Behavioral Biases in Annuity Choice: An Experiment*

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Abstract

We conduct a neutral-context laboratory experiment to systematically investigate the role of the hit-by-bus concern in explaining the annuitization puzzle: the low rate of retirement-asset annuitization relative to the predictions of standard models. We vary endowed asset (annuity vs. stock of wealth vs. no explicit endowment), and find a strong endowment effect. Furthermore, we find that the ordering of survival risks matters. Compared to a frame in which a single draw from a known distribution determines survival outcome, annuity choice is lower when subjects must sequentially survive early periods to reach periods in which the annuity dominates. We conclude with policy implications.

JEL Classification: C91, D14, D81, G22, J26

Key words: experimental economics, behavioral, retirement, annuities

1 Introduction

Private life annuities play a very small role in most households' retirement portfolios. Only approximately 6% of U.S. elderly households receive income from private annuities, accounting for approximately 2% of total income.[1] Their absence from retiree portfolios is surprising given their theoretical welfare benefits (Yaari 1965, Davidoff, Brown and Diamond 2005).

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[1]Data are from the Health and Retirement Study. Elderly households refer to households 65 years and older. See Johnson, Burman and Kibes (2004) for more household-income composition details.

This apparent annuity gap has lead to a large body of research, both empirical and theoretical, on the determinants of annuity choice. The evidence from over 35 years of inquiry has identified a number of key factors suppressing annuity demand, most notably incomplete markets (for life annuity and long-term care insurance), bequest motives, and existing annuities from Social Security and other sources. While there is growing consensus that some combination of these factors largely accounts for the low observed demand among low-wealth households, it remains difficult to reconcile fully the choices of high-lifetime-income households with these fully rational models (Davidoff et al. 2005).

A growing body of evidence suggests that behavioral biases influence financial decision making. These biases plausibly affect the annuity decision, and thus might well be important components of the remaining annuity gap (Brown 2007, p. 3). In this paper, we focus on two biases plausibly underlying the commonly-expressed "hit by a bus" concern.[2] First, a retiree may be unduly reluctant to exchange her liquid-asset endowment for an annuity (an endowment bias stemming from loss aversion). This bias may be particularly salient with 401(k) participants focused on asset accumulation, and may partly explain why only 6 percent of 401(k) participants take retirement distribution as an annuity when given the option.[3] Second, she may give undue salience to the probability of dying early and, consequently, to early utility comparisons for which a lump-sum likely dominates an annuity. We evaluate the strength of these biases in a laboratory setting capturing many of the salient features of the retiree's annuitization decision, and discuss their potential role in the wild.

The risk-ordering bias we investigate has not been previously studied to the best of our knowledge. We believe it may stem from two sources. First, the retiree may focus on earlier comparisons and risks because they are, well, earlier and perhaps more focal. Second, it may also result from the compound, sequential nature of risks inherent in mortality. Surviving to age 70 requires surviving age 69, which requires surviving age 68, and so forth. For perhaps both reasons, when faced with this sequence of risks, it is our hypothesis that some place too much salience on early-period utility comparisons over later-period comparisons. Note that we do not assume that a retiree has incorrect beliefs about mortality rates, nor that she overly discounts future utility. Rather, given her morality-rate beliefs and the discounted utility for each option and for each retirement length, she is biased towards early comparisons.

The perfect-world case for annuitizing retirement assets is strong. Yaari (1965) and

[2]This concern is frequently identified by market surveys and anecdotal evidence as an important obstacle to annuitization. In some surveys, a slightly different iteration is noted: that of dying soon after buying an annuity and losing the principal *to the insurance company.* Potentially, loss of control or distrust of the insurer might also be important deterrents. These latter two biases, however, are not considered in this paper and remain to be explored.

[3]Note that only one in five 401(k) plans even offer the option to take retirement distributions as an annuity (Hewitt Associates 2005). Anecdotal evidence suggests that employers choose not to offer the option because of low demand (Iwry and Turner Forthcoming).

Davidoff et al. (2005) show that when faced with uncertain mortality, the retiree without bequest motive ought to completely annuitize her assets to insure against outliving her resources. By pooling risks and resources, annuities move funds from those states in which the marginal utility of consumption is zero (i.e., after death) to those states in which it is high (i.e., toward the end of a long retirement) and thus raise overall and expected utility.

Despite the potential gains, markets for non-mandated private annuities are thin. High loads, at least somewhat due to adverse selection, certainly lower annuitization gains (Mitchell, Poterba and Warshawsky 1999). However, actuarially unfair annuities do not completely account for low rates of purchase. In simulations, Mitchell et al. (1999) find that single individuals should be willing to forego about a third of their wealth at age 65 to purchase actuarially fair annuities, which is more than the then-estimated loads on annuities.[4] In fact, less than actuarially fair annuities could even be welfare enhancing for individuals with higher than average mortality.[5]

A number of other factors reduce the amount of wealth optimally annuitized. Bequest motives (Friedman and Warshawsky 1990) increase the attractiveness of maintaining transferable assets. Likewise, households anticipating long-term care expenses may rationally choose to self-insure by holding liquidity (Sinclair and Smetters 2004, Turra and Mitchell 2004).[6] Within marriage risk pooling (Kotlikoff and Spivak 1981) reduces the attractiveness of private annuities (Brown and Poterba 2000) or at least argues for purchase delay (Dushi and Webb 2004).

It is thus generally agreed that partial rather than full annuitization may be optimal given incomplete or alternate annuity markets and bequests (Davidoff et al. 2005). Furthermore, the majority of households receive annuity payments through Social Security. For low-earning households, Social Security benefits replace more than half of pre-retirement income.[7] These households are likely adequately annuitized.

However, Social Security replacement rates for medium and high-earning households are lower. While many of these households receive additional annuity payments through

[4]Based on annuity prices in 1995, Mitchell et al. (1999) estimate the expected present discounted value of annuity payments to be approximately 80-85 percent of the annuity premium (that is, a load factor of 15-20 percent), with approximately one-half of the load attributable to adverse selection.

[5]In utility-based terms, Gong and Webb (2006) find that even accounting for pre-annuitized wealth and longevity risk-sharing within marriage, the average black, white and hispanic households would benefit from annuitization, although the estimated benefits to the average hispanic and black households are small. Earlier work by Brown (2003) estimated much larger benefits for those with higher than average mortality, but did not account for pre-existing annuities and risk-sharing from marriage.

[6]Late life medical expenses can be large (De Nardi, French and Jones 2006) and the market for long-term care insurance is incomplete (Finkelstein and McGarry 2006).

[7]The 2007 Social Security Trustees Report estimates replacement rates of 56 percent for low earners, 42 percent for medium earners, 35 percent for high earners, and 29 for steady maximum earners, under intermediate assumptions about demographic and economic growth (Social Security Administration 2007).

defined-benefit (DB) plans, Dushi and Webb (2004) estimate that the optimal degree of annuitization is quite high. Wealthier households (who have lower mortality and lower pre-existing annuity income) and single individuals (who cannot benefit from intra-household risk pooling), particularly women, could likely gain from additional annuitization at retirement.[8]

The decline of DB pensions and the shift to 401(k)-type defined contribution (DC) retirement plans could arguably increase the annuity gap for future retirees. Dushi and Webb (2004) estimate that the capitalized value of DB pension payments accounts for 20 percent of total wealth for the median retiree in 2000 whereas total DC assets account for merely 2 percent of the total. This ratio is projected to shift dramatically over time as more workers are covered by and contribute longer to DC accounts. Poterba, Venti and Wise (2007) project the ratio to decline to 0.1 or 0.15 by 2040.[9] While demand for private annuities among 401(k) participants may possibly increase as a result, the evidence to date suggests that any increase would like fall short of reaching current pre-annuitized levels.[10] The need to fully understand the annuity decision is more important than ever.

Biases such as hyperbolic discounting, loss aversion, mental accounting and those arising from the frame of reference have been shown to affect saving, investment and other financial decisions, and are suggested to explain anomalies in financial decision-making.[11] Hu and Scott (2007) argue that well documented behavioral biases may plausibly contribute to low rates of retiree annuitization. Recent survey (Brown, Kling, Mullainathan and Wrobel 2008a, Brown, Kling, Mullainathan, Wiens and Wrobel 2008b) and experimental (Agnew, Anderson, Gerlach and Szykman 2008) studies find that framing has potentially important effects on annuity valuation and may explain, to some extent, why the market for private annuities is much thinner than expected given standard assumptions.

In this study, we conducted a laboratory experiment to systematically investigate the roles of endowment and risk-ordering biases. A retiree may be averse to exchanging the lump sum in her retirement account for a stream of payments. Attaching ownership to her endowed stock of wealth, she willingly forgoes some annuitization gains in order to ensure that she does not lose her endowment.[12] We therefore compare annuity-choice likelihood as we vary the denomination of experimental retirement assets. Subjects either a) earn a

[8]Milevsky and Young (2007) also show that for a given level of pre-existing annuity income, if partial annuitization is available, individuals who are more risk-averse or who have lower pre-annuitized wealth would find immediate annuitization attractive.

[9]The 401(k) projections assume historical equity returns less 300 basis points. DC account balances would be lower and, thus, the ratio would be higher if projections account for cashouts, portfolio re-balancing, and administrative costs.

[10]Declines in Social Security benefits and increasing Medicare premiums will further contribute to the decline in pre-existing annuitized wealth (Munnell 2003).

[11]See Barberis and Thaler (2002), Benartzi and Thaler (1995), and Benartzi and Thaler (2007).

[12]We do not in this study consider alternative endowment-effect causes, such as transaction costs associated with evaluating and carrying out a trade.

401(k)-like account balance; b) earn a claim on annuity-like payment stream; or c) are not explicitly endowed with either option.

We further note that the possibility of principal loss from an early death confronts the consumer when evaluating the annuity. The placing of too much weight on the probability of dying early (more than is warranted by actual probabilities) relative to the probability of a long retirement decreases the perceived relative value of the annuity. To test for the presence of this risk-ordering bias in a retirement-like decision, we compare annuity choice in a frame in which subjects must survive earlier periods to reach later ones (the Sequential frame) to a frame in which we remove the sequential ordering of risks (the Simultaneous frame) by resolving all retirement-length uncertainty with a single draw from a known probability distribution.

We find that subjects in Sequential sessions are less likely to select the annuity-like option than subjects in Simultaneous sessions. We also find that when earned assets are denoted as a lump-sum, subjects are less likely to select the annuity-like option relative to the no endowment session. Furthermore, when earned assets are denoted as a stream of payments, subjects are more likely to select the annuity-like option relative to the lump-sum session.

The extent to which behavioral biases contribute to any annuity gap has implications on the effectiveness of proposed policy interventions. For instance, a proposed fix for an endowment bias in 401(k) plans is to change the denomination of DC assets: instead of specifying balances as a lump sum, specify them as a claim on a stream of payments. Assigning ownership to the stream of payments rather than the lump sum may well deter retirees from taking their retirement assets as a lump sum. Results from this experiment indicate that endowment effects are present when subjects have to make annuity-like decisions in the laboratory. While acknowledging the many differences (both in context and stakes) between the decision facing experiment subjects and that of the retiree, we do believe these results suggest that such a policy intervention might increase the proportion of annuitized retirement assets.

2 Experiment Design

In the real world, the decision to annuitize retirement wealth is not a binary decision. A retiree may choose to annuitize only a fraction of her wealth, and has some flexibility in purchase timing. In order to focus on the behavioral aspects of the annuitization decision, we consider the simplest case: at the time of retirement, a retiree must choose either a stock of wealth out of which she can consume or a life annuity.

This relatively straightforward decision highlights an inherent tradeoff faced by a retiree with a rational attachment to maintaining a lump-sum of (somewhat) liquid assets (e.g., a bequest motive). Should she die early in her retirement, maintaining the lump sum delivers higher utility due to bequest value and (likely) higher consumption utility in those early years. However, should she live many years, the annuity delivers higher overall utility as risk pooling allows higher later-year consumption possibilities.

In the laboratory, we offered subjects a payout-option choice analogous to the retiree's choice between the utility outcomes available under full annuitization and those available as a result of the optimal consumption out of a stock of wealth. When choosing between payout options, subjects had a table indicating for each option (lump sum or annuity) the payment for each retirement length. Subjects knew the process for retirement-length determination. The Payout Phase of the experiment (i.e., retirement) lasted from 1 to 15 rounds, with each event (retirement length) equilikely. To foster comprehension of experiment instructions, subjects completed a series of incentivized review questions.

To test our hypotheses, we varied conditions not affecting choices under the expected-utility-maximization assumption. In one dimension, we varied endowed asset type. In some sessions we endowed subjects with the annuity payout option, in some the lump-sum payout option, and in the final set of session we did not endow them with either option. In the second dimension, we varied the manner of resolving retirement-length uncertainty. In one set of sessions, we determined retirement length by sequential survival, thus making clear that the risk of an early post-annuitization death preceded that of low consumption toward the end of a long, non-annuitized, retirement. In a second set of sessions, a single draw from a known distribution determined retirement length. We made no mention of periods. Therefore, outcome determination was a single event as opposed to a string of events. Sessions in which subjects faced sequential survival endowed with a lump-sum of assets mimic the current 401(k) frame of reference.

We used a neutral context in the laboratory, avoiding language such as retirement, bequests and death. In Section 5, we discuss the relative merits of this choice.

2.1 Payout Options

Payout tables captured the inherent trade-off in the annuitization decision.[13] The lump-sum's declining per-round payment mimics the declining consumption path generally optimal for consumption out of a stock of wealth. The annuity delivered a constant payment path. The lump-sum option paid more in the event of a short retirement, less in a long retirement, and had a lower expected payout.

We attempted to minimize inter-treatment payout-table differences. Tables listed a payment corresponding to consumption utility (the **Type-I** payment in the Instructions and Payoff Table) and a payment corresponding to bequest utility (the **Type-II** payment) for

[13]In Appendix A, we provide details on how we arrived at payout values.

both annuity and lump-sum. As we assumed complete annuitization for the annuity option, the Type-II (i.e. bequest) payments for this option were always zero. A subject choosing the lump sum started with an account from which Type-I payments were made.[14] After a subject's final round, she received a Type-II payment equal to a fraction of the amount remaining in her account after subtracting Type-I payments received. We include sample experiment instructions and Payout Tables in Appendix B.

We did not allow the subject choosing the lump-sum option to actually choose per-period consumption. First, simplifying the subject's decision problem allows us to focus on the behavioral hypotheses of interest. Given the complexity of the problem and the limited time to optimize, a subject may make serious mistakes in her allocation. If this subject chose the annuity, we would not know whether it is because she preferred the annuity's consumption path to the lump sum's or whether she miscalculated the latter's utility possibilities. Second, the subject choosing the annuity would make many fewer decisions than the subject choosing the lump sum. Preferences over number of decision may then be driving decisions.

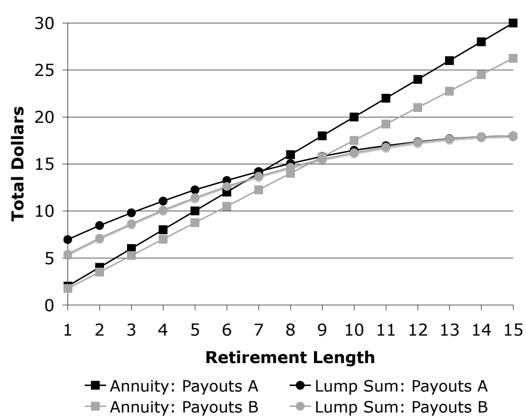

Figure 1: Payment to subject surviving exactly a given number of rounds under Payouts A and B in sessions where endowments are not earned.

As a first step towards establishing the robustness of our results, we used two sets of payouts: Payouts A and Payouts B. Under Payouts A, the expected payoff from the lump-sum option is 88% of the annuity's. The difference in the maximal payoffs was also rather large, with the lump sum's maximal payment only 60% of the annuity's. We made expected payoffs in Payouts B more equal (the lump-sum's expected payout is 97% of the annuity's) and the difference in maximal payoffs smaller (lump-sum's maximal payoff is almost 70% of annuity's). We show in Figure 1 the base payment schedule for each payout option under both

[14]In those sessions in which the default option is the Lump-Sum Payout option, we referred to the account as *their* account.

Payouts A and B. While we required subjects to earn endowments in some sessions and thus introduced some endowment heterogeneity, the payout options were always a proportional rescaling of either Payouts A or B.

2.2 Experiment Treatments

In one dimension, we varied the denomination of retirement assets. In **No Endowment** sessions, we did not endow subjects with a particular payout option—we simply asked them to choose between the Annuity and Lump-Sum payout options. In the other two sets of sessions, a subject was endowed with either the annuity payout path (**Annuity Endowment**) or the lump-sum payout path (**Lump-Sum Endowment**). We then asked the subject, in essence, whether she would like to trade for the other payout path.

Previous experiments have found that hypothetical endowments are not always sufficient to induce an endowment effect. Just as the real-world retiree earns her retirement assets, subjects earned retirement assets by performing a timed memory task (the Earnings Phase in the Instructions).[15] We translated points accumulated in the memory task into Payout-Phase assets, reported as either a per-round annuity payment (akin to the Social Security statement we receive each year) or a stock of wealth (akin to the 401(k) statement we receive each quarter). The idea is that retirees and subjects may develop a sense of ownership over the *type* of asset when they have earned the underlying asset. To further foster a sense of ownership, we split the Earnings Phase into two four-minute periods, and reported the current and projected per-round payment (in the Annuity sessions) or account balance (in the Lump-Sum sessions) between earning periods.

While subjects earning n points in either earned-endowment treatment received the same payout table, tables varied according to Earnings-Phase points. A concave function from points into payouts mitigated inter-subject endowment variation. We attempted to control for inter-treatment variation by parameterizing so that the expected earned endowment equaled that of the No Endowment sessions. Prior to the Earnings Phase, subjects received a table indicating, for a range of points earned, either the per-round payment (Annuity Endowment sessions) or account balance (Lump-Sum Endowment sessions).

After the Earnings Phase, we offered subjects the alternate payout option. We did not further favor the initially endowed option. A subject earning an $18 account balance or the equivalent per-round payment received the exact same choice sheet as a subject in a No Endowment session.

In the second dimension, we varied the determination of the number of Payout-Phase

[15] A subject's monitor displayed five letters. She clicked okay after reviewing the letters and was presented with three letters. The subject then indicated whether all of the three letters were in the original five. Points earned equalled the number of correct responses minus the number of incorrect responses.

rounds (i.e., retirement length). In **Simultaneous** sessions, a single draw from a bag containing 15 lettered chips determined retirement length. There was no mention of time or rounds. We identified retirement lengths as Events A, B, . . . , O, with Event A corresponding to a one-round Payout Phase.[16]

In **Sequential I** sessions, sequential survival determined retirement length.[17] In each Payout-Phase round, the subject drew a marble from a bag of marbles to determine survival into the next round. If she drew a green marble in round t, she received the round $t+1$ consumption (Type-I) payment and then drew another marble to determine survival into round $t+2$. If she drew a red marble in round t, her Payout Phase ended and she collected no more per-round payments, but she did receive the round t bequest (Type-II) payment if she had chosen the lump-sum option. The bag contained 14 green marbles and 1 red marble in round 1. In each subsequent round (until she pulled a red ball), the bag contained one fewer green marble than in the preceding round.

There was no difference in survival probabilities across treatments. For example, both Event G in the Simultaneous treatment and surviving exactly 7 periods in a Sequential treatment occurred with probability $\frac{1}{15}$ and had the same subject payoff (conditional on having the same level of retirement assets). However, in the Sequential treatments, she only reached those states in which the annuity dominated by first surviving those states in which the lump sum dominated. If in fact the ordering of risks matters in the manner we hypothesize, we should find lower annuitization rates in Sequential treatments.

In Sequential I sessions, we presented the probability of surviving to the next period conditional on survival to the current period, but not the unconditional probability of surviving a given number of periods. While a subject in a Simultaneous session knew that the probability of Event G was $\frac{1}{15}$, a subject in a Sequential I session might not have known that she had this chance of surviving exactly 7 periods. While a lower rate of annuitization in Sequential I may be due to early events having more salience, it may also be due to an inability to calculate unconditional probabilities. To rule out this possibility, we conducted **Sequential II** sessions identical to Sequential I sessions except that we provided both conditional and unconditional probabilities. In all Sequential II sessions, we did not explicitly endow subjects with either option, and thus subjects did not need to earn endowments.[18]

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[16]By listing outcomes associated with an early death first, we potentially introduce a bias. This bias ought to work in the same direction as the ordering bias, and thus works against finding a difference between treatments.

[17]Fatas, Lacomba and Lagos (2007) used a similar method to determine retirement length in their investigation of retirement timing.

[18]Nonetheless, we administered the timed memory task to these subjects after they had made their choices. We used their performance on the task as a proxy for cognitive ability.

2.3 Additional Details

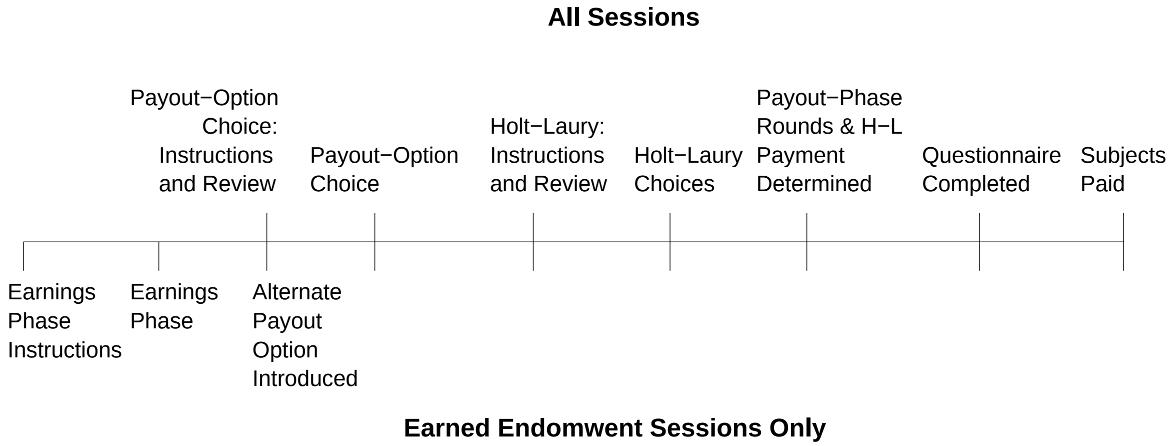

Figure 2: Summary and timeline of session events. We list events occurring in all sessions above the timeline, and those occurring only in Earned-Endowment sessions below.

The main procedural difference between treatments was the need for subjects in the earned-endowment sessions to earn payout-phase assets. We present in Figure 2 a summary and timeline of session events.

After all subjects made the choice of payout option, each subject completed a Holt-Laury risk-aversion assessment (Holt and Laury 2002) further described in section 4.2. Subjects also completed a demographic questionnaire, and answered incentivized review questions before both the payout-option choice and the risk-aversion assessment.

	Simultaneous	**Sequential I**	**Sequential II**	**Total**
No Endowment	27 Payout A 28 Payout B **55 Total**	26 Payout A 25 Payout B **51 Total**	32 Payout A 28 Payout B **60 Total**	85 Payout A 81 Payout B **166 Total**
Lump Sum Endowment	26 Payout A 22 Payout B **48 Total**	25 Payout A 24 Payout B **49 Total**		51 Payout A 46 Payout B **97 Total**
Annuity Endowment	29 Payout A 28 Payout B **57 Total**	28 Payout A 25 Payout B **53 Total**		57 Payout A 53 Payout B **110 Total**
TOTAL	82 Payout A 78 Payout B **160 Total**	79 Payout A 74 Payout B **153 Total**	32 Payout A 28 Payout B **60 Total**	193 Payout A 180 Payout B **373 Total**

Table 1: Number of subjects in each treatment.

We conducted sessions at George Mason University's ICES laboratory in September and October 2008 and February 2009. Approximately 14 subjects participated in a session, without duplication. Table 1 details the treatments and subject participation in this study. Participants were George Mason University students. Parts of the experiment (the Earnings Phase and the quizzes) were programmed and conducted with z-Tree (Fischbacher 2007). The No Endowment sessions lasted approximately 60–75 minutes, whereas earned-endowment sessions lasted approximately 75–90 minutes. The average payoff was about $23.45, including a $7 show-up fee.

3 Hypotheses

Given uncertainty over outcomes, the unbiased subject chooses the payout option with the greater expected utility. While it is plausible that a *retiree's* per-period utility depends on only per-period consumption, a subject likely evaluates session earnings. Let x_t^j be the Type-I (consumption) payment and b_t^j be the Type-II (bequest) payment for payout option j in round t. With p_t the probability of surviving to at least round t and d_t the probability of surviving exactly t rounds, expected utility for subject i for payout option j is:

$$\begin{aligned} EU_i^j &= \sum_{t=1}^{15} \left[p_t - p_{t+1}\right] u_i \left(\sum_{\tau=1}^{t} x_\tau^j + b_t^j \right) \\ &= \sum_{t=1}^{15} d_t u_i \left(\sum_{\tau=1}^{t} x_\tau^j + b_t^j \right) \\ &= \sum_{t=1}^{15} d_t u_i \left(y_t^j \right) \qquad (1) \end{aligned}$$

where $b_t^{an} = 0$ for all t. Equation 1 expresses an option's expected utility in terms of the probability the Payout Phase lasts exactly t rounds and the total payment if that is the case (y_t^j). Defining $\Delta_i \equiv \ln(\frac{EU_i^{an}}{EU_i^{ls}})$, a subject chooses the annuity option if $\Delta_i \geq 0$.

We first suppose that following Cumulative Prospect Theory (Tversky and Kahneman 1992), the weights that a subject assigns to different outcomes, $\vec{\delta}$, may deviate from actual probabilities, $\vec{d}$. Given these subjective weights, we define subjective expected utility

$$EU_i^j \left(\vec{\delta} \right) \equiv \sum_{t=1}^{15} \delta_t u_i \left(y_t^j \right). \qquad (2)$$

Defining $\Delta_i \left(\vec{\delta} \right) \equiv \ln \left(\frac{EU_i^{an}\left(\vec{\delta}\right)}{EU_i^{ls}\left(\vec{\delta}\right)} \right)$, a subject chooses the annuity option if $\Delta_i \left(\vec{\delta} \right) \geq 0$. In particular, we make the following assumption about decision weights in our treatments.

Assumption 1. *In the Sequential treatments,* $\sum_{\tau=1}^{t}\delta_\tau > \sum_{\tau=1}^{t} d_\tau$ *and* $\sum_{\tau=t}^{15}\delta_\tau < \sum_{\tau=t}^{15} d_\tau$ *for* $0 < t < \bar{t} < 15$*, with* $\sum_{\tau=1}^{15}\delta_\tau = 1$*. In the Simultaneous treatments,* $\vec{\delta} = \vec{d}$*.*

Subject payments for the lump-sum option are greater than those for the annuity option if the Payout Phase lasts fewer than 7 rounds under Payouts A (8 rounds under Payouts B). Therefore, under Assumption 1, it will generically be the case that $\Delta_i\left(\vec{\delta}\right) < \Delta_i$. This leads to the following hypotheses concerning the effect of probability framing.

Hypothesis 1. *For each endowment frame, the proportion of subjects choosing the annuity payout option will be greater in the Simultaneous treatment than in the Sequential treatment.*

We next suppose, once again following (Cumulative) Prospect Theory, that a subject evaluates uncertain outcomes relative to her initial endowment: $v(y^j)$. Given this value function, we define subjective expected value conditional on endowment J:

$$EU_i^j\left(\vec{\delta}, J\right) \equiv \sum_{t=1}^{15} \delta_t v_i\left(y_t^j\right). \tag{3}$$

We define $\Delta_i\left(\vec{\delta}, J\right) \equiv \ln\left(\frac{EU_i^{an}\left(\vec{\delta},J\right)}{EU_i^{ls}\left(\vec{\delta},J\right)}\right)$, with $J = \{an, ls\}$. Endowed with the annuity option, she keeps the annuity option if $\Delta_i\left(\vec{\delta}, an\right) \geq 0$, and if endowed with the lump-sum option, she does not trade for the annuity if $\Delta_i\left(\vec{\delta}, ls\right) < 0$.

In the spirit of Prospect Theory, we make the following assumption about the value function:

Assumption 2. *Endowed with option* j*, the value function* $v(\cdot)$*:*

- *is convex for* $y_t^{-j} < y_t^j$ *(i.e., over losses relative to endowment);*
- *in concave and equal to* $u(\cdot)$ *for* $y_t^{-j} \geq y_t^j$ *(i.e., over gains relative to endowment);*
- *equal to* $u(\cdot)$ *at* $y_t^{-j} = y_t^j = 0$*.*

Under Assumption 2, it will generically be the case that $\Delta_i\left(\vec{\delta}, an\right) > \Delta_i\left(\vec{\delta}, ls\right)$. This relationship will hold when $\vec{\delta} = \vec{d}$. This leads to the following hypothesis comparing choices across payout-option endowments.

Hypothesis 2. *For each probability frame, the proportion of subjects choosing the annuity payout option will be greater in the Annuity Endowment treatment than in the Lump-Sum treatment.*

While equation (1) is the appropriate expression for the expected utility of the experiment subject, it is not appropriate for the retiree. Under the assumptions specified in Appendix A and with $\beta u(w_t)$ the utility from a bequest of w_t, expected utility for retiree i for payout option j is

$$EU_i^j = \sum_{t=1}^{15} [p_t - p_{t+1}] \left(\beta u \left(w_t^j \right) + \sum_{\tau=1}^{t} u \left(c_\tau^j \right) \right)$$

with $w_t^{an} = 0$ for all t. Under our assumptions, the rational retiree always chooses to annuitize, although this prediction is highly dependent on the strength of the rational attraction to maintaining a stock of liquid wealth (the bequest motive in our model). We do note that under Assumptions 1 and 2, the hypotheses remain unchanged for a population of retirees drawn from a generic distribution of βs.

4 Results

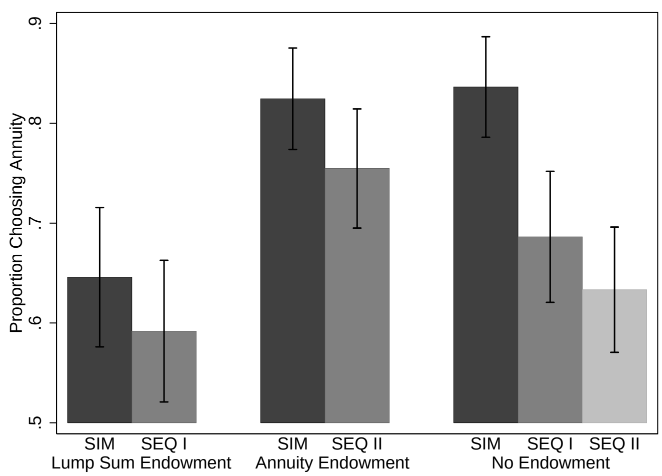

Figure 3: Proportion of subjects choosing annuity, by treatment, with standard error bars.

In Figure 3, we depict for each treatment the proportion of subjects choosing the annuity payout option. A few observations are evident. First, in all treatments, a significant proportion of subjects chose the annuity option. Second, the ordering of risks seems to matter in the hypothesized direction. Regardless of endowment, annuity choice is likelier in Simultaneous treatment than in the Sequential treatment. Third, Figure 3 suggests an endowment effect, as the proportion of subjects choosing the annuity payout option is smallest when endowed with the lump-sum payout option.

Endowment	Probability Frame	Annuity Choice Proportion	χ^2 Test H_0	p-value
No Endowment	Simultaneous	83.6%	NoE:Sim=NoE:Seq I	0.069
	Sequential I	68.6%	NoE:Seq I=NoE:Seq II	0.558
	Sequential II	63.3%	NoE:Sim=NoE:Seq II	0.014
Lump Sum	Simultaneous	64.6%	LS:Sim=LS:Seq I	0.584
	Sequential I	59.2%	LS:Sim=Ann:Sim	0.037
Annuity	Simultaneous	82.5%	Ann:Sim=Ann:Seq I	0.368
	Sequential I	75.5%	LS:Seq I=Ann:Seq I	0.079

Table 2: Annuity choice proportions by treatment and χ^2 test results.

4.1 Hypothesis Testing

We present in Table 2 the proportion of subjects choosing the annuity payout option by treatment. We also note for each null hypothesis the p-value of the χ^2 test. We now formally test our hypotheses.

Result 1. *The proportion of subjects choosing the annuity payout option is greater in the Simultaneous treatment than in the Sequential treatment when subjects are not explicitly endowed with a payout option. The same difference is not significant when subjects are explicitly endowed with a payout option.*

Support: We present in the final column of Table 2 the p-values for the χ^2 test of the null hypotheses of equal proportions.

Result 1 is consistent with an ordering of risks affecting decision making. In the No Endowment treatment, we can reject the hypotheses of annuity-choice equality at the 10% level of significance when comparing Simultaneous to Sequential I, and at the 5% level comparing it to Sequential II.[19] While annuity-choice proportion is greater in the Simultaneous frames than the Sequential in the earned-endowment treatments, we cannot reject the null of equality of proportions.

Result 2. *The proportion of subjects choosing the annuity payout option when endowed with the annuity payout option is greater than the proportion when endowed with the lump-sum option regardless of probability frame (Sequential or Simultaneous).*

Support: We present in the final column of Table 2 the p-values for the χ^2 test of the null hypotheses of equal proportions.

[19] We cannot reject the hypothesis of Sequential I versus II annuity-choice equality. Pooling these two treatments and comparing with Simultaneous, we reject the hypothesis of annuity-choice equality ($p = 0.016$).

Result 2 suggests a fairly strong endowment effect in decisions akin to asset allocation in retirement. When there is no temporal ordering of retirement risks (Simultaneous), we reject the null hypotheses of proportion equality at the 5% level of significance, and reject the corresponding null hypotheses at the 10% level of significance when retirement risks are temporally ordered (Sequential I).

4.2 Regression Analysis

While treatments were randomly assigned to experiment sessions, subject characteristics could very well vary across sessions. These inter-treatment differences in subject characteristics could potentially exaggerate or understate differences attributable to treatment effects.

Importantly, we ought to control for risk preferences. We based payout tables on the *utility* paths offered by the options. However, while the expected-utility-maximizing retiree cares only about expected utilities and not their variances, the subject cares about payment variance unless risk neutral. In evaluating the range of potential outcomes for each option, a subject's risk aversion affects her choice. Therefore inter-treatment risk-preference differences could drive some of the Table 2 treatment differences.

We elicited an ordinal measure of risk preferences (Holt and Laury 2002). For each of 10 decisions, a subject chose between a safe option (where "Left" pays $2.00 and "Right" $1.60) and a risky option (where "Left" pays $3.85 and "Right" $0.10). The probability of left linearly increased from 1/10 in decision one to 10/10 in decision ten. We define the HL Score as the decision number the subject first chose the risky option. We treat as missing the nearly 20% of subjects who switched back and forth multiple times between the riskier and safer option. As the probability of the good outcome (Left) increased monotonically from decision one to ten, consistency dictates only one switch from safe to risky option (or the same option for all decisions).[20]

As we presented subjects one of two sets of payout schedules, we do not use the Scores directly in our regression analysis. Instead, we construct an indicator equal to one if the expected-utility-maximizing subject would have selected the annuity given her HL Score. To construct this variable, we solve for the range of risk preferences consistent with each HL Score assuming CRRA utility. We also compute the level of risk preference consistent with indifference between the annuity and lump-sum option for a given payout table (that is, Payout A or B). With these two pieces of information, we identify those subjects who should prefer the annuity option.

Just as inter-treatment heterogeneity in risk preferences may account for treatment differences, so may differences in other dimensions. In Table 3, we present subject characteristics

[20] To increase our non-missing sample, we retained 26 observations in which there was only one "stray" choice among a consistent pattern of choices.

	Total Obs.	No Endowment SIM	No Endowment SEQ(1)	Endowments Annuity SIM	Endowments Annuity SEQ	Endowments Lump-Sum SIM	Endowments Lump-Sum SEQ
Mean Risk (Holt-Laury) Score	303	6.41	7.25	6.57	6.46	6.54	6.68
Prop. in Prefer Annuity Range	303	0.51	0.42	0.41	0.48	0.49	0.57
Prop. with Missing HL Scores	373	0.25	0.18	0.14	0.13	0.19	0.24
Prop. Took Review Questions	373	0.78	0.70	1.00	0.72	1.00	1.00
Prop. Received Payouts B(2)	373	0.51	0.48	0.49	0.47	0.46	0.49
Points Earned	207	n.a.	n.a.	85.63	79.32	77.52	76.65
(Std Dev)				(21.25)	(21.75)	(20.80)	(20.10)
Male	350	0.75	0.62	0.70	0.74	0.67	0.53
Born in the US(3)	348	0.47	0.40	0.47	0.47	0.44	0.61
Mean Age	347	21.46	21.60	21.42	21.41	21.69	21.36
Graduate Student	373	0.36	0.41	0.33	0.42	0.38	0.33
Working for Pay	362	0.57	0.49	0.67	0.61	0.91	0.65
Ever Taken Calculus	357	0.87	0.82	0.84	0.90	0.75	0.92
Ever Taken Trigonometry	357	0.91	0.89	0.86	0.92	0.87	0.92
Ever Taken Statistics	364	0.69	0.70	0.82	0.72	0.77	0.75

Notes:
(1) Includes 60 SEQ II subjects. Group's mean Points Earned is 76.07, with a std dev of 20.09.
(2) Payouts B has smaller differences in expected and maximal payoffs than Payout A.
(3) 60% of foreign born are graduate students compared to 6% of US born.

Table 3: Inter-Treatment Heterogeneity.

across treatment groups. In addition to inter-treatment differences in risk preferences, we present other subject characteristics—such as age, education background, cognitive abilities, and U.S. nativity— plausibly affecting the valuation of the annuity relative to the lump sum. For example, a subject's math background may provide information about ability to compute expected values, and ability to comprehend experiment instructions may be correlated with U.S. nativity.

We make a few observations. First, the proportion of subjects with HL Scores in the range that should prefer the annuity varies substantially across treatments. This proportion in the Lump-Sum treatment (in both Sequential and Simultaneous frames) is greater than in either the Annuity or the No Endowment treatment. This difference likely understates the effect of the Lump-Sum treatment on annuity choice. Likewise, in both the Annuity and Lump-Sum frames, the proportion of subjects in the prefer-annuity range is greater in

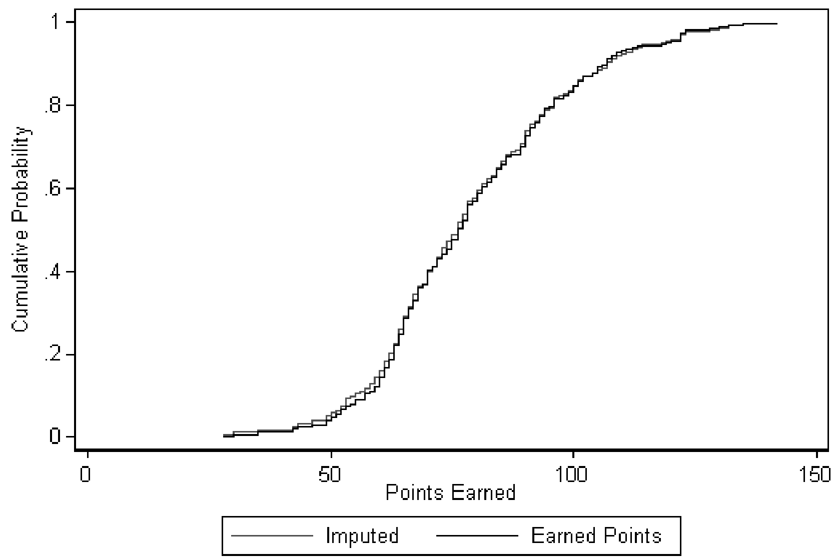

Figure 4: CDFs of Earned and Imputed Memory Task Points.

Sequential sessions than in Simultaneous sessions. Again, this difference likely understates the effect of the Sequential treatment on annuity choice in those frames.

Second, we observe inter-treatment differences in memory-task points earned. Points in Sequential sessions were significantly lower than in Simultaneous sessions, and significantly lower in Lump-Sum than in Annuity sessions. Inter-treatment point differences may be important if performance in the memory task measures a dimension of cognitive abilities affecting annuity choice.

Third, about 15% of subjects, concentrated in the No Endowment sessions, did not answer experiment-instruction review questions. We did not administer these questions in the first sessions we ran. This inter-treatment difference could plausibly contribute to systematic differences across treatments in annuity choice.

Fourth, across treatments, subjects vary in gender, U.S. nativity, and educational background. However, there does not appear to be a clear pattern across treatments that would systematically bias the measured treatment effect in one direction or the other.

Fifth, we code as missing HL Scores for a reasonably large proportion of subjects. This proportion varies across treatments. Although we hold no priors that suggest subjects with missing scores would systematically behave differently from their counterparts with non-missing scores, the possibility exists.

Finally, points earned are missing for most subjects the No Endowment sessions. This was by construction since subjects in these sessions received, rather than earned, their endowments. Given the wide distribution of points earned and the possibility that the variable absorbs important inter-treatment variation in cognitive differences (not absorbed by the other demographic variables), we impute for missing points earned.[21] We use a multiple imputation hot-deck method.[22] Hot-deck imputation preserves the distribution of points earned, while multiple imputations introduce variability, generating larger (better) standard error estimates than a single imputation.[23] In Figure 4, we show the cumulative distributions of imputed and actual points earned.

We now turn to regression evidence of treatment effects, controlling for inter-treatment heterogeneity. We characterize annuity choice with an underlying latent process. From Section 3, we define $\Delta_i\left(\vec{\delta}, J\right) = \ln\left(\frac{EU_i^{an}(\vec{\delta},J)}{EU_i^{ls}(\vec{\delta},J)}\right)$. The subject chooses the annuity option if $\Delta_i\left(\vec{\delta}, J\right) \geq 0$. Correspondingly, we have

$$Pr(Y_i = 1|X_i, Z_i) = \Phi(\beta_x X_i + \beta_z Z_i), \tag{4}$$

with X_i a vector of treatment indicator variables and Z_i a vector of control variables. The treatment vector includes indicator variables for Sequential, No Endowment, and Annuity Endowment sessions. The omitted categories are Simultaneous and Lump-Sum.

The vector of coefficients β_x, reporting our treatment effects, is the coefficient vector of interest. If the manner in which we resolve uncertainty affects the annuity decision, we expect the coefficient on Sequential to be $\beta_1 < 0$. If endowed asset type affects the annuity decision, we expect $\beta_2 > 0$ (for the No Endowment treatment) and $\beta_3 > 0$ (for the Annuity treatment).

To account for inter-treatment differences in observable characteristics and experiment setup, we incrementally include control variables in the probit model. In all, we account for risk preferences (proxied by the indicator for whether the subject's risk-aversion level is consistent with choosing the annuity), cognitive differences (proxied by points earned), a parsimonious set of demographic controls given the relatively small sample size, an indicator for whether the subject took the review questions, and relative payouts (by including a indicator if she faced Payouts B). The full sample includes 373 observations. Our sample size decreases when we add additional controls due to missing data.

Of course, the controls enable us to parse out the effects of *observable* characteristics

[21]In later No Endowment sessions (60 subjects), we administered an incentivized memory-task phase after the risk-aversion assessment.

[22]It is reasonable to assume data are missing at random. There is no systematic organization of treatments in terms of session date or time, and recruitment emails do not differ across treatments.

[23]The standard errors from multiple imputations are constructed using the between- and within-imputation variation (Rubin 1987). We generate 10 complete imputed data sets due to the high missing rate. Due to relatively small cell sizes, we limit predictors for imputing to two: gender and U.S. nativity.

from treatment effects. *Unobservable* factors may influence annuity choice.[24] As the vector β_x captures *changes* in choice probability relative to the omitted case, so long as these unobservable effects do not vary systematically across treatments (i.e., they are uncorrelated with the treatment variables), any randomly distributed unobserved effect will be differenced out.

In Table 4, we report the coefficients we estimate for six regression models, reporting marginal estimates (evaluated at the mean). In model one, our base estimate of treatment effects, we estimate a probit equation with only treatment dummies. In the second model, we include the risk-preference proxy whose distribution may lead to model one understating treatment effects. In model three, we add the demographic and experimental setup controls which may affect annuity choice: age and indicators for U.S. nativity, taken calculus, review questions, and Payouts B. In model four, we account for differences in points earned (using imputed values for the No Endowment sessions), which potentially proxies for cognitive differences.[25] We include the points earned and its squared term. In our fifth model, we account for possible selection by including subjects with missing HL scores. An indicator variable, set to 1, identifies missing HL scores. In our final model, we focus on earned-endowment sessions only.

There are four important points to take away from the results. First, subjects in the Sequential treatment are at least 10 percentage points less likely to choose the annuity option than subjects in Simultaneous treatment. This result is robust across all six specifications. Comparing estimates for models (1) and (2), the inclusion of the risk-preference proxy substantially increases the estimated effect of Sequential frame on annuity choice: from -11.3 percentage points to -15.3 percentage points. The effect remains with the inclusion of demographic and cognitive controls. Not surprisingly, accounting for missing HL scores reduced the magnitude of the estimated coefficient on the treatment variables. To the extent that subjects who had difficulty comprehending the HL risk assessment also had difficulty comprehending the annuity choice, we would not expect to observe a systematic pattern in annuity choice. Although our results are robust even with the inclusion of missing HL scores, our preferred specification would exclude those cases.

Second, subjects in both the No Endowment and Annuity Treatments are more likely to choose the annuity option than subjects in the Lump-Sum treatment. The estimated effect is large, significant and robust across all six specifications. The annuity-choice probability difference between the Annuity and Lump-Sum treatments is generally larger then the corresponding difference between the No Endowment and Lump-Sum treatments. In the Annuity

[24]For example, a subject may focus only on round 15 Total Payments.

[25]We were unable to impute Earned Points for all subjects in the No Endowment sessions due to missing demographic values in the donor (predictor) pool.

	(1) dy/dx	(2) dy/dx	(3) dy/dx	(4) dy/dx	(5) dy/dx	(6) dy/dx
Treatments						
Sequential I	-0.113**	-0.153***	-0.137**	-0.154***	-0.096*	-0.188**
	(0.05)	(0.05)	(0.06)	(0.06)	(0.06)	(0.08)
No Endowment	0.111**	0.112*	0.145**	0.161**	0.182**	
	(0.06)	(0.06)	(0.07)	(0.07)	(0.07)	
Annuity Endowment	0.159***	0.195***	0.190***	0.190***	0.158**	0.163**
	(0.05)	(0.06)	(0.06)	(0.06)	(0.06)	(0.07)
Risk Preferences						
Should Prefer Annuity		0.136***	0.139**	0.144**	0.115*	0.109
		(0.05)	(0.06)	(0.06)	(0.06)	(0.08)
Environment						
Payouts B			-0.008	0.017	-0.058	-0.075
			(0.07)	(0.07)	(0.06)	(0.08)
Sequential II			-0.061	-0.042	-0.095	
			(0.09)	(0.09)	(0.09)	
Other Controls						
Demographic	no	no	yes	yes	yes	yes
Imputed Earned Points	no	no	no	yes	yes	n.a.
Missing HL Indicator	no	no	no	no	yes	no
Observations	373	303	291	279	344	158
LR χ^2	13.1	23.3	26.8	28.1	25.4	18.7
Prob> χ^2	0.004	0.000	0.003	0.003	0.013	0.009

Notes: dy/dx is for a discrete change of indicator variable from 0 to 1. Significant at: * 10-percent level; ** 5-percent level; *** 1-percent level. Standard errors in parenthesis. Omitted groups are Simultaneous and Lump-Sum Endowment. HL Scores refer to Holt-Laury risk assessment scores, and Should Prefer Annuity is based on HL Score and Payouts A vs. B. Payouts B has smaller difference in expected total payment and maximal payoff than A. Imputed earned points include the main and squared terms. Sequential II was only administered in the No Endowment frames. Demographic controls: age, US born, ever taken calculus. Missing demographic variables reduce sample sizes in models (3-6).

Table 4: Probit Estimates: Marginal Effects of Sequential and Endowment Treatments on Annuity Choice.

vs. Lump Sum comparison, accounting for risk preferences increases the estimated effect of the endowment bias whereas accounting for selection absorbs some of the difference. In the No Endowment vs. Lump Sum comparison, the effect strengthens with additional controls.

Third, recall that based on the chi-square test, we could not reject the hypothesis of equality of annuity-choice proportions between Sequential and Simultaneous frames when subjects earned a particular payout option. This is not the case after accounting for risk preferences. Model six includes only subjects in earned-endowment sessions. Our specification includes only those who had valid HL scores for the reasons discussed above. We estimate that those receiving the Sequential treatment were nearly 19 percentage points more likely to choose the annuity option than subjects in the Simultaneous treatment. Furthermore, when endowments were denominated as an annuity, subjects were 16 percentage points more likely to choose the annuity option than when denominated as a Lump-Sum.[26]

Finally, our specification-check variables assure us that neither maximal payoffs or the inability to compute unconditional probabilities are driving our results. We varied the expected total payment and maximal payoff between the annuity and lump-sum options (Payouts A vs. B) in case these comparisons contributed to treatment differences. We also varied whether we included unconditional probabilities in the payout table in Sequential treatments (Sequential I vs II), in case choices were largely driven by mistakes computing survival probabilities. Neither appear to be significant in the annuity-choice decision.

5 Discussion

Since Yaari's (1965) seminal work, a large literature has attempted to explain why observed annuitization rates are lower than generally predicted under standard neoclassical models. Even accounting for factors such as pre-existing annuities, bequest motives, and precautionary saving for uninsured late-life medical expenses, these models are generally unable to explain fully the gap. Recent evidence suggests that frame-induced biases may provide additional traction in explaining the annuity decision. We contribute to this line of inquiry, focusing on the oft-expressed concern of dying shortly after annuity purchase. We break this concern down into two plausible behavioral biases. Our first hypothesis is a risk-ordering bias: retirees effectively overweight the *early* risk (an early death) relative to the *later* risk (a longer-than-anticipated retirement). Our second hypothesis is an endowment effect stemming from loss aversion.

We find support for these hypotheses in a laboratory setting capturing many of the salient aspects of the annuity decision. Changing the endowment from a wealth stock to an annuity payout significantly increased annuity choice, and regression results indicating a significant difference between no explicit endowment and the lump-sum endowment. Likewise, our Simultaneous treatments, in which we remove the temporal ordering of outcomes, increased annuity choice.

[26]This specification excludes cases with missing HL Scores. Treatment effects are smaller (13% and 13%) and less precisely estimated when cases with missing Scores are included.

Our preferred explanation of the mechanism by which our sequential treatment reduced annuity choice is that the ordering of states induced subjects to effectively overweight early states. We do admit alternative explanations. For example, a person plausibly experiences disutility as she waits to find out if her decision paid off. In the simultaneous sessions, we resolved uncertainty immediately. In the sequential sessions, the annuity choice meant approximately 8 rounds of being at risk of having made the wrong choice.[27] Of course, the real-world annuitant faces the same situation.

We take care in extrapolating our results to the real-world retiree's annuity decision, especially in considering the relative magnitude of these effects. While the laboratory allows us to cleanly investigate these biases in a context capturing key aspects of the decision, the laboratory differs from the wild in a number of potentially important ways.

First, we believe ourselves on firm ground describing the retirement-asset allocation decision as "context rich" (as we would any decision in which mortality plays such a large part). In the laboratory, we used a neutral context, avoiding language such as retirement, bequests and death. We did so because we believe context to be so important. In order to focus on the hypothesized biases of interest, we felt it necessary to control for additional biases that context may have introduced. Whether the identified biases are mitigated or augmented by context-dependent biases is left for future research.

Second, we use university students in a relatively low-stakes environment to proxy for the very high-stakes decision made by retirees. One can naturally ask whether either age or increased stakes might overcome the identified biases, and we plan to do so in future work. We note that while those making the annuity decision are older, it is not clear why older subjects would be less prone to these biases. The annuity decision is largely one shot with little to no feedback, conditions conducive to the continued existence of biases (Thaler and Sunstein 2008). Furthermore, while an increase in stakes most surely decreases the likelihood and extent of less-than-perfectly-rational behavior, there is considerable evidence that it does not extinguish it.

The control offered by the laboratory environment does offer benefits. For example, it would be difficult to disentangle mistaken survival-probability beliefs from an overweighting of early events despite correct beliefs. In fact, recent evidence suggests that retirees hold generally correct beliefs. Hurd and McGarry (2002) and Smith, Taylor and Sloan (2001) find that subjective survival probabilities are reasonably close, on average, to life tables and possibly even more optimistic (Gan, Gong, Hurd and McFadden 2004). Our results suggest a mechanism by which the perceived unattractiveness of the annuity persists despite accurate or optimistic survival beliefs.

[27]We thank Casey Rothschild for this insight.

We also point out that the risk-ordering bias we investigate (overweighting the relative *probability* of near periods) is closely related to discounting, such as hyperbolic discounting, that overweights current-period *utility* relative to classical models with exponentially discounted utility. (See Frederick, Loewenstein and O'Donoghue (2002) for an excellent overview.) In fact, Sheshinski (2007) notes the near equivalence of hyperbolic discounting and pessimistic survival beliefs. Empirically, it would be difficult to disentangle overweighting the *probability* of early events from underweighting the *utility* of later periods. This is less of an issue in the laboratory. Our experimental design allows us to focus on the former as subject payment occurs at the same time whether "retirement" is long or short.

Our results suggest a near-future bias, plausibly operating *in addition to* non-exponential discounting of future utility. This is important as the effect of hyperbolic discounting on annuity demand is ambiguous. The sophisticated hyperbolic discounter, realizing she will be present biased in future periods, receives great benefits from the annuity's commitment value (Laibson 1997, Diamond and Köszegi 2003). The naïve hyperbolic discounter, who believes her present bias only temporary, does benefit relative to the exponential discounter from bringing utility to the current period. However, the difference between the annuity valuations of the naïve hyperbolic discounter and her exponential counterpart is likely small. First, the naïvely present-biased retiree looks to bump up consumption today as opposed to today and tomorrow. This is consistent with reducing the amount annuitized (to increase current-period consumption) as opposed not annuitizing. Second, curvature of the utility function moderates overall utility gains from reallocating consumption to the current period. Our calculations suggest that at plausible (given the context) levels of risk aversion, the optimal first-period consumption for the naïve hyperbolic discounter does not greatly differ from her exponential counterpart, and therefore their relative valuations of even full annuitization do not greatly differ.[28] Taken together, we believe that the assumption of naïve hyperbolic discounting by an otherwise rational retiree can by itself only explain a very moderate reduction in the amount annuitized at retirement.

Furthermore, our results might help explain the only partial effectiveness of guarantees in increasing annuity demand. The combination of a risk-ordering bias and endowment effect suggests that guarantees may provide an incomplete fix for the risk of death shortly after annuitization. First, while the guarantee mitigates a bequest loss, it does so only partially. An early death still results in a loss relative to having maintained the wealth stock.

[28] For example, consider the environment faced by our Appendix A representative retiree with discounting but without a bequest motive. Ms. Exponential discounts future utility at $0.944^{\tau-t}$ while Mr. Quasi-Hyperbolic naïvely discounts at $(.7)0.957^{\tau-t}$ (Angeletos, Laibson, Repetto, Tobacman and Weinberg 2001). We calculate the increase wealth necessary to make utility from consumption out of a wealth stock equal to the utility from the actuarially fair annuity. With $\rho = 2$, the exponential discounter needs a 74% increase while the naïve quasi-hyperbolic discounter needs a 70% increase in assets.

Second, a guarantee does not cover other losses relative to the initial endowment (such as loss of consumption control or loss of utility due to an unanticipated medical expense) which might contribute to a loss-aversion-induced endowment bias. Finally, guarantees might also have the unintended consequence of increasing focus on early death and contributing to the overweighting of an early death relative to a long retirement.

Given the annuity paradox and the impending bulge of largely non-annuitized retirees, a number of policies aimed at increasing annuitization rates have been proposed, with some receiving careful analysis (Gentry and Rothschild Forthcoming). We believe our results have implications in this policy arena. Our finding of an endowment bias (stemming from loss aversion) in payout options suggests that changing the denomination of 401(k) assets from a lump sum to a claim on a per-period payment might increase annuitization rates. This idea has been proposed in policy circles and would be a relatively inexpensive and straightforward option to implement (Iwry and Turner Forthcoming).

The policy implications stemming from the risk-ordering bias we identify are non-obvious as the risk of an early death naturally precedes the risk of outliving one's assets. However, Brown et al. (2008a) find that framing matters in this context, and we share their belief that a more thorough understanding of the frame through which annuities are sold is needed. We also wonder whether making a large annuity decision *at retirement* might exacerbate the fear of losing one's principal. If so, the retiree may find more palatable recently introduced longevity (i.e., delayed payout) annuities (Scott 2007).

While our results provide support for changing the denomination of 401(k) assets and the eventual success of longevity annuities, the extent to which these innovations (or other policy or market innovation) will increase demand depends on the interaction of our identified biases with other context-dependent biases (such as loss of control, especially when paired with investor over-confidence). Addressing these interactions may require taking the experiment out of the laboratory and into the field.

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A Optimal Consumption

A.1 No Endowment Treatments

We assume no inflation and set the risk-free interest rate equal to zero. We further assume that a representative retiree enters retirement with a stock of wealth W, and can survive from 1 to 15 periods with each retirement length equilikely. Under these assumptions, and letting p_t be the probability of surviving at least to period t, the actuarially fair annuitization of W pays

$$y = \frac{W}{\sum_{t=1}^{15} p_t} = \frac{W}{8}$$

each period starting in the first period (Creighton and Piggott 2006). To simplify matters, we assume that the retiree consumes her entire annuity payment in each period ($c_t = y$).[29]

We assume that the retiree who does not annuitize retirement wealth optimally consumes from her stock of wealth W. The solution to this optimization problem will depend on her utility function as well as survival probabilities. We assume constant relative risk aversion (CRRA), with $u_t(c_t) = \frac{c_t^{1-\rho}}{1-\rho}$ the per-period utility function of our representative retiree with ρ the coefficient of relative risk aversion. We implement a rational attraction to maintaining a stock of wealth (i.e., make reasonable a "hit by a bus" concern) by assuming a bequest motive.[30] We assume that the value of a bequest of wealth is $v(w_t) = \beta\frac{w_t^{1-\rho}}{1-\rho}$, where w_t is wealth remaining as of time t. The retiree thus solves the following:

$$max_{c_t} E(U) = u(c_1) + \sum_{t=2}^{15}\left[p_t \cdot u(c_t) + (1 - \frac{p_{t+1}}{p_t})v(w_t)\right] \tag{5}$$

subject to:

$$w_t = W - \sum_{\tau=1}^{t} c_\tau;$$

$$c_{15} = w_{15}; \text{ and}$$

$$p_{16} = 0;$$

where

$$u(c_i) = \frac{c_i^{1-\rho}}{1-\rho} = \frac{v(\cdot)}{\beta}.$$

[29] Under our assumptions, reallocating consumption between retirement periods subsequent to annuitization decreases utility. However, a retiree with a bequest motive might find it optimal to not consume her entire annuity payment.

[30] Our specification follows the "warm glow" model of Andreoni (1989) rather than an altruistic model that incorporates children's utility, based on evidence in Kopczuk and Lupton (2007).

We consider $\rho = \frac{1}{3}$,[31] $\beta = 0.865$,[32] and $W = 1000$. We solve for optimal consumption, and scale utility by dividing by 20.

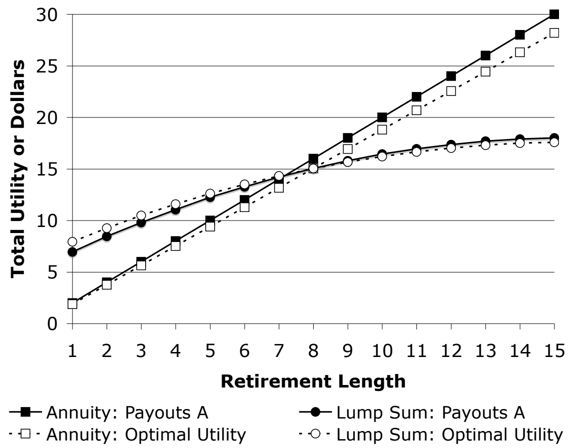

Figure 5: Representative retiree utility vs. Subject Payouts A.

In Figure 5 we depict the cumulative utility for the retiree who annuitizes and the retiree who consumes out of the lump sum of assets. We base our Payouts A on these utility paths, paying \$1 per util with the following caveats. In our **No Endowment** sessions, we desired to present all payoffs in multiples of \$0.05. We also desired to translate the payoffs, particularly those arising from the lump-sum option, into rules easily explainable to subjects. We therefore offered subjects an annuity payment of \$2.00 per period as opposed to \$1.88. We set the lump sum account value equal to \$18.00, with round 1 Type-I (consumption) payment equal to \$2.25 in the first round. The "consumption" payment decreases by \$0.15 with each passing round. Type-I payments are subtracted from the account balance, and the subject choosing the lump-sum payout option receives a Type-II (bequest) payment equal to 30% of the amount remaining in the account as of the final round.

As a first step toward checking the robustness of our results to changes in the relative values of our subject payments, we slightly alter Payout A. We decrease the Type-I payment

[31] We choose this level of risk aversion to match median and modal levels of risk aversion exhibited by experiment subjects. Holt and Laury (2002) find a median level of risk aversion in the range of $0.15 < \rho < 0.41$ for low-stakes gambles (safe choice pays approximately \$1.80) and $0.41 < \rho < 0.68$ for high-stakes gambles (safe choice pays approximately \$36.00).

[32] We initially choose this high weight on bequest motives for a few reasons. First, we are interested in decisions where both annuities and the lump-sum distribution are attractive. With $\rho = \frac{1}{3}$, without regard for a loss of assets due to death (i.e., $\beta = 0$), the expected utility of the optimal consumption of the lump-sum is only 81% of the actuarially fair annuity's. Furthermore, we desire that both options deliver the same utility should the subject live for eight periods. This is the case with $\beta = 0.865$, and expected utility from the optimal consumption of the lump sum is 95% of the the actuarially fair annuity's.

subject to annuitization to \$1.75 (akin to moving the annuity away from actuarially fair). Further, we decrease the annuity weight by decreases the fraction of the account balance received by the subject from 30% to 20% if the subject choose the lump sum. We depict the changes in Figure 1.

A.2 Endowment Treatments

In the treatments in which a subject must earn her retirement endowment, we translate points earned in the Earnings Phase into either per-round payments or account balances in the Payout Phase.

We start by noting the following about the payoffs in the No Endowment treatments. First, for both Payouts A and B, we calculate the amount by which we need to multiply the per-round annuity payment to recover the round-one lump-sum Type-I payment: $\alpha_A == \frac{2.25}{2.00}$, and $\alpha_B = \frac{2.25}{1.75}$. Second, letting x_1 be the round-one Type-I payment subsequent to choosing the lump sum, payments decrease each round by $\delta = \frac{x_1}{15}$. We use these relationships between the Annuity and Lump-Sum payouts in the No Endowment treatments in deriving payments for the endowment treatments.

We assume a linear relationship between points earned in the Earnings Phase and the stock of wealth brought into retirement by our representative retiree, $W_i = points \times \gamma$. An actuarially fair annuity pays $y_i = \frac{W_i}{8}$, yielding scaled per-period utility (and Type-I payment) $u_1 = .05\frac{y_i^{1-1/3}}{1-1/3}$. The round-one Type-I payment subsequent to choosing the lump sum is $x_1 = u_1 * \alpha$, subsequent Type-I payments declining by $\frac{x_1}{15}$ each round. The subject's account balance is the summation of Type-I payments over all rounds.

We wanted most earned-endowment subjects to have payouts in line with those faced by No Endowment subjects. We projected that the median subject would earn 90 points in the Earnings Phase. For example, setting $\gamma = 10$ results in $W = 900$, with an actuarially fair annuity paying 112.5 and scaled utility equal to 1.75, exactly the per-round payout for Payout B.

In the experiment, 40% of subjects earned between 77 and 104 points, thus placing them within ±10% of the No Endowment payouts, and 56% earned between 71 and 111 points, placing them with ±15% of the No Endowment payouts.

B Instructions and Payoff Tables

We reproduce below instructions for the annuity-choice portion (Part A) of our experiment. Instructions for the risk-aversion assessment (Part B), as well as our questionnaire, are available upon request.

Introduction ***[All sessions.]***

- You are about to participate in a session in which you will make choices in situations in which the amount of money you receive depends on both your choice and chance. This is part of a study intended to provide insight into certain features of decision processes. I encourage you to follow the instructions carefully, as the amount of money you accumulate will depend on the decisions you make as well as chance. You will be paid in cash at the end of the experiment.

- *During the experiment, I ask that you please do not talk to each other.* If you have a question, please raise your hand and an experimenter will assist you.

- This experiment will consist of 2 parts: Part A and Part B.

Part A Procedures ***[No Endowment, Simultaneous.]***

- For Part A, you will first choose between the Blue and Orange payout options. Later in the experiment, you will draw 1 of 15 chips from a bag. Your payout depends on the chip you draw as well as whether you chose the Blue or Orange payout option.

- You will choose Blue or Orange first, and I will collect your Choice. You will draw your chip later in the experiment.

- You will draw 1 chip out of a bag containing 15 chips. Each chip is lettered, with letters ranging from A through O (the first 15 letters of the alphabet). Each chip has one and only one letter, and each letter is on one and only one chip. Prior to drawing, you may inspect the chips to verify this.

- I have just handed each of you a Choice Sheet.

- For each payout option, the payment you receive for a particular chip has been split into Type I and Type II payments. Your total payment for the chip you draw from the bag is the sum of Type I and Type II payments for the payout option you chose.

- The set of blue columns on the Choice Sheet indicates the Type I and II earnings, as well as your total earnings for each chip, if you choose Blue. The set of orange columns on the Choice Sheet indicates the Type I and II earnings, as well as your total earnings for each chip, if you choose Orange.

- Prior to making your choice, your monitor will display a series of review questions to test your understanding of these Experiment Instructions. You may refer to the Experiment Instructions and the Choice Sheet in answering the review questions. You will be paid $0.10 for each correctly answered question.

- After completing the review questions, you will get as much time as you need to make your Choice. When you have made your Choice, please circle it in the place indicated on the Choice Sheet. I will collect the sheets when everyone has made a Choice.

- At the end of the experiment, I will pay you, in cash, your show-up fee and your earnings from Parts A and B of this experiment.

- Are there any questions?

Part A Overview *[Prior to Earnings Phase: Lump Sum, Sequential]*

- There are two phases to Part A: the Earning Phase and the Payout Phase.

- You earn points in the Earnings Phase by successfully completing tasks in each of two 4-minute periods. The number of points you earn in the Earnings Phase determines the the size of your Payout-Phase account. It is from this account that payments are made to you in the Payout Phase.

- The Payout Phase proceeds in a series of rounds. The number of rounds will be determined by chance. Your number of Payout-Phase rounds will be as few as 1 and as many as 15. In each round that your Part A lasts, you receive a payment from your account. After your final Part A round, you also receive a fraction of what is remaining in your account after the per-round payments to you have been subtracted. Your payment for Part A will depend on total funds you accumulate in your account during the Earnings Phase, as well as the number of Payout-Phase rounds.

- **The more tasks you successfully complete in Earnings Phase, the more points you generate, the larger the Payout-Phase account and thus the larger your Part A payment.**

Earnings Phase Procedures *[Prior to Earnings Phase: Lump Sum, Sequential]*

- In each of two 4-minute periods, your computer monitor will present you with a series of tasks. For each task, your monitor first presents you with 5 letters. After you click the OK button, your monitor will present you with a series of 3 letters. You are then asked to click **Yes** if all of the new 3 letters were in the original 5 letters, and **No** if any the new 3 letters were not in the original 5.

- If your response is correct, your monitor will immediately present you with the next set of 5 letters. If your response is incorrect, your computer monitor will present a screen indicating that your response is incorrect. After clicking the OK button, your monitor will then present you with the next set of 5 letters.

- The computer will keep track of your correct and incorrect responses. The number of points you earn in an Earnings Period is the number of correct responses minus the number of incorrect responses in the 4-minute period. The number of points you earn in the Earnings Phase is the sum of the points you earn in the two Earnings periods.

- The Points Table indicates for each number of total points you accumulate in the Earnings Phase the funds in your account in the Payout Phase.

- The Earnings Phase starts with a short practice round. The purpose of the practice round is to give you an opportunity to familiarize yourself with the computer interface. You do not accumulate points in the practice round.

Payout Phase Procedures *[Prior to Earnings Phase: Lump Sum, Sequential]*

- The number of points you earn in the Earnings Phase determines the value of your Payout-Phase account.

- Later in the experiment, I will call you up individually to determine your number of Payout-Phase rounds.

- You receive a payment from your Payout-Phase account each round. Your per-round payments are subtracted from your account. Your per-round payment decreases with each round.

- In each round, I present you with a bag of marbles. If you draw a green marble, you proceed to the next round and receive the per-round payment for that next round. If you do not draw a green marble, you do **not** proceed to the next round and your Part A is over. After your final round, you receive 20% of what remains in your account after your per-round payments have been subtracted.

- Note that you will receive all of the funds in your Payout-Phase account only if your Payout Phase lasts all 15 rounds.

- You start in round 1 and therefore collect the round 1 per-round payment. I will present you with a bag with 15 marbles, 14 of which are green. (If you wish, you may count the marbles in the bag.)

- If you select a green marble, you move on to round 2 and thus collect the round-2 per-round payment. I would then present you the same bag of marbles, which would now contain 14 marbles, 13 of which are green. Again, if you draw any one the green marbles, you move on to round 3, and collect your per-round payment for round 3. The bag would now contain 13 marbles, 12 of which are green.

- The rounds proceed until you fail to draw a green marble, at which point your Part A ends. You receive the per-round payment for each Payout-Phase round you last, as well as 20% of what remains in your account after the per-round payments have been subtracted.

- At the end of the experiment, I will pay you, in cash, your show-up fee and your earnings from Parts A and B of this experiment.

- Are there any questions?

[After Earnings Phase: Lump Sum, Sequential]

- I am now going to offer you an alternate payout schedule for the Payout Phase. I encourage you to listen carefully as you will be asked to choose between the original and alternate schedules.

- Depending on the number of Payout-Phase rounds, sometimes the original payout schedule will result in higher payouts, and sometimes the alternate payout schedule will result in higher payouts.

- Based on your points and thus the Payout-Phase account you earned, we have calculated your per-round payment for each Payout-Phase round. These are the Type-I payments on the Choice Sheet for the original schedule. We have also calculated 20% of the remaining account balance after per-round payments have been subtracted. These are the Type-II payments on the Choice Sheet for the original schedule.

- In the alternate payout schedule, there are also per-round Type-I payments, although unlike the original payout schedule these payments are equal in each round. You receive these Type-I payments for each round you last.

- If you choose the alternate payout schedule, in your final round, you do not receive a Type-II payment.

- The set of blue columns on the Choice Sheet indicates the alternate payout schedule. It indicates the Type-I payment for each round you last. The set of orange columns on the Choice Sheet indicates the Type-I and Type-II payments for the original payout schedule. Recall that you receive the the Type-I payment for **each** round, and receive only one Type-II payment: the Type-II payment associated with your final round. The last column of each color indicates your total Part-A earnings if you chose that option and your game lasts *exactly* a given number of rounds.

- The last set of columns indicates for each round the number of green marbles in the bag for that round as well as the total number of marbles. The final column indicates for each round the chance of drawing a green marble and thus proceeding to the next round.

- Prior to making your choice, your monitor will display a series of review questions to test your understanding of these Experiment Instructions. You may refer to the Experiment Instructions and the Choice Sheet in answering the review questions. You will be paid $0.10 for each correctly answered question.

- After completing the review questions, you will get as much time as you need to make your Choice. When you have made your Choice, please circle it in the place indicated on the Choice Sheet. I will collect the sheets when everyone has made a Choice.

- At the end of the experiment, I will pay you, in cash, your show-up fee and your earnings from Parts A and B of this experiment.

- Are there any questions?

B.1 Payoff Tables in No Endowment Treatments

	BLUE OPTION			ORANGE OPTION			
Chip	**Type I Earnings**	**Type II Earnings**	**TOTAL Earnings for this Chip**	**Type I Earnings**	**Type II Earnings**	**TOTAL Earnings for this Chip**	**Chance You Draw this Chip**
A	$2.00	$0.00	$2.00	$2.25	$4.70	$6.95	1/15
B	$4.00	$0.00	$4.00	$4.35	$4.10	$8.45	1/15
C	$6.00	$0.00	$6.00	$6.30	$3.50	$9.80	1/15
D	$8.00	$0.00	$8.00	$8.10	$2.95	$11.05	1/15
E	$10.00	$0.00	$10.00	$9.75	$2.50	$12.25	1/15
F	$12.00	$0.00	$12.00	$11.25	$2.00	$13.25	1/15
G	$14.00	$0.00	$14.00	$12.60	$1.60	$14.20	1/15
H	$16.00	$0.00	$16.00	$13.80	$1.25	$15.05	1/15
I	$18.00	$0.00	$18.00	$14.85	$0.95	$15.80	1/15
J	$20.00	$0.00	$20.00	$15.75	$0.70	$16.45	1/15
K	$22.00	$0.00	$22.00	$16.50	$0.45	$16.95	1/15
L	$24.00	$0.00	$24.00	$17.10	$0.25	$17.35	1/15
M	$26.00	$0.00	$26.00	$17.55	$0.15	$17.70	1/15
N	$28.00	$0.00	$28.00	$17.85	$0.05	$17.90	1/15
O	$30.00	$0.00	$30.00	$18.00	$0.00	$18.00	1/15

(a) Simultaneous Table; Payouts A

	BLUE OPTION			ORANGE OPTION					
Round	**Type I: Payment this Round**	**Type II Payment if Last Round**	**TOTAL Earnings if Last Round**	**Type I: Payment this Round**	**Type II Payment if Last Round**	**TOTAL Earnings if Last Round**	**Number of Green Marbles in Bag**	**Number of Marbles in Bag**	**Chance of Continuing to Next Round**
1	$1.75	$0.00	$1.75	$2.25	$3.15	$5.40	14	15	14/15
2	$1.75	$0.00	$3.50	$2.10	$2.75	$7.10	13	14	13/14
3	$1.75	$0.00	$5.25	$1.95	$2.35	$8.65	12	13	12/13
4	$1.75	$0.00	$7.00	$1.80	$2.00	$10.10	11	12	11/12
5	$1.75	$0.00	$8.75	$1.65	$1.65	$11.40	10	11	10/11
6	$1.75	$0.00	$10.50	$1.50	$1.35	$12.60	9	10	9/10
7	$1.75	$0.00	$12.25	$1.35	$1.10	$13.70	8	9	8/9
8	$1.75	$0.00	$14.00	$1.20	$0.85	$14.65	7	8	7/8
9	$1.75	$0.00	$15.75	$1.05	$0.65	$15.50	6	7	6/7
10	$1.75	$0.00	$17.50	$0.90	$0.45	$16.20	5	6	5/6
11	$1.75	$0.00	$19.25	$0.75	$0.30	$16.80	4	5	4/5
12	$1.75	$0.00	$21.00	$0.60	$0.20	$17.30	3	4	3/4
13	$1.75	$0.00	$22.75	$0.45	$0.10	$17.65	2	3	2/3
14	$1.75	$0.00	$24.50	$0.30	$0.05	$17.90	1	2	1/2
15	$1.75	$0.00	$26.25	$0.15	$0.00	$18.00	0	1	0

(b) Sequential I Table: Payouts B

Table 5: Examples of No Explicit Endowment Payout Tables. We depict Payouts A in the top table, and Payouts B in the bottom table. Tables for Sequential II follow the same format as Sequential I, but with final column of Simultaneous table added.