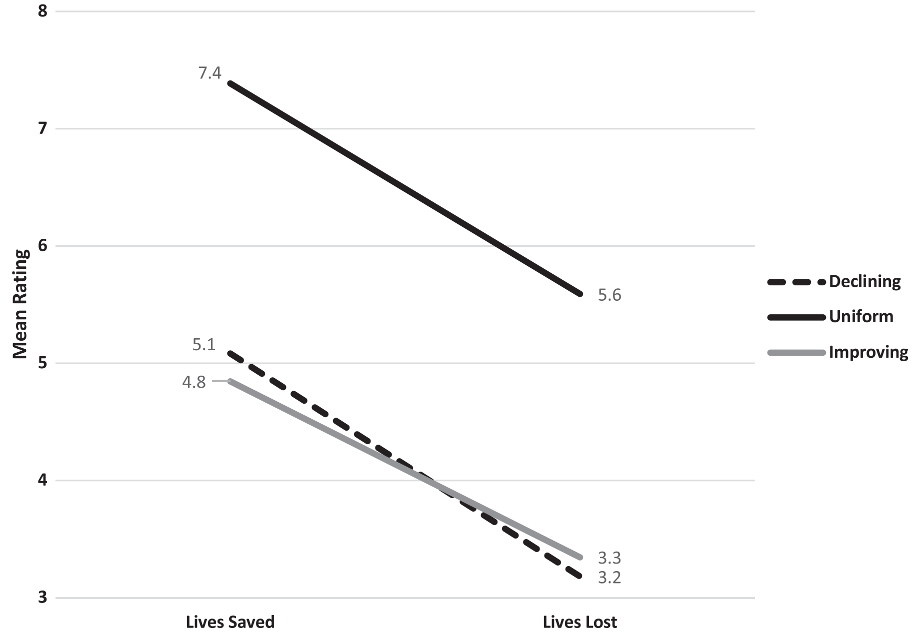
	Analysis 1: Both lives saved and lives lost			Analysis 2(a): Lives saved only			Analysis 2(b): Lives lost only		
Factor	*df*	*F*	MS_e	*df*	*F*	MS_e	*df*	*F*	MS_e
Shape	2	44.35***	1,517.90	2	33.57***	794.88	1.90[a]	33.89***	771.34
Magnitude	1	2.53	9.16	1	0.32	1.19	1	8.65**	28.85
Save/Lose	1	66.75***	1,817.57						
Initial Timing	1	0.48	1.44	1	0.00	0.01	1	1.24	2.50
Shape × *Magnitude*	2	0.01	0.03	2	2.10	3.77	2	1.06	3.04
Shape × *Save/Lose*	2	0.79	8.72						
Magnitude × *Save/Lose*	1	5.99*	20.88						
Shape × *Magnitude* × *Save/Lose*	2	2.96	6.78						
Shape × *Initial Timing*	2	0.25	0.38	1.90[a]	0.43	0.68	1.87[a]	0.01	0.02
Magnitude × *Initial Timing*	1	0.45	1.07	1	0.18	0.56	1	0.20	0.52
Shape × *Magnitude* × *Initial Timing*	2	0.44	0.80	1.90[a]	3.49*	6.28	1.91[a]	0.82	1.54
Save/Lose × *Initial Timing*	1	0.42	1.07						
Shape × *Save/Lose* × *Initial Timing*	2	0.16	0.28						
Magnitude × *Save/Lose* × *Initial Timing*	1	0.00	0.00						
Shape × *Magnitude* × *Save/Lose* × *Initial Timing*	2	3.93*	6.64						

Note. Sphericity was assumed via results of the Mauchly (1940) test unless otherwise indicated.
[a]*df* values are corrected via Greenhouse and Geisser (1959) estimate to account for the lack of sphericity.
$^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

ratings for lives-lost scenarios across the board, regardless of the influence of gain/loss asymmetry.

Looking only at the declining sequence shape (dashed line) and the solid light line (improving) in Figure 1, the steeper dashed line might be considered partial evidence of gain/loss asymmetry. This particular anomaly predicts that the discount rate for gains is higher than for losses, which would reveal itself as a larger difference in the mean ratings of declining and improving sequences shapes in gains (5.1–4.8) relative

Figure 1. Mean Ratings Across Sequence Shapes



to the differences in the means associated with losses for declining versus improving sequences (3.2–3.3).

To disentangle the significant interactions displayed in "Analysis 1" of Table 4, the data were partitioned into two sets: one set for the scenarios involving only lives being saved and the other set for those scenarios where the lives were lost. Results from these partitioned sets are also listed in Table 4 as "Analysis 2(a)" and "Analysis 2(b)," respectively. Based on "Analysis 2(a)," we find nonsignificance of the *Magnitude* factor ($F_1 = 0.32$, $p > 0.50$). The difference in mean ratings across the two different magnitudes of lives used in this study only exists in the lives-lost domain, as shown by the significant main effect of *Magnitude* in "Analysis 2(b)" ($F_1 = 8.65$, $p < 0.01$). Figure 2 displays a graphical representation of this interaction of *Magnitude* by lives saved or lost.

Because the main effect of *Magnitude* does not appear in "Analysis 2(a)," which was performed only on the lives-saved data, the solid line at the top of Figure 2 is not significantly different from a flat line. This indicates no reported difference in the mean ratings between the small and large magnitudes of lives saved. This could be an indication of an insensitivity to scope (Kahneman et al. 1999) in the domain of lives saved; the mean ratings associated with saving 24 lives do not significantly differ from those of saving 600 lives. A closely related example of insensitivity of scope as found in our result is reported by Baron and Greene (1996, study 7). They found a large number of subjects who reported the same willingness to pay to prevent a death (i.e., save a life) for a pair of scenarios, even though the quantities of lives involved varied by a factor of 10. Conversely, note that this same insensitivity to scope does not seem to be present in our results when the lives are being lost. The significance of the main effect of *Magnitude* in "Analysis 2(b)" indicates that there is a difference between mean ratings for sequences of relatively small magnitudes versus relatively large magnitudes of lives being lost in this study. Mean preference ratings for sequences of lives lost decreased as the lost-lives magnitude increased. This finding appears also to be additional evidence that losses loom larger than gains (Kahneman and Tversky 1979). The difference in the magnitude of lives *saved* did not influence the mean ratings, but when the scenario involved lives being *lost*, the larger amount of lost lives was rated lower on average, independent of the sequence shape.

The four-way interaction between *Shape* × *Magnitude* × *Save/Lose* × *Initial Timing* in "Analysis 1" only remains as the three-way interaction between *Shape* × *Magnitude* × *Initial Timing* for lives saved in

Figure 2. Magnitude by Lives Saved or Lost Interaction

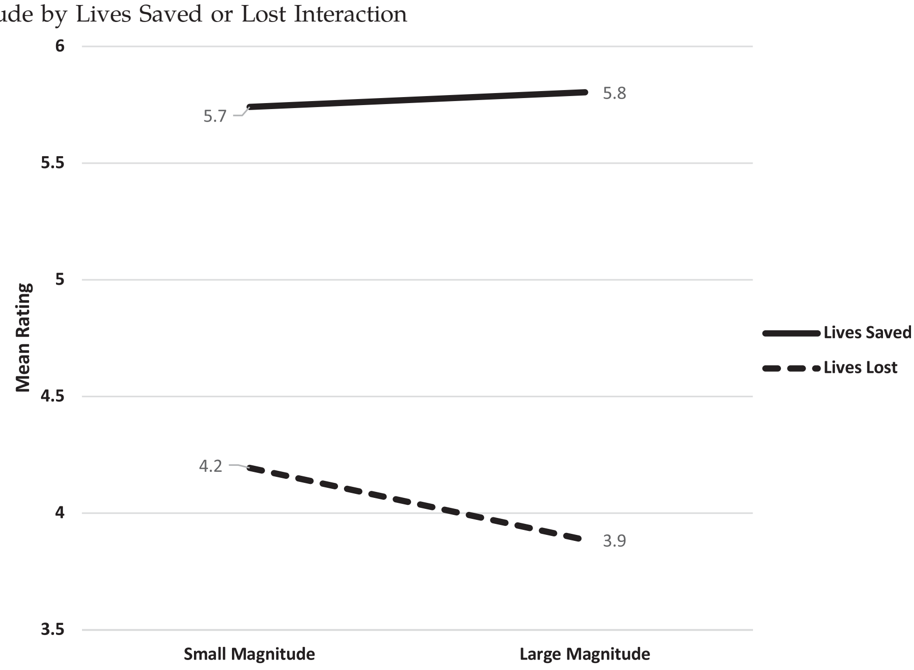
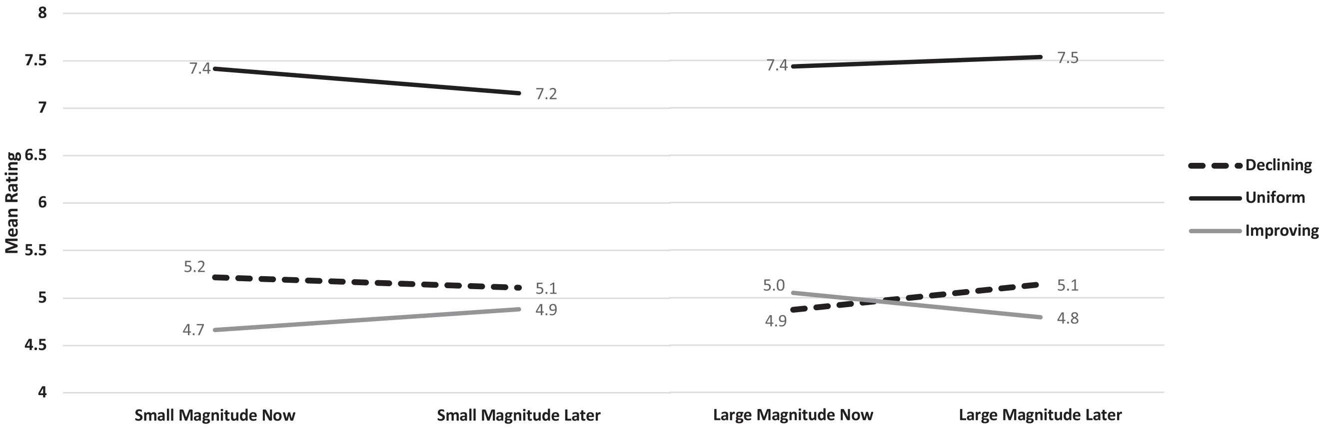


Figure 3. Lives Saved Now vs. Later Interaction Between Sequence Shape and Magnitude



"Analysis 2(a)" ($F_{1,900} = 3.49$, $p < 0.05$) and is absent from the lives-lost data in "Analysis 2(b)" ($F_{1,910} = 0.82$, $p > 0.40$). Figure 3 displays a graphical representation of this interaction in the lives-saved domain.

When examining Figure 3, notice that the uniform (solid black) and the declining (dashed line) sequence shapes appear to be separated only by the main effect of *Shape*—that is, they appear to be fairly parallel in both the left-hand and right-hand graphs. Additional analysis on the saved-lives data omitting the improving shape (light solid line) supports this. The *Shape* × *Magnitude* × *Initial Timing* interaction loses its significance when omitting the improving sequence shape from the analysis ($F_1 = 0.002$, $p > 0.90$). The black solid and black dashed lines in both graphs in Figure 3 could be running parallel to each other. In contrast, when including the improving sequence shape, the three-way interaction term becomes significant (as seen in Table 4, "Analysis 2(a)"), indicating that the improving sequence shape's light solid line is not running in parallel to the other two. Therefore, the mean ratings of the improving sequence shape associated with lives being saved are influenced differently by the relative magnitude, as well as the initial timing of the sequence. It appears to be a reflection or inverse of the other two—that is, when the mean ratings are decreasing (increasing) on average for the uniform and declining sequences, they are increasing (decreasing) for the improving sequence. The absolute magnitude effect anomaly predicts that lower quantities are typically discounted at a higher rate than larger quantities. A higher discount rate would indicate more impatience, which would mean a tendency to give a higher rating to the declining sequence when smaller magnitudes are involved. See in Figure 3 that the mean rating of 5.2 for the small magnitude now does exceed the 4.9 of the large magnitude, but for later outcomes, the ratings averaged 5.1 for both small and large magnitudes. Likewise, short/long-term asymmetry predicts a higher discount rate in the short term versus the long term. This would also predict a higher mean rating for the declining sequence shape in the short term. The effect we observe here is of a form consistent with these two anomalies occurring simultaneously in the gains domain because there is an increase in the average rating associated with declining sequence shape when relatively small amounts of lives are saved in the short term. It is indicated by the movement of the mean rating for the declining sequence (dashed line) from 4.9 to 5.2 (*large* magnitude *now* to *small* magnitude *now*) as well as from 5.1 to 5.2 (*small* magnitude *later* to *small* magnitude *now*) in Figure 3.

In summary, there is evidence that the preferences were influenced by some of the factors associated with the anomalies of intertemporal choice. There appears to be a strong preference for spreading across all scenarios involving both lives saved and lives lost. Short/long-term asymmetry appears to explain the variation in the percentage of participants rating the declining sequence shape as best, along with evidence that the preference for spreading grows in strength as the timing of the outcomes shifts further into the future. Factors associated with the absolute magnitude effect and short/long-term asymmetry are also seen to explain the observed increase in the average rating associated with the declining sequence shape when a relatively small amount of lives were to be saved in the short term.

The reported results up to this point indicate that the ratings given by the participants in this study are not in accordance to the standard discounting model; specifically, there is a prevailing preference for spreading. Therefore, we would like to investigate whether an alternative model to the standard discounting model can be employed that would better capture and detail the importance of the factors affecting the participants' ratings for these sequences of lives. The following section covers this investigation.

3. Application of the Fitted Intertemporal Value Model

Based on the preceding analysis, the standard discounting model does not accurately capture the preference ratings reported by the participants for these sequences of lives. The standard discounting model with a positive discount rate will predict preferences for declining sequences only. If a negative discount rate were allowed (negative time discounting), it will predict preferences for improving sequences only. In both cases, the uniform should be second highest in rating, and the remaining sequence shape should be rated lowest. This predicted preference pattern under discounting is independent of the (nonzero) magnitude of the discount rate. When the discount rate is zero, all sequence shapes across all scenarios should receive the same exact rating. It has been noted that no participant in this study provided ratings that were associated with a zero discount rate across all eight scenarios.

An intertemporal value model proposed by Loewenstein and Prelec (1993) may be able to capture and identify the importance of the factors that lead to the relatively high ratings for the uniform sequence shape, as well as possible patterns for the ratings for both the improving and declining shapes.

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

$$\textit{Sequence Value} = \sum_{t=1}^{n} u_t + \beta \sum_{t=1}^{n} d_t + \sigma \sum_{t=1}^{n} |d_t|, \tag{3}$$

where for each period t, u_t is the utility associated with receiving the outcome at time t. If the parameter β is positive, then an individual prefers improving sequences over time. If it is negative, then the individual prefers declining sequences over the time horizon. The parameter σ indicates whether the individual prefers relatively uniform sequences ($\sigma < 0$) or prefers a nonuniform shape ($\sigma > 0$). The term d_t is the difference between the cumulated utility received up to time t and the cumulated utility that would have been received had the total utility been allocated in a uniform fashion up to that point. This term is formulated as follows:

$$d_t = \frac{t}{n} \sum_{i=1}^{n} u_i - \sum_{i=1}^{t} u_i. \tag{4}$$

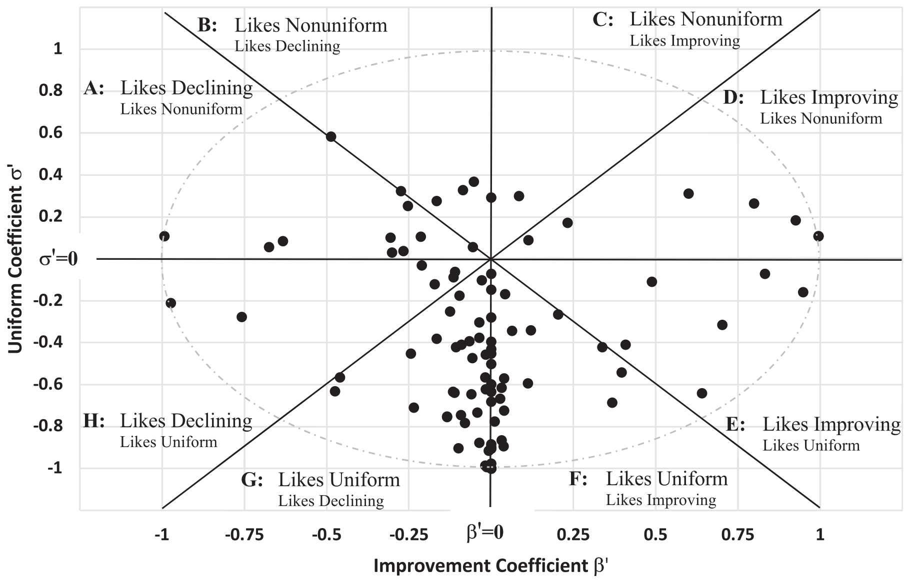
In this study, the sequence value in Equation (3) was used as a predictor for the ratings elicited for each of the sequence triples across all eight scenarios. The free parameters were β and σ . Because the ratings elicited for the uniform sequence differed both between and within the participants of this study, u_t in Equation (3) was estimated as the mean rating of the uniform sequence across the eight scenarios for a particular participant. The cumulative deviations of the improving and declining sequences were then calculated and used to determine the summations in the second and third terms in Equation (3). Least-squares optimization was performed to find the values for parameters β and σ that best fit the raw ratings data per participant. Therefore, a separate model was constructed, with different β and σ values, for each of the 101 participants in the study.

3.1. Results of Model Fitting

Figure 4 displays the partitioning of the (β, σ) parameter space, which is similar to that in Loewenstein and Prelec (1993, figure 3). The values of the (β, σ) pair determine the preference patterns exhibited by each participant. The large label on top in each partition of A–H in Figure 4 displays the dominant feature of the preferred sequence for the given (β, σ) pair. For example, if an individual's (β, σ) pair fell into area A of Figure 4, then that person would like sequences that both declined and that were nonuniform but would find the declining shape to be more important (higher weight) than the nonuniformity.

Figure 4 also contains the plots for the best-fitting[5] normalized regression coefficients (β', σ') pairs for each participant in this study. Normalization was performed

Figure 4. Scatterplot of Normalized Loewenstein and Prelec Model Coefficients for All 101 Participants



in accordance with the method proposed by Lowenstein and Prelec (1993) as

$$\beta' = r\frac{\beta}{\sqrt{\beta^2 + \sigma^2}},\ \sigma' = r\frac{\sigma}{\sqrt{\beta^2 + \sigma^2}}, \tag{5}$$

where r is the individual correlation between the predicted sequence value using the Lowenstein and Prelec model and the elicited ratings given by the participant for each of the individual 24 sequences (from eight scenarios with three sequences each). The mean correlation between the predicted and actual elicited ratings was 0.599, which is significantly different from zero ($t_{100} = 21.61$, $p < 0.001$). The median correlation was 0.632 with a minimum of 0.070 and a maximum of 1.000. When the correlation is 1.00, then all of a participant's ratings were perfectly predicted by the Lowenstein and Prelec model. In this case, the individual's plotted (β', σ') pair would lie on the dotted ellipse in Figure 4. We found that 7 of 101 (7%) of the participants' ratings were perfectly predicted by the Lowenstein and Prelec model, with four of the participants overlapping at the (β', σ') point of (0, −1).

Plotted points close to the vertical axis ($\beta' = 0$) indicate a relative indifference between declining and improving sequence shapes. Plotted points close to the horizontal axis ($\sigma' = 0$) reveal preferences that are relatively indifferent between uniform and nonuniform sequence shapes. Twenty-one participants' best-fitting normalized β' values were equal to zero, with all but one having a negative σ'. This indicates a relative indifference between improving and declining sequence shapes for these 21 participants. No best-fitting normalized σ' was equal to zero.

Table 5 reports the frequencies and relative frequencies for each of the partitions in the normalized (β', σ') parameter space. The points falling on the vertical axis are accounted for in Table 5 as area B & C and area F & G. We found that 67% (68/101) of the participants in this study "liked uniform" as their primary preference. Overall, 77% (78/101) "liked uniform," as indicated by a negative value for the best-fitting σ'. The fitting of this model at the participant level helps us to better understand the factors leading to the preference patterns that are observed.

4. Discussion and Conclusion

We investigated preferences over human-mortality sequences over time. Aside from the ability to observe a preference for spreading and negative time discounting directly in our participants' responses, we included scenarios with gains/losses, long-term/short-term initial timing of the sequences, and large/small magnitudes of the outcomes to account for possible influences of these additional associated anomalies of intertemporal choice. It is customary to value human

Table 5. Frequency and Relative Frequency Distributions for Responses in the Partitions of Figure 4

Area	Primary	Secondary	Count	Relative
A	Likes declining	Likes nonuniform	9	9%
B	Likes nonuniform	Likes declining	5	5%
B & C	Likes nonuniform	Indifferent between improving and declining	1	1%
C	Likes nonuniform	Likes improving	1	1%
D	Likes improving	Likes nonuniform	7	7%
E	Likes improving	Likes uniform	4	4%
F	Likes uniform	Likes improving	17	17%
F & G	Likes uniform	Indifferent between improving and declining	20	20%
G	Likes uniform	Likes declining	31	31%
H	Likes declining	Likes uniform	6	6%
Total			101	100%

life by first assigning a monetary value to the lives involved and then applying the standard discounting model. The subject pool for our study is from the undergraduate student body at a large public university. The participants are of young voting age. The regulatory policies that are implemented will often affect the younger demographics, who arguably may be subject to policies of this nature for a relatively longer amount of time. Therefore, there is value in understanding their preferences. We find that our participants on average do not actually apply the standard discounting model as previously proposed when making decisions involving sequences of human mortality outcomes. Future work in this area could include an investigation that elicits preferences from stakeholders who are relatively older, comparing and contrasting the results accordingly.

Our participants were asked to rate various sequences of outcomes involving human lives, including improving, uniform, and declining sequences. We found that our participants have overwhelming preferences for spreading throughout the time horizons. These hypothetical scenarios could assist in the decision-making process for budgetary policies on saving immediate lives or investing in healthcare research that could save lives in the future. Generally, a policy that saves an equal number of lives per year would best match the preferences we found in this study. The effects of health and environmental policies typically take several decades to unfold. This paper serves to help policymakers better understand the preferences of the generation that may be most affected by their decisions. Additional research should be done to get other demographic stakeholders' preference patterns.

The five anomalies (preference for spreading, negative time discounting, gain/loss asymmetry, short/long-term asymmetry, and the absolute magnitude effect) associated with intertemporal choice in the monetary domain were investigated within these sequences of lives. We find that when our participants are making decisions on human-mortality outcomes, they do exhibit three of the anomalies: a consistent and strong preference for spreading, as well as a subtle hint of the absolute magnitude effect and short/long-term asymmetry for lives saved. Short/long-term asymmetry appears also to explain the difference in the percentage of participants rating the declining sequence shape as best, along with evidence that the preference for spreading grows in strength as the timing of the outcomes shifts further into the future.

Loewenstein and Prelec (1993) proposed a model intended to capture the preference for spreading and negative time discounting found in the sequence of outcomes literature. This model allows the three sequence shapes (declining, uniform, or improving) to follow any preference order. Prior to this model, it was customary to expect that people would prefer to receive gains early and delay losses, which is consistent with the standard (positive) discounting model. However, various studies have shown that people, in fact, in certain situations, prefer to receive either gains or losses in a uniform or improving fashion. Using the data collected for this study, we modeled the preferences at the participant level (with Loewenstein and Prelec's model) and revealed that two-thirds of the participants in this study "liked uniform" as their primary preference regarding sequences of lives over time, and over three-quarters of the participants "liked uniform" sequences in general.

Several potential research directions are worthwhile to pursue. In this study, we used a design that focused on sequences of outcomes. It would be interesting to investigate whether the standard discounting model with a positive discount rate is a good fit for matching or choice-type tasks involving lives, while controlling for the anomalies of intertemporal choice. This could lead to a richer understanding of the public's preferences for different policies that involve human-mortality outcomes, as well as incrementally improve the methodologies used by researchers when trying to elicit such preferences.

Our within-subjects design allowed us to fully investigate preferences at the participant level while controlling for the possible effects of factors associated with the anomalies of intertemporal choice. A within-subject design is appropriate for reducing errors arising from natural variances between individuals. Each participant in a within-subject design serves as his or her own baseline for comparison and, having seen all variations of the stimuli, may be less prone to context effects and inconsistencies in responses. A disadvantage of the within-subjects design is fatigue and practice, known as the *carryover effect*. To counteract this, our experiment was kept relatively short (eight scenarios total were presented) as well as counterbalanced (the scenario order was completely randomized prior to being presented to each of the participants). A between-subjects study, although shown previously to lead to inconsistent results when eliciting preferences for sequences, could help to establish the robustness of the preference for spreading for sequences of lives lost or saved over time.

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Endnotes

[1] Discounted utility, in its most restrictive form, states that a sequence of attribute levels ($x_0, \ldots, x_T$) will be preferred to the sequence ($x'_0, \ldots, x'_T$) if and only if $\Sigma_{t=0-T}\ \delta^t u(x_t) > \Sigma_{t=0-T}\ \delta^t u(x'_t)$, where $u(c)$ is a concave ratio scaled utility function, and $0 < \delta < 1$ is the constant discount factor for one period, which is equal to $1/(1 + r)$, where r is the discount rate (Koopmans 1960).

[2] In such a case, we say a person's *implicit* discount rate is negative. We use the term *implicit* because the person may not actually be thinking about a discount rate.

[3] For our analysis, we assume a linear utility function over lives, so each life at any one time is treated equally in terms of value. In this case, the discounted utility model computes the net present value of lives lost or saved.

[4] Ties were allowed. To account for ties, the unit score was divided proportionally across sequence shapes with the highest ratings. A three-way tie = {1/3, 1/3, 1/3}, and a two-way tie = {1/2, 1/2, 0} across the three sequence shapes in the scenario, with the two tied with the highest rating receiving a score of 1/2 each.

[5] Each of these normalized (β', σ') pairs graphed in Figure 4, when used in Equation (4), resulted in the minimum squared difference between the predicted sequence value and the elicited rating for each of the 24 (8×3) sequences presented to the participants.

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