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.

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 due to 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:

$$Discounted\,Value = \sum_{t=0}^{T} \delta^t P_t \tag{1}$$

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 primarily focuses on monetary outcomes or consumer goods and services such as VCRs and restaurant meals (Benzion, Rapoport and Yagil, 1989; Loewenstein, 1988; Loewenstein and Prelec, 1991 and 1992; Thaler, 1981). However, discounting of human lives (or years of life) saved (or lost) is much more controversial (Roth, Ing, and Ross 1978, Eddy 1980, and Klarman, Francis, and Rosenthal 1968). 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 the average annual discount rates respondents placed when comparing lives saved now versus lives saved 3 to 5 years into the future is between 4.5% to 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 to a distant future of 100 years (3.8%).

The 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, Loewenstein, and O'Donoghue 2002). The 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 (Chapman 1996, Guyse, Keller, and Eppel 2002, Loewenstein and Prelec 1993). 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 (Ahlbrecht and Weber 1997, Loewenstein and Prelec 1991, Shelley 1993, Thaler 1981). *Short/Long Term Asymmetry*, also known as the *immediacy effect* (Read, Loewenstein, and Kalyanaraman 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 (Ahlbrecht and Weber 1997, Benzion, Rapoport, and Yagil 1989, Chapman 1996, Kirby and Marakovic 1995, Stevenson 1992, Thaler 1981). For example, a person's discount rate between 15 years 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 (Benzion *et al. 1*989, Chapman and Elstein 1995, Kirby and Marakovic 1995, Loewenstein and Prelec 1992, Thaler 1981). See Frederick, Loewenstein, and O'Donoghue (2002) for a comprehensive review of all three anomalies.

Guyse and Simon (2011) provides a detailed analysis of the consistency between the two elicitation methods discussed above 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 the application of the standard discounting model would accurately reflect the preferences of the public when the outcomes are (non-monetary) human lives. Descriptive studies have investigated whether or not individuals adhere to the standard discounting model for other types of non-monetary outcomes. Our earlier work (Guyse, Keller, and Eppel 2002) on how people value sequences of non-monetary 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 Discountin*g in these domains. Keeler and Cretin (1983) present a normative argument in favor of using the same discount rate for monetary and non-monetary 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, Bleichrodt, L'Haridon, Peretti-Watel, and Seror (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).

There has been sparse evidence 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 utilized 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 (Study 2b).

Our paper extends and synthesizes the breadth of differing results discussed above. We investigate if 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 utilizing 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 or not 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 has the ability to 1) 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 if 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

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 old.

Procedure and Design:

Participants were presented with 8 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. 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 over 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* and/or *Negative Time Discounting* are 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 assures 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 negative one 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 three-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 of the outcomes in the four tasks described above by 25.

Therefore, the design incorporated a 2 (save lives vs. lose lives) x 2 (short vs. long initial timing of the sequences) x 2 (relatively small vs. relatively large magnitude of lives) factorial design, creating eight possible combinations. Since we employed a within-subjects design in our experiment, we are 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 of the participants eventually saw all 8 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 response for a given scenario were submitted.

2.2. Results

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 of 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 the 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:

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

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 of the 8 scenarios presented to them. 94% (95/101) of the participants were *not* in accordance in 4 or more of the 8 scenarios. Based on our study, few participants actually rated these sequences of lives over time in accordance with the standard discounting model.

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

Number of Scenarios Rated in Accordance	Number of Participants (N = 101)	Percentage of Participants	
0	67	66.3%	One or More Violations of Standard Discounting
1	11	10.9%	
2	7	6.9%	
3	2	2.0%	
4	8	7.9%	
5	1	1.0%	
6	1	1.0%	
7	2	2.0%	
8	2	2.0%	Standard Discounting

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*. Since 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 of the scenarios presented to him or her in accordance with zero discounting. Table 2 displays a summary of the findings across the participants in this study.

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	
Negative	3	0.92	Discounting but Sign Differs from Standard Discounting
Zero	0	0.57	
Positive	2	1.03	Standard Discounting

Since the participants overwhelmingly did not assign ratings that were in accordance with the standard discounting model, then the question 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.

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 above, the standard discounting model would predict that the declining sequence shape would be rated the best by all participants in all scenarios since 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 8 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 amount of lives in the later time horizon, but even there only 1 in 4 participants rated the declining shape the best.

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: $^{****}p < 0.001$

The percentage of participants rating each sequence shape the best is indeed dependent 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 be dependent on whether the lives are saved or lost. Notice that when the lives are saved, the declining sequence shape is generally the 2nd 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 2nd best rated across scenarios. A preference for improving 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 the 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 2nd 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).

Do The Three Embedded Anomaly Factors Affect Observed Ratings?

To see if any of the embedded factors associated with the anomalies of intertemporal choice had an influence on the raw mean ratings, we examine the mean ratings reported for each sequence at the participant level. A repeated measures 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”.

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

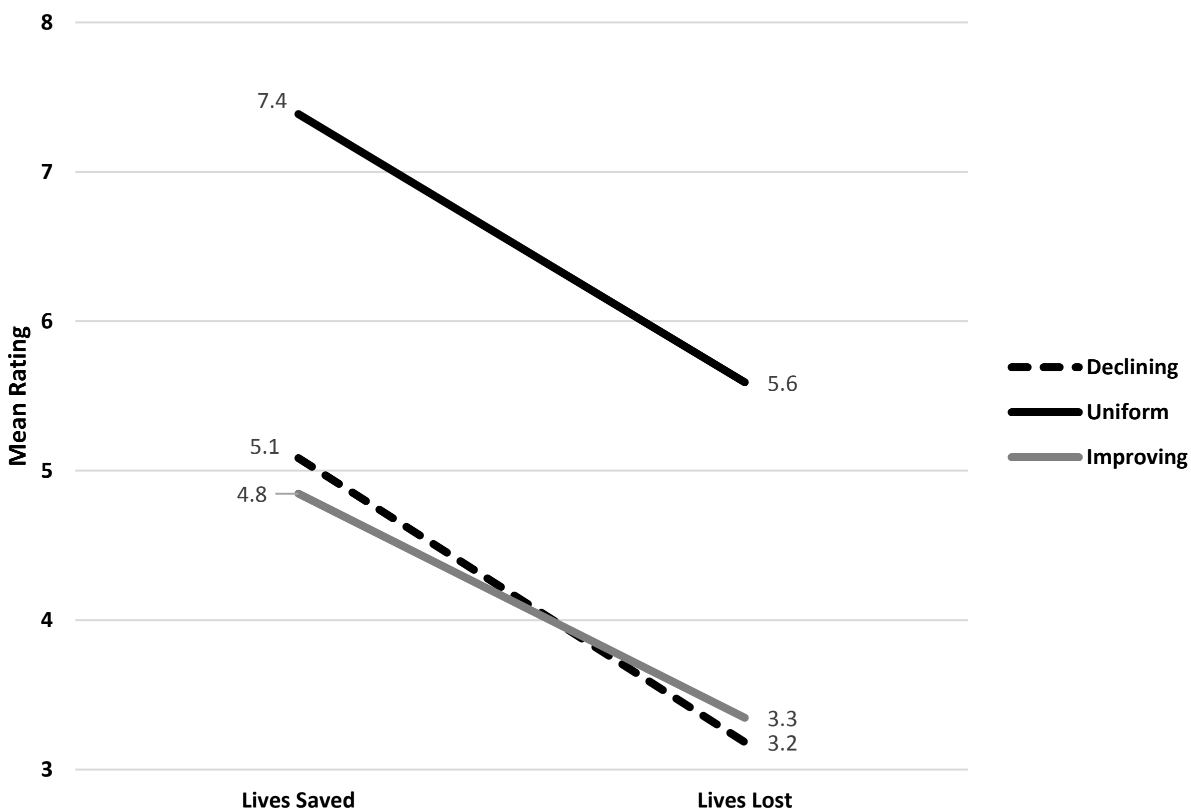
	Analysis 1 Both lives saved & lives lost			Analysis 2a Lives saved only			Analysis 2b Lives lost only		
Factor	*df*	*F*	MS_e	*df*	*F*	MS_e	*df*	*F*	MS_e
Shape	2	44.35***	1517.90	2	33.57***	794.88	1.90†	33.89***	771.34
Magnitude	1	2.53	9.16	1	0.32	1.19	1	8.65**	28.85
Save/Lose	1	66.75***	1817.57						
Initial Timing	1	0.48	1.44	1	0.00	0.01	1	1.24	2.50
Shape x Magnitude	2	0.01	0.03	2	2.10	3.77	2	1.06	3.04
Shape x Save/Lose	2	0.79	8.72						
Magnitude x Save/Lose	1	5.99*	20.88						
Shape x Magnitude x Save/Lose	2	2.96	6.78						
Shape x Initial Timing	2	0.25	0.38	1.90†	0.43	0.68	1.87†	0.01	0.02
Magnitude x Initial Timing	1	0.45	1.07	1	0.18	0.56	1	0.20	0.52
Shape x Magnitude x Initial Timing	2	0.44	0.80	1.90†	3.49*	6.28	1.91†	0.82	1.54
Save/Lose x Initial Timing	1	0.42	1.07						
Shape x Save/Lose x Initial Timing	2	0.16	0.28						
Magnitude x Save/Lose x Initial Timing	1	0.00	0.00						
Shape x Magnitude x Save/Lose x Initial Timing	2	3.93*	6.64						

Note: Sphericity assumed via results of Mauchly's Test (1940) unless indicated by † in which *df* are corrected via Greenhouse-Geisser (1959) estimate to account for the lack of sphericity.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

The shape of the sequence and whether the lives were saved vs. 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* x *Magnitude* x *Save/Lose* x *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).

FIGURE 1: Mean Ratings Across Sequence Shapes



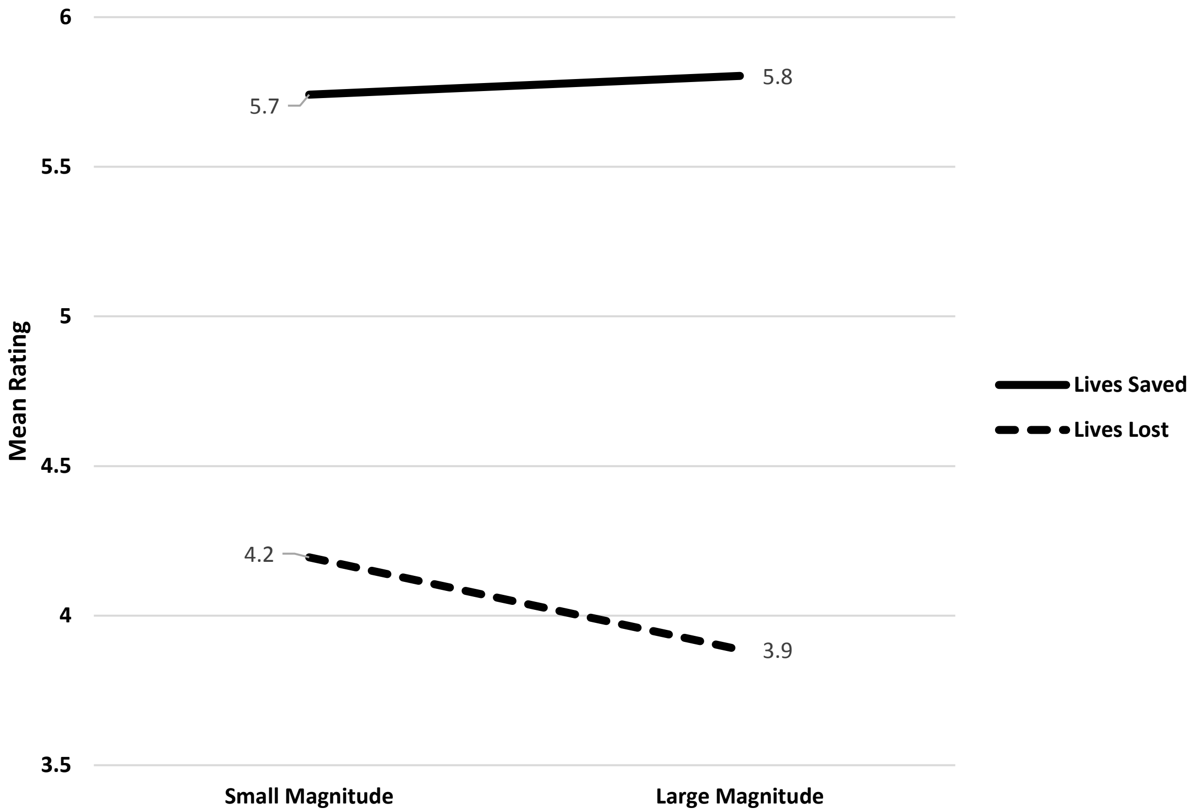
The main effect of *Shape* in Analysis 1 of Table 4 indicates that at least one of the three different sequence shapes (declining, uniform, or improving) received a different mean rating than the others. Figure 1 graphically displays the effect that the shape of the sequence had on the mean ratings.

The participants in this study gave the uniform sequence shape the best mean rating. This result is consistent with the analysis in the previous 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 vs. 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 of the scenarios presented to them. This behavior may be considered logical since losing lives is definitely less desirable than saving lives. Since 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 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 to the differences in the means associated with losses for declining vs. improving sequences (3.2 – 3.3).

To disentangle the significant interactions displayed in Analysis 1 of Table 4, the data was 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 2a" and "Analysis 2b" respectively. Based on Analysis 2a, we find non-significance 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 2b (F_1 = 8.65, p < 0.01). Figure 2 displays a graphical representation of this interaction of magnitude by lived saved or lost.

FIGURE 2: Magnitude by Lives Saved or Lost Interaction



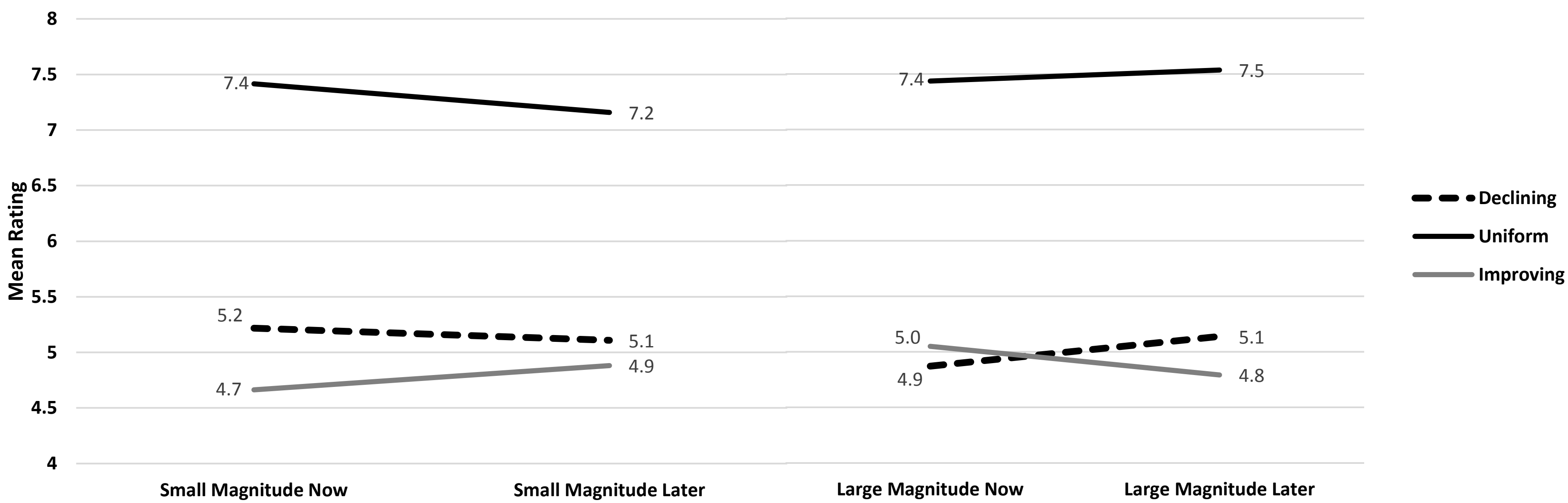
Since the main effect of *Magnitude* does not appear in Analysis 2a which was performed only on the lives saved data, the solid line at the top of Figure 2 is not significantly different from a flat line. This indicates no reported difference in the mean ratings between the small and large magnitudes of lives saved. This could be an indication of an *insensitivity to scope* (Kahneman, Ritov, and Schkade 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 2b 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 x Magnitude x Save/Lose x Initial Timing* in Analysis 1 only remains as the three-way interaction between *Shape x Magnitude x Initial Timin*g for lives saved in Analysis 2a ($F_{1.900} = 3.49$, $p < 0.05$) and is absent from the lives lost data in Analysis 2b ($F_{1.910} = 0.82$, $p > 0.40$). 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 x Magnitude x 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's Analysis 2a) 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, the mean rating of 5.2 for the small magnitude now does exceed the 4.9 of the large magnitude now, 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, since there is an increase in the average rating associated with declining sequence shape when relatively small amount 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.

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



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 Fitted Intertemporal Value Model

Based on the analysis above, 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 (non-zero) 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 8 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:

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

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 non-uniform 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 the current 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. Since 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 a different β and σ value, for each of the 101 participants in the study.

Results of the Model Fitting

Figure 4 displays the partitioning of the (β, σ) parameter space which is similar to Loewenstein and Prelec's (1993, Figure 3, p. 99). 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 non-uniform, but would find the declining shape to be more important (higher weight) than the non-uniformity.

FIGURE 4: Scatterplot of Normalized L & P Model Coefficients for All 101 Participants

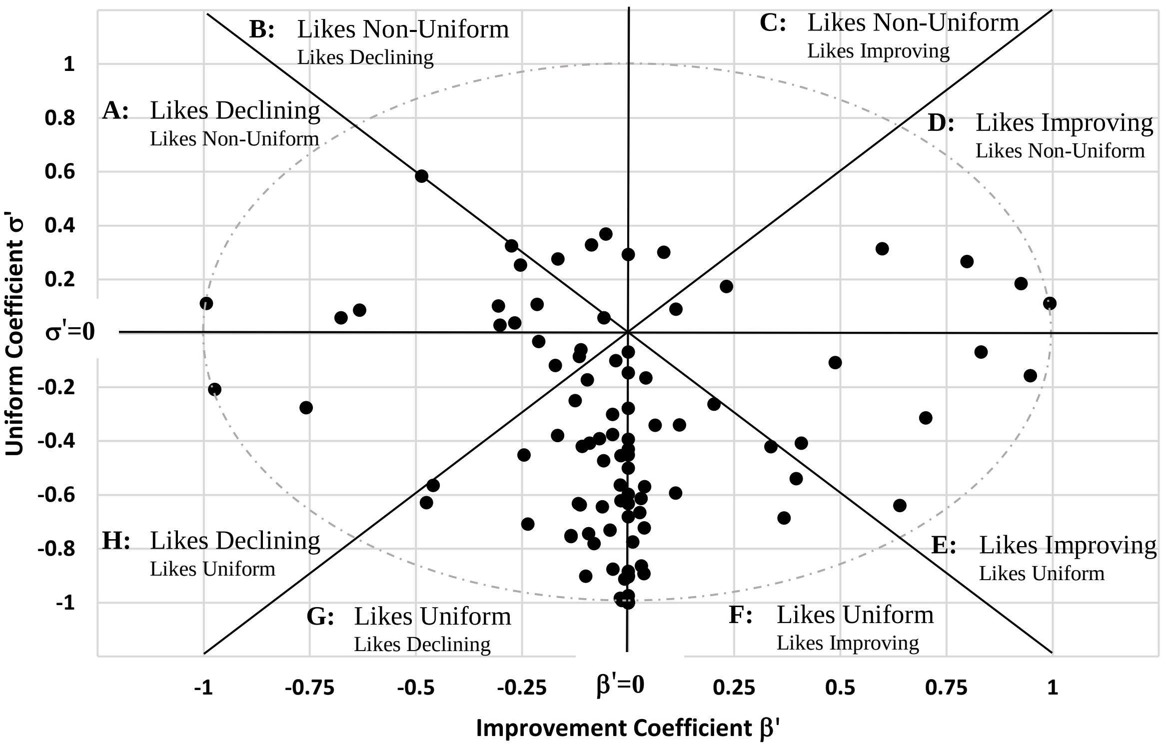


Figure 4 also contains the plots for the best fitting[5] normalized regression coefficients (β', σ') pairs for each participant in this study. Normalization was performed in accordance with the method proposed by Lowenstein and Prelec (1993 page 102) as:

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

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 8 scenarios with 3 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. 7/101 (7%) of the participants' ratings were perfectly predicted by the Lowenstein and Prelec model, with 4 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 non-uniform sequence shapes. Twenty one participants' best fitting normalized β'*s* 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: Frequency and Relative Frequency Distributions for Responses in the Partitions of Figure 4

Area	Primary	Secondary	Count	Relative
A	Likes Declining	Likes Non-Uniform	9	9%
B	Likes Non-Uniform	Likes Declining	5	5%
B & C	Likes Non-Uniform	Indifferent between Improving & Declining	1	1%
C	Likes Non-Uniform	Likes Improving	1	1%
D	Likes Improving	Likes Non-Uniform	7	7%
E	Likes Improving	Likes Uniform	4	4%
F	Likes Uniform	Likes Improving	17	17%
F & G	Likes Uniform	Indifferent between Improving & Declining	20	20%
G	Likes Uniform	Likes Declining	31	31%
H	Likes Declining	Likes Uniform	6	6%
Total			101	100%

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”. 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 life by first assigning a monetary value to the lives involved, 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 which 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 health care 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 2/3 of the participants in this study "liked uniform" as their primary preference regarding sequences of lives over time, and over 3/4 of the participants "liked uniform" sequences in general.

Several potential research directions are worthwhile to pursue. In this study, we utilized a design that focused on sequences of outcomes. It would be interesting to investigate whether or not 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 their 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 (8 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.

References

Ahlbrecht, M., M. Weber. 1997. An empirical study on intertemporal decision making under risk. *Management Science* **43**(6) 813-826.

Attema, A., H. Bleichrodt, O. L'Haridon, P. Peretti-Watel, V. Seror. 2018. Discounting health and money: New evidence using a more robust method. *Journal of Risk and Uncertainty* In Press. Published Online 09 May 2018.

Benzion, U., A. Rapoport, J. Yagil. 1989. Discount rates inferred from decisions: An experimental study. *Management Science* **35**(3) 270-284.

Baron, J., J. Greene. 1996. Determinants of insensitivity to quantity in valuation of public Goods: contribution, warm glow, budget constraints, availability, and prominence. *Journal of Experimental Psychology: Applied* **2**(2) 107-125.

Chapman, G. B. 1996. Expectations and preferences for sequences of health and money. *Organizational Behavior and Human Decision Processes* **67**(1) 59-75.

Chapman, G. B., E. S. Elstein. 1995. Temporal discounting of health and money. *Medical Decision Making* **15**(4) 373-386.

Clemen, R. T., T. Reilly. 2014. *Making Hard Decisions with Decision Tools Suite,* 3rd ed. Duxbury Press, Pacific Grove, CA.

Cropper, M. L., Aydede, S. K., & Portney, P. R. (1992). Rates of time preference for saving lives. *The American Economic Review* 82(2), 469-472.

Eddy, D. M. 1980. *Screening for Cancer: Theory, Analysis and Design*. Prentice-Hall, Inc., Englewood Cliffs, NJ.

Fishburn, P. C., A. Rubenstein. 1982. Time preference. *International Economic Review* **23**(3) 677-694.

Frederick, S. 2003. Measuring intergenerational time preference: Are future lives valued less? *Journal of Risk and Uncertainty* **26**(1) 39-53.

Frederick, S., G. Loewenstein. 2008. Conflicting motives in evaluations of sequences. *Journal of Risk and Uncertainty* **37**(2) 221-235.

Frederick, S., G. Loewenstein, T. O'Donoghue. 2002. Time discounting and time preference: A critical review. *Journal of Economic Literature* **40**(2) 351-401.

Greenhouse, S. W., S. Geisser. 1959 On methods in the analysis of profile data. *Psychometrika* **24**(2) 95-112.

Guyse, J. L., J. Simon. 2011. Consistency among elicitation techniques for intertemporal choice: A within-subjects investigation of the anomalies. *Decision Analysis* **8**(3) 233-246.

Guyse, J. L., L. R. Keller, T. Eppel. 2002. Valuing environmental outcomes: Preferences for uniform or improving sequences. *Organizational Behavior and Human Decision Processes* **87**(2) 253-277.

Horowitz, J.K. and Carson, R.T., 1990. Discounting statistical lives. *Journal of Risk and Uncertainty* 3(4) 403-413.

Kahneman, D., A. Tversky. 1979. Prospect theory: An analysis of decision under risk. *Econometrica* **47**(2) 263-291.

Kahneman, D., I. Ritov, D. Schkade. 1999. Economic preferences or attitude expressions?: An analysis of dollar responses to public issues. *Journal of Risk and Uncertainty* **19**(1-3) 203-235.

Keeler, E. B., S. Cretin. 1983. Discounting of life-saving and other nonmonetary effects. *Management Science* **29**(3) 300-306.

Kirby, K. N., N. N. Marakovic. 1995. Modeling myopic decisions: Evidence for hyperbolic delay-discounting within subjects and amounts. *Organizational Behavior and Human Decision Processes* **64**(1) 22-30.

Klarman, H. E., J. D. Francis, G. D. Rosenthal. 1968. Cost-effectiveness analysis applied to the treatment of chronic renal disease. *Medical Care* **6** 48.

Koopmans, T. C. 1960. Stationary ordinal utility and impatience. *Econometrica* **28**(2) 207-309.

Loewenstein, G. 1988. Frames of mind in intertemporal choice. *Management Science* **34**(2) 200-214.

Loewenstein, G., D. Prelec. 1991. Negative time preference. *American Economic Review* **81**(2) 347-352.

Loewenstein, G., D. Prelec. 1992. Anomalies in intertemporal choice: Evidence and interpretations. *Quarterly Journal of Economics* **107**(2) 573-597.

Loewenstein, G., D. Prelec. 1993. Preference for sequences of outcomes. *Psychological Review* **100**(1) 91-107.

Loewenstein, G., J. Elster. (eds.) 1992. *Choice Over Time*. Russell Sage Foundation, New York.

Loewenstein, G., N. Sicherman. 1991. Do workers prefer increasing wage profiles? *Journal of Labor Economics* **9**(1) 67-84.

Mauchly, J. W. 1940 Significance test for sphericity of a normal *n*-variate distribution. *The Annals of Mathematical Statistics* **11**(2) 204-209.

O'Donoghue, T., M. Rabin. 1999. Doing it now or later. *The American Economic Review* **89**(1) 103-124.

Prelec, D., G. Loewenstein. 1991. Decision making over time and under uncertainty: A common approach. *Management Science* **37**(7) 770-786.

Read, D., G. Loewenstein, S. Kalyanaraman. 1999. Mixing virtue and vice: Combining the immediacy effect and the diversification bias. *Journal of Behavioral Decision Making* **12**(4) 257-273.

Read, D., M. Powell. 2002. Reasons for sequence preferences. *Journal of Behavioral Decision Making* **15**(5) 433-460.

Roth, C. A., R. T. Ing, D. A. Ross. 1978. Letter to *New England Journal of Medicine* **299** 1088.

Schmitt, D. R., T. D. Kemper. 1996. Preference for different sequences of increasing or decreasing rewards. *Organizational Behavior and Human Decision Processes* **66**(1) 89-101.

Shelley, M. K. 1993. Outcome signs, question frames and discount rates. *Management Science* **39**(7) 806-815.

Stevenson, M. K. 1992. The impact of temporal context and risk on the judged value of future outcomes. *Organizational Behavior and Human Decision Processes* **52**(3) 455-491.

Thaler, R. H. 1981. Some empirical evidence on dynamic consistency. *Economic Letters* **8**(3) 201-207.

Weber, B. J., G. B. Chapman. 2005. The combined effects of risk and time on choice: Does uncertainty eliminate the immediacy effect? Does delay eliminate the certainty effect? *Organizational Behavior and Human Decision Processes* **96**(2) 104-118.

Wu, G. 1999. Anxiety and decision making with delayed resolution of uncertainty. *Theory Decision* **46**(2) 159–199.

Online Supplement

Our study was conducted with 101 undergraduate students from a large public research university in the west coast. Students were recruited from a pool of subjects organized by the Social Science department. The Social Science department also gives the students extra credit for their participation in a course in their department. Of the 101 undergraduate students, the majority of students (61 students) identified themselves as Social Science majors (e.g., Political Science, Psychology), 14 were undecided, 3 were studying Natural Sciences (e.g., Biology, Chemistry), 2 were Business/Economics majors, and the remaining students left the question blank.

The following is the actual survey administered to the subjects. The survey consists of 8 questions, presented to participants in random order. After the 8 questions, students respond to 5 additional demographics and survey discussion.

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Study Information Sheet

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- You are being asked to participate in a research study to preferences for different outcome patterns involving lives lost versus saved over time.
- The research procedures involve completing a short survey via Sona Systems.
- The only foreseeable discomforts associated with the study are those associated with normal computer usage.

- Participation in this study is voluntary. There is no cost to you for participating. You may choose to skip a question or a study procedure. You may refuse to participate or discontinue your involvement at any time without penalty. You are free to withdraw from this study at any time by exiting the webpage on your web browser.

- You will receive extra course credit for an eligible course through the UCI Social Sciences human subjects' pool. You will receive a ½ unit of course credit for each ½ hour of participation in this study. Total amount of credit you may earn for this study is ½ credit. The course instructor offering extra course credit for participation in research must provide alternatives to earn extra course credit. The alternative assignment must require equal or less time and effort for the amount of extra credit that can be earned through participation in research.

- All research data collected will be stored securely and confidentially on our databases. This information is password protected and completely anonymous.

- The research team, authorized UCI personnel, the study sponsor (if applicable), and regulatory entities such as the FDA, may have access to your study records to protect your safety and welfare. Any information derived from this research project that personally identifies you will not be voluntarily released or disclosed by these entities without your separate consent, except as specifically required by law.

- If you have any comments, concerns, or questions regarding the conduct of this research please contact the researchers listed at the top of this form.

- If you are unable to reach the researchers listed at the top of the form and have general questions, or you have concerns or complaints about the research, or questions about your rights as a research subject, please contact UCI's Office of Research Administration by phone, (949) 824-6662, by e-mail at IRB@rgs.uci.edu or 5171 California Avenue, Suite 150, Irvine, CA 92617.

Introduction

Business firms and government agencies sometimes face decisions on projects or environmental regulations involving risks to life, such as cancer risks due to toxic chemical exposures. Different possible actions will often lead to different spreads of outcomes over time. We are investigating what patterns of outcomes over time people prefer.

The following couple of pages lists different sequences of lives saved or lives lost. These groups of sequences differ on the number that is saved (or lost) and when the event takes place. Since the sequences differ on the number of lives involved, whether the lives are saved or lost, and when the lives are saved (or lost), your answers may vary from sequence to sequence. It all depends on your individual preferences with respect to the problem at hand.

An example 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	24	0	0

Option B	8	8	8
Option C	0	0	24

You will fill in a rating from 1 (relatively poor distribution of lives compared to the other distributions) to 10 (a relative excellent distribution of lives compared to the others) for each of these 3 sequences.

Also make sure to notice that the timings of the events can differ, either starting this year or 15 years from now.

Please fill out the following questionnaire with your preference, as you perceive them to be at this point in time. In reality, there are no "correct" answers to the following questions. Your answers may vary from others and from question to question because your preferences differ. Just be as honest as you can.

Question 1

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	

Question 2

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 15 years from now**.

	Year 15	Year 16	Year 17
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	

Question 3

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 **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	

Question 4

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 **lost** for sure for three consecutive years, **starting 15 years from now**.

	Year 15	Year 16	Year 17
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	

Question 5

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 **600 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	600

Option B	200	200	200
Option C	600	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	

Question 6

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 **600 lives** could be **saved** for sure for three consecutive years, **starting 15 years from now**.

	Year 15	Year 16	Year 17
Option A	0	0	600
Option B	200	200	200
Option C	600	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	

Question 7

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 **600 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	-600
Option B	-200	-200	-200
Option C	-600	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	

Question 8

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 **600 lives** could be **lost** for sure for three consecutive years, **starting 15 years from now**.

	Year 15	Year 16	Year 17
Option A	0	0	-600
Option B	-200	-200	-200
Option C	-600	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	

Question 9

What is your age?

Question 10

What is your gender?

- o Male
- o Female

Question 11

What is your area of study or expertise? Please choose the one you feel closest to or most appropriate.

- o Business / Economics
- o Engineering / Math
- o Humanities
- o Natural Science (e.g., Biology, Chemistry)
- o Social Science (e.g., Political Science, Psychology)
- o Other/Undecided

Question 12

	Not Difficult	Somewhat Difficult	Average	Somewhat Easy	Easy
How difficult was this survey (select one)?					

Question 13

	Not Interesting	Somewhat Interesting	Average	Somewhat Interesting	Very Interesting
How interesting was this survey (select one)?					

Question 14

In general, did you have a specific way of answering the questions? What was it?

[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, $\Sigma_{t=0 \text{ to } T}\ \delta^t u(x_t) > \Sigma_{t=0 \text{ to } T}\ \delta^t u(x'_t)$ 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" since 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. Three way tie = {1/3, 1/3, 1/3} and 2 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 5, 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 x 3) sequences presented to the participants.