Writing Sample

# Don't Stop Now: The Sunk Cost Effect in an Incentivized Lab Experiment

**Collin Weigel**

**Abstract** Though widely accepted in psychology, the Sunk Cost Effect (SCE) finds little support from recent evidence in economics. The SCE is when individuals continue along an unprofitable course because of resources expended. The present study employs an abstract laboratory setting with a simple optimal decision rule and repeated decisions to estimate the SCE. The unique design, modeled after penny auctions, allows subjects to endogenously accumulate sunk costs, which psychologists claim is an important component. I find evidence that sunk costs increase one's willingness to continue along an unprofitable course of action by 21.9%. Subjects do not learn to ignore sunk costs. Reference-based theories provide an alternative mechanism for SCE behavior. Though I find evidence against Realization Utility, reference points explain observed behavior better than sunk costs do. This draws into question whether there is a need for a separate SCE or if the Effect is only a special case of Prospect Theory. Proposed potential mediators are responsibility for sunk costs, gain/loss domain of the choice, profitability of the action, and time between sinking costs and taking action.

JEL Classification: C91, D11

**Keywords** Sunk costs · Sunk Cost Effect · Experiment · Prospect Theory · Realization Utility

This material is based upon work supported by the National Science Foundation under Grant No. 1326235.

C. Weigel
Environmental Health and Engineering, Johns Hopkins University, Baltimore 21218, USA
Tel.: 503-936-4440
E-mail: collinw@jhu.edu
ORCID: 0000-0003-3090-4484

## 1 Introduction

Psychologists have studied human behavior that deviates from a rational model of decision-making far longer than economists have. Attempting to bridge the gap between economics and psychology, behavioral economists have branched out from the safety of standard models in favor of ones that better fit the data, such as Prospect Theory (Kahneman and Tversky 1979). The Sunk Cost Effect (SCE), also called the Sunk Cost Fallacy, has been widely accepted by psychologists but has found little support when tested by economists. The SCE is the tendency to continue on an unprofitable course of action due to the costs sunk to undertake the action. Sunk costs are costs that have been paid and cannot be recovered, and therefore should have no impact on future decisions. The present experiment is a test for the SCE using the unambiguous and monetarily incentivized methodology of experimental economics with the psychological drivers required by psychology.

Penny auctions have made headlines because of their alluring format in which the winner pays only a fraction of the auction item's value. Penny auctions are less like traditional auctions and more like a War of Attrition. Small, standardized "bids" are paid until no participant is willing to place another bid, causing the auction to end. All losers have to abandon their sunk costs and leave the auction with nothing. The environment is ideal for the SCE, and the high profit by penny auction companies is evidence that suboptimal bidding is taking place. Auction data have been investigated by Augenblick (2016) who finds the SCE among inexperienced bidders. Problems with using real-world data include potential confounds, such as selection and reputation, strong assumptions on strategies and beliefs in complex and dynamic games, and limited ability to observe actions. Penny auctions in particular do not have data on how a bidder would have acted had another player not bid, making it ambiguous when a player drops out of the auction.

The present experiment is modeled after penny auctions but simplifies the game by eliminating other players. The subject can bid, paying a small amount for a chance to win a prize, or quit. If she does not win, that payment is sunk and she has the option to bid again, though possibly for a different cost. She repeats this process until she either wins the prize or quits, giving up all she has sunk. Her marginal incentives depend only on the cost of the bid and her chance of winning. The optimal strategy is a simple stopping rule: she should quit whenever the cost to bid is above a particular amount. At multiple points in the experiment she will face the same marginal incentives but with different sunk costs. This design allows for a within-subject test of the SCE. A novel attribute of the experimental design, within economics experiments, is that the subject is responsible for her sunk costs.

I find evidence of the SCE and test two prominent theories that may explain it. I compare Prospect Theory and Realization Utility (Barberis and Xiong 2012), finding the strongest evidence in favor of the former. Further, I find that reference points explain behavior better than sunk costs do and that additionally accounting for sunk costs does not notably improve model fit.

While the data support the existence of the SCE, they also suggest that there is no need for a SCE theory beyond what already exists in Prospect Theory.

The paper is organized as follows. In the next section I present the related literature and show where it fails to meet both the standards of economics and psychology. In Section 3 I discuss the relevant theories that go beyond the standard rational model to predict the SCE. In Section 4 I discuss the design of this experiment in detail and the hypotheses to be tested. In Section 5 I present the results and discuss the implications in Section 6. The final Section concludes and offers a perspective on future research. Appendices include a proof and visualizations as well as instructions for the subjects.

## 2 Related Literature

There are many studies in psychology that demonstrate the SCE (Staw 1976; Fox and Staw 1979; Arkes and Blumer 1985; Arkes 1996; Arkes and Ayton 1999; Arkes and Hutzel 2000; Soman and Cheema 2001; Soman 2001; Soman and Gourville 2001; Strough et al. 2008; Molden and Hui 2011; Liang et al. 2014, and many others). The vast number and breadth of situations that involve sunk costs make it important to understand if those costs systematically bias decisions. Leveraging sunk costs may increase product usage or program participation; however, there has been little documented success of doing so. Studies to date tend to fall short of standards in economics or in psychology, or have potential confounds. This experiment aims to use methods that are acceptable in both fields with a laboratory setting to eliminate potential confounds.

Friedman et al. (2007) describe the flaws in anecdotal data and psychology studies from the view of economists. Many real-world anecdotes, such as politicians allocating money or troops, can be explained by reputation concerns. Mcafee et al. (2010) point out that budget constraints are affected by sunk costs and could influence the feasibility of future choices. Psychology experiments are usually unincentivized and ask the subject to imagine a scenario such as owning two mutually exclusive tickets to a ski resort for the weekend which cost different amounts to obtain and cannot be refunded or transferred. Subjects are told to imagine that they prefer the less costly trip, and then asked to decide which trip they would choose to go on. Economists may take issue with three points on this experiment. As Friedman et al. (2007) note, the subjects may use their own preferences rather than the preferences given to them by the experimenters. The replacement cost of the less costly ticket is lower. If the subject wanted to go to both resorts, it is better to only have to repurchase the less costly ticket even if it means going on the less-preferred vacation first. The way the question was asked categorizes answers as supporting the standard model or displaying the SCE, meaning that a group of subjects responding randomly would display the SCE half the time, roughly the rate it is found in Arkes and Blumer (1985).

A recent attempt to replicate findings from a study using hypotheticals failed to find the SCE (Otto 2010). However, not every study from psychology is purely hypothetical. Arkes and Blumer (1985) use real incentives in one experiment by randomly giving discounts to students buying season tickets to the theater. They have a small sample, with an average of 18 subjects in each treatment. The authors find the SCE, but only for the first half of the season; this is interpreted as the SCE diminishing over time.

Studies by economists are also subject to criticism for failing to include the necessary psychological drivers, confusing subjects, or using real-world data for which is it impossible to fully disentangle the confounds of selection, reputation, and subjective beliefs. Economists have looked for the SCE empirically. Camerer and Weber (1999) and Staw and Hoang (1995) find the SCE in NBA minutes played, though it is difficult to isolate the SCE because of unknown private beliefs and reputation concerns. Other studies on cars (Ho et al. 2017) and houses (Genesove and Mayer 2001) may similarly suffer from confounds of the real world. Ashraf et al. (2010), Berry et al. (2015), and Cohen et al. (2015) conduct field experiments in Africa to determine if paying for health products increases their use. They avoid selection problems by offering the products using a Becker-DeGroot-Marschak mechanism (i.e. generating random prices) but do not find evidence of the SCE. Field experiments are the ideal setting to test the SCE in action, but are less practical for identifying mediators. The random price mechanism may be insufficient to induce responsibility for the costs sunk. Responsibility may be necessary for the SCE (Staw 1976). A lab setting allows for control over many factors that exist in the real world and complicate the interpretation of the SCE (Mcafee et al. 2010).

Friedman et al. (2007) use a computerized game that randomly generates the sunk cost. The authors detect only a very small SCE in one of several treatments, and a stronger reverse SCE in other treatments. Inducing the SCE in the lab may require a different approach from standard experiments. If Staw (1976) is correct, sunk costs must arise endogenously, making subjects responsible for their sunk costs. Subjects must commit their funds by choice, meaning that the "treatment" of sunk costs cannot be exogenously assigned. Brockner (1992) likewise claims that self-justification plays a significant role in the SCE. The role of responsibility has been drawn into question by Schulz-Hardt et al. (2009) due to confounding designs in earlier work, and Schoorman and Holahan (1996) suggest responsibility increases the SCE but is not critical. Haita-Falah (2017) runs a lab experiment where the optimal strategy is to sell at a loss. Some subjects did not invest even though it was optimal and therefore could not participate in the remainder of the experiment, the subjects may not have understood the task.

A field experiment by Just and Wansink (2011) explores the other side of sunk costs: a reduced sunk cost may reduce commitment to a course of action. They find that people who get a 50% discount for all-you-can-eat pizza end up eating 27.9% less than those who paid full price. The authors control for party size, but it is not possible to identify income effects that may result from mental accounting for a "lunch budget." With 66 subjects, the study may be

underpowered for many economically significant effect sizes, such as a 20% difference. The present study has a similar sample size but employs a within-subject design-which, tends to have 4–8 times the power of between-subject designs (Bellemare et al. 2014).

Augenblick (2016) utilizes a large dataset of penny auctions. In a penny auction each bid is a fixed payment, not necessarily a penny, which is immediately sunk. Only one participant wins the auction, and all others lose what they sunk. The auction has a time limit that is extended every time a bid is made, making it impossible to bid at the last second to win. Augenblick finds a SCE for less experienced bidders; participants slowly learn to overcome the bias. Herrmann et al. (2015) likewise evaluate penny auctions and suggest that the likelihood of an irrational action increases with the amount of sunk costs. A limitation of penny auction data is that bidding strategies are complicated and simultaneity of bidding makes it impossible to know how one would have acted had other bidders not bid.

## 3 Theory

Psychologists and economists alike have proposed models to explain the SCE. I focus on the reference dependence models because they provide competing predictions. I also mention two others that have received notoriety recently but these are left to future research as they cannot be tested with this design.

Just and Wansink (2011) use the transaction utility (Thaler 1980) framework that assigns utility to getting a good deal. In the all-you-can-eat pizza context, one can pay a lower average price by eating more pizza. Applied to the penny auction environment, one is clearly getting a bad deal if they have paid money and get nothing in return. The transaction utility framework is a potential mechanism for the SCE but it does not provide a testable prediction apart from the existence of the SCE. Eyster (2002) proposes a model of regret, following regret framework from Loomes and Sugden (1982) and Sugden (1993), wherein missed opportunities and unsuccessful investments are detriments to current utility. This study uses a design that gives subjects responsibility for their sunk costs, but does not vary responsibility and therefore cannot test its necessity.

Alternatively, the SCE could be explained by reference point theories. Thaler (1980) and Arkes and Blumer (1985) propose Prospect Theory (Kahneman and Tversky 1979) as an explanation for the SCE. Fiegenbaum and Thomas (1988) note that firms show greater risk-seeking behavior when below a reference point. Tversky and Kahneman (1981) cite situations, such as betting on long shots at the end of a race, where risk tolerance appears to increase as sunk costs grow. Mental Accounting (Thaler 1985) would exacerbate the SCE because it allows small changes to be of meaningful magnitude within a particular account. Prospect Theory is characterized by concave utility in gains and steeper, convex utility in losses. Tversky and Kahneman (1992) use a power function to represent utility, giving subjects decreasing absolute risk

aversion. As sunk costs rise, a subject becomes less wealthy, increasing her risk aversion until she reaches the point of inflection at the reference point. Then as the subject becomes less wealthy she will be progressively more risk-seeking.

For example, a myopic subject in this experiment could be in a gain position of 600 and consider bidding if the cost is 75 for a 10% chance to win 750. Using the power function from Tversky and Kahneman (1992), we have:

$$U(quit) = 600^{.88} = 278.47$$
$$U(bid) = 525^{.88} * .9 + 1050^{.88} * .1 = 276.47$$

It is optimal for her to quit. If instead she is in a loss position of -800,

$$U(quit) = -(800)^{.88} = -358.69$$
$$U(bid) = -(875)^{.88} * .9 - (125)^{.88} * .1 = -356.31$$

In this case, starting in the loss[1] domain rather than the gain domain makes it optimal for her to bid instead of quit.

Realization Utility (Barberis and Xiong 2012) works in tandem with Prospect Theory by claiming that people feel the loss/gain when it is realized, i.e. when the stocks are actually sold at a loss rather than when their price drops. An agent may take risky gambles that give her some chance of avoiding a realized loss, even if she would not take those gambles when in a gain positions. Realization Utility does not apply when a subject is in a position such that she cannot possibly realize a gain. There is no reason to take on additional risk if she cannot avoid a loss. This is in contrast to Prospect Theory which predicts that the SCE will get stronger as a subject moves deeper into loss territory. Both theories may influence decisions. I test which prediction better represents the data.

## 4 Experiment Design

The design for this experiment is rooted in penny auctions. A penny auction is a nearly ideal environment for the SCE because every bid is sunk leaving the bidder with the option to quit and forgo what she has poured into the auction thus far or pay a small amount to have a hope of gaining something to offset her investments. This experiment removes other players, reducing the complexity of optimal bidding, making it clearer to infer suboptimal behavior.

[1] The exponent of .88 in the power function comes from Tversky and Kahneman (1992). Though they use a scaler, $\lambda$, for loss values, it is omitted here for clarity without affecting the interpretation.

While penny auctions have continuous bidding, the auction in this experiment is discretized into periods. In each period the subject can bid, which gives her a chance to win the 750-point prize, or she can quit, which ends the auction. A lottery replaces competition among subjects, the prize is won at after each bid with known probability. Instead of one fixed bid amount, each period has a cost to continue, called "bid" in the experiment, which is drawn from a known distribution. The cost to continue is paired with a probability of winning the prize in that period if she continues. The combinations are given in Table 1. The auction ends when the subject either wins the prize or quits. The subject starts each auction with an endowment, which varies across subjects but not within subject. The subject is not limited by her endowment; that is, she can keep bidding even when she has used her entire endowment. The endowment is used to shift her position from the reference point.

| Type | Cost | Probability of Winning |
|---|---|---|
| 1 | 50 | 10% |
| 2 | 50 | 30% |
| 3 | 100 | 10% |
| 4 | 300 | 10% |

Table 1: Possible Types of draws.

The auction in this experiment is an optimal stopping problem, independent of the endowment or sunk costs. All periods are independent and there is an unlimited number of periods, therefore marginal incentives are equal for any two periods with the same draw Type. A risk-neutral, profit-maximizing agent will continue for all Types except Type 4 (proof shown in Appendix A). Each round is an auction. The experiment is made up of 20 independent rounds[2]. To avoid income effects, one round is randomly chosen at the end of the experiment for payment.

As an example, a subject in the high endowment treatment will start the round with an endowment of 600. In the first period, shown in Figure 1, she can pay the stated amount or quit. If she pays and wins, the round is over and her earnings for that round are 600+750-50=1,300. If she does not win, she moves to the next period and faces another decision to either quit with her remaining 550 or pay the new cost for another chance to win. Subjects are not limited by their endowment—she can continue even if she has spent more than she started with. Subjects took a quiz to ensure they understood they could continue regardless of their remaining endowment, potentially incurring a loss in that round.

[2] The first 19 subjects were given 12 rounds and the other 44 subjects were given 20 rounds. Subjects were able to complete the task more quickly than those in the pilot study so I extended the number of rounds. Results are robust to dropping subjects who only had 12 rounds.

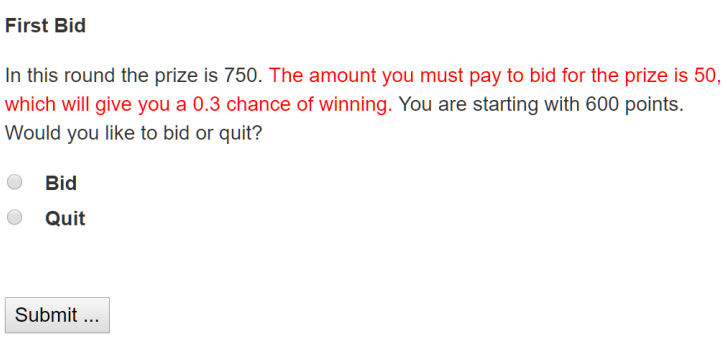


Fig. 1: The first period.

If in the first period she chooses to continue but does not win, she faces another choice in period 2, shown in Figure 2. She is explicitly reminded of how much she has spent so far in this round. Every time she continues and does not win, she is presented with another chance to continue or quit.

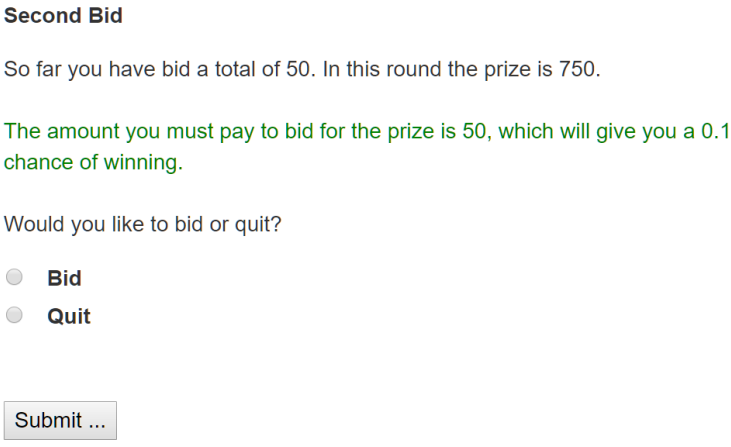


Fig. 2: The second period.

This subject would see Figure 3 when she has already paid 1,150 points in this round. She has used up all of her endowment, but this does not prevent her from continuing. She is faced with the same incentives as her first decision: pay 50 for a 30% chance of winning. Her sunk costs, however, are substantially different.

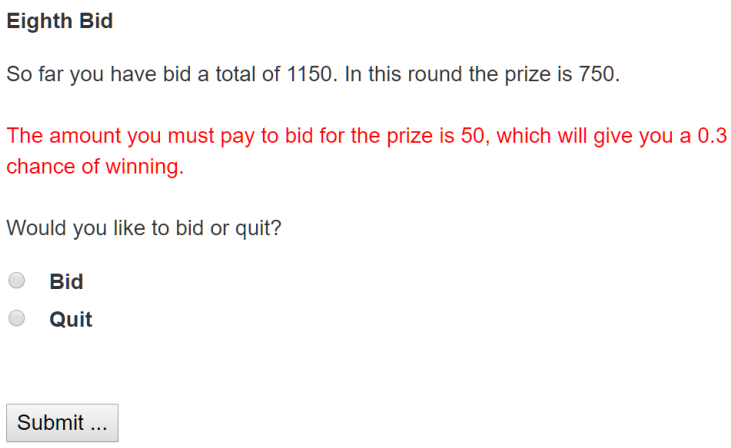


Fig. 3: The eighth period.

Despite taking place in a lab, the experiment is an observational study insofar as sunk costs cannot be exogenously assigned (Staw 1976; Brockner 1992). Outcomes can be perfectly measured, and reputation effects are eliminated due to assured privacy. The lab also allows for repeated observations of the same subject, which are used by the fixed effects model to eliminate time-invariant characteristics such as an aggressive subject's tendency to continue. Controlling for these factors, this experiment tests for whether the SCE is present, whether reference-dependence theories sufficiently explain behavior, and whether subjects learn to ignore sunk costs with repetition.

This experiment was conducted at the University of Arizona using students enrolled in economics courses. A total 63 students participated and took one hour[3]. Average earnings were $20 for all experiments combined. Subjects earned points in the experiment which were converted to cents for payment. The study was conducted using partitioned computer terminals running SoPHIE - Software Platform for Human Interaction Experiments, created by Hendricks (2012).

Reference points may be an alternative explanation of the SCE. This experiment uses framing to create varied reference points across subjects. Each subject is randomly assigned an endowment treatment. The endowment is how much they start each round with, but the endowment should not affect the stopping rule. The level of endowment at the start of each round is either high (600), low (400), or none (0). Subjects have the same endowment

[3] Two experiments took place after this one: a test of the importance of responsibility for the sunk cost and a replication of Haita-Falah (2017). The responsibility design resulted in too little data to analyze. While the replication of Haita-Falah (2017) included lengthy instructions and examples, numerous subjects stated that they did not understand the game. Those experiments took place after this one and could not affect behavior in this experiment. The other experiments helped to ensure no subject had negative earnings.

treatment for all rounds. The endowment is purely framing; in the introduction to the experiment subjects who receive lower endowments at the start of each round are told they will receive an additional fixed payment at the end of the experiment. The additional payment equates the expected payoff across all treatments, but subjects are unaware of differences in endowments. All language in the experiment is tailored to the subject's treatment. Subjects participated in two additional experiments following this one. The other payments and choice of parameters made it very unlikely that a subject would end with debt to the experimenter.

All hypotheses are for the Type 4 draw only, since for any other draw it is already optimal for most subjects to continue, and therefore the SCE is redundant. The hypotheses to be tested are:
**H1: The Sunk Cost Effect** - Subjects are more likely to continue when their sunk costs are greater. To test this, the null is the standard rational model: there is no SCE. To reject, the likelihood of continuing must be significantly correlated with greater sunk costs.
**H2: Reference Dependence** - The SCE is the result of preferences that are reference dependent. For Realization Utility, this would result in a desire to realize a gain, rather than maximize total earnings. For Prospect Theory, preferences should show diminished sensitivity to losses. Both result in risk-seeking behavior in loss territory. The null is that reference dependence does not explain the SCE, and that position, gain or loss, does not provide additional predictive power when sunk costs are accounted for explicitly. To differentiate between Prospect Theory and Realization Utility, Realization Utility will be rejected if the likelihood to continue does not decrease after the point of no recovery.
**H3: Learning** - The SCE exists in early rounds but not later rounds. The null is that there is no difference between early and late rounds.

## 5 Results

### 5.1 General Results

Other laboratory experiments are missing incentives, have design flaws, or only interpret error as evidence of the SCE. The highest quality lab experiment (Friedman et al. 2007) finds essentially no SCE, but subjects are not responsible for their acquisition of sunk costs. The present experiment uses a within-subject design to test for the SCE in a clear and incentivized setting with responsibility for sunk costs. For a risk-neutral, profit-maximizing rational agent, it is optimal to quit when facing a Type 4 draw. The analysis will focus on the Type 4 decisions because the SCE has no bite when one should already continue. Ten subjects never continue for a Type 4 draw. Four subjects always continue for a Type 4 draw, but their behavior is not consistent with a cutoff rule because they quit at other times.

Continuation rates, coded as 1 for continue and 0 for quit, for Types 1, 2, 3, and 4 were 87%, 94%, 75%, and 55%, respectively. For the remainder, I focus on Type 4 because it is the Type of interest for sunk costs. The other Types exist to give subjects an incentive to sink costs[4]. Figure B1 plots the average individual continuation rate at each level of sunk costs. To avoid over-weighting the individuals who continue very often, I calculate the average continuation rate for each subject at each level of sunk costs for a Type 4 draw. I then average the individual averages at each level of sunk costs. The figure shows that subjects generally continue at a much higher rate when their sunk costs are greater. While high sunk costs are correlated with a greater continuation rate, without fixed effects for individuals a regression does not account for highly aggressive subjects being generally more likely to continue and more likely to have high sunk costs. The correlation comes about because sunk costs are endogenous, they cannot be randomly assigned because subjects must feel responsible for their sunk costs. Appendix B contains additional figures of continuation rates.

### 5.2 The Sunk Cost Effect

I analyze the data using a logistic regression with fixed effects. This regression is robust to the endogenous acquisition of sunk costs, which would violate the random effects specification. Continuing, or bidding, is coded as 1 and quitting is coded as 0. Each regression uses fixed effects for individuals with clustered standard errors at the individual level, as well as controls for periods, rounds, Types, and attrition.

I include indicators for the period in which the decision was made. Including the period absorbs the average effect of the Gambler's Fallacy, fatigue, learning, or desire to participate across subjects. As an example, the Gambler's Fallacy is a potential confound of the SCE because if a subject incorrectly believes that she is more likely to win when she has failed to win several times, the fact that she is in a later period could change her perceived marginal incentives relative to earlier periods and would be correlated with sunk costs. Few subjects continued for more than 10 periods in a round, making the data too sparse to estimate. I make the data coarser by grouping together periods 11–15 and 16+ into their own indicators and achieve convergence. Each period up to 10 has its own indicator.

The control for attrition is a series of indicators for the number of times, within that round and before the present decision, the subject has faced a Type 4 draw. Simulation shows that failing to include an indicator for attrition leads to downward biased estimates. The idea is that one can only choose to quit once in a round, which will be the time when their sunk costs are greatest, resulting in a negative correlation between sunk costs and the likelihood of continuing. Simulation also finds that using attrition indicators for the other

[4] Type 3 exists both because it has a positive expected value and to avoid collinearity between the period and sunk costs.

Types worsens estimates, inflating variation of the estimate, and therefore are not included in the preferred specification. Like in later periods, few subjects reach six or seven Type 4 decisions in a round. I truncate the attrition variable at 5. Individual fixed effects are used to control for the likelihood of continuing that is constant within an individual, such as risk preferences. Indicators are used to control for the draw Type.

Using logit with fixed effects and the above controls, Table 2 shows a significant increase in the likelihood to continue when sunk costs are larger for a Type 4 draw. The table displays odds ratios with t-statistics below. The interpretation for the coefficient is that the effect of 100 in additional sunk costs is a 21.9% increase in the likelihood of continuing. For a Type 4 decision, the average and median sunk costs were 247 and 100, respectively, and subjects chose to continue 55% of the time. Table B1 displays the analogous regression for the other Types, which show either no effect or a Reverse SCE. This is consistent with concave utility, which has been found before (Friedman et al. 2007; Zeelenberg and van Dijk 1997). The second regression includes an indicator for having won in the last round, for which the estimate is noisy but large. Even with the indicator for having won, the SCE is similar.

Table 2: Main SCE

| | FE | FE with Won Last |
|---|---|---|
| Continue | | |
| Sunk x Type 4 | 1.219*** | 1.186*** |
| | (5.51) | (4.50) |
| Won Last Round x Type 4 | | 1.678* |
| | | (2.09) |
| Observations | 3329 | 3329 |

Exponentiated coefficients; $t$ statistics in parentheses
Type, period, round, and attrition controls included. 63 groups.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

## 5.3 Reference Dependence

Even if subjects are more likely to continue when they have sunk costs, there are broader theories that predict similar behavior. Reference-dependent preferences can similarly cause one to be more likely to continue the further along they are. If subjects become more risk-loving as they move further into loss territory, as in Prospect Theory, or attempt to realize gains at the expense of maximizing expected returns, as in Realization Utility, this behavior would be similar to the SCE. To determine if reference points are an explanation of the SCE, the experiment uses three endowment treatments. If subjects take zero as the reference point then the three groups will start with different levels of gain relative to their reference points. Subjects may instead consider their

endowment to be their reference point, which would lose variation in reference points since every subject would start at the origin. Endowments are constructed with framing. Subjects in lower endowment treatments are informed that they will receive an additional fixed amount at the end of the experiment, which keeps expected earnings by treatment constant.

If subjects do not take the zero as the reference point, either because they see through the framing or take their endowment as their reference point, all starting positions are the same relative to reference points. I test for variation in starting position by checking for differences in behavior by endowment type, which further requires that subjects use the reference point in decision-making. I compare the average rate at which a subject chooses to continue when they reach a Type 4 draw. The continuation rate is computed for each individual, and those rates are averaged by endowment treatment. Table 3 reports the continuation rate by endowment group, using only the first Type 4 draw within a round as well as the average for all periods. Using a Wilcoxon-Mann-Whitney rank-sum test, I find that the group with no endowment is significantly different from the two groups who receive an endowment, though the two groups with endowment are not distinguishable (p=.62 and .66). $p$ values relative to the respective zero-endowment group are given below the continuation rates in Table 3. This is evidence that subjects are affected by framing, taking 0 as the reference point and their endowment as a move into gain territory. The pattern of lower continuation rates for those with higher endowments is consistent with both the curvature of Prospect Theory and gain-seeking of Realization Utility.

| Endowment | First Type 4 Draw | All Periods |
|---|---|---|
| High | 35% | 38% |
| (600) | (0.002) | (0.004) |
| Low | 39% | 42% |
| (400) | (0.063) | (0.004) |
| None (0) | 65% | 74% |

Table 3: Continuation Rate by Endowment Group. $p$ values relative to the no-endowment group in parentheses.

Reference points are known to affect decisions in many contexts and are not a new contribution of this research. Instead, I determine if the amount of sunk costs is informative once the reference point is accounted for. Both Prospect Theory and Realization Utility only predict the SCE in loss territory. To test the several predictions of Reference Dependent theories, I run regressions to determine: 1) if the position relative to the reference point is as useful as sunk cost information; 2) if domain accounts for SCE behavior; 3) if continuation rates significantly drop when the subject is beyond recovery; and 4) if the SCE exists in the gain domain.

The first regression in Table 4 is the FE specification from Table 2. The second regression shows that the endowment remaining (i.e. endowment minus sunk costs) is a significantly better predictor of behavior according to the BIC (Raftery 1995). The odds ratio shows that subjects are 19.3% less likely to continue for each additional 100 points they have remaining, which is very similar to the estimate of the SCE. The third regression shows that sunk cost information adds little once the amount remaining is accounted for.

Table 4: Reference Points: Amount Remaining

| | Sunk Costs | Amount Remaining | Combined |
|---|---|---|---|
| Continue | | | |
| Sunk x Type 4 | 1.219*** | | 0.952 |
| | (5.51) | | (-0.78) |
| Endowment Remaining | | | |
| x Type 4 | | 0.807*** | 0.781*** |
| | | (-7.10) | (-4.78) |
| Observations | 3329 | 3329 | 3329 |
| *BIC* | 2617.0 | 2594.3 | 2601.8 |

Exponentiated coefficients; $t$ statistics in parentheses
Type, period, round, and attrition controls included. 63 groups.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 5 adds interactions with the domain in which the subject is making the decision. The first regression adds an interaction with loss domain to the main specification, resulting in a smaller but still significant estimate of the SCE. The second regression adds another interaction for being beyond recovery; that is, if the subject has spent her endowment and at least 750, she would not realize a gain even if she won. Realization Utility does not apply when subjects cannot possibly realize a gain. Subjects are not more likely to quit when they cannot realize a gain. The data for beyond recovery are sparse given that only 13 subjects reached that point. Since I am distinguishing the relative quality of theories to explain the SCE, these may be the most suitable individuals because they exemplify the SCE. Figure B4 shows continuation rates for only the subjects who reach the point of no recovery.

Table 5: Reference Points: Domain

| | Loss Domain | Loss and Unrecoverable Domains | Gain Only |
|---|---|---|---|
| Continue | | | |
| Sunk x Type 4 | 1.126** | 1.061 | |
| | (2.85) | (1.17) | |
| In Loss Domain | | | |
| x Type 4 | 2.759*** | 3.000*** | |
| | (3.45) | (3.70) | |
| In Unrecoverable Domain | | | |
| x Type 4 | | 6.433 | |
| | | (1.90) | |
| Sunk x Type 4 x Gain Domain | | | 0.960 |
| | | | (-0.61) |
| Observations | 3329 | 3329 | 3329 |

Exponentiated coefficients; $t$ statistics in parentheses
Type, period, round, and attrition controls included. 63 groups.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Prospect Theory claims a concave utility function in the gain territory and convex utility function in loss territory. Absolute risk aversion decreases as the subject gains wealth in the gain domain. This implies that risk aversion will increase with sunk costs (i.e. as wealth diminishes) in the gain domain and risk aversion will decrease in the loss domain as the subject goes further into debt, resulting in the reverse SCE and the SCE, respectively. The final regression estimates the SCE for the gain domain and finds there is no effect from sunk costs. If the regression is restricted to the groups with positive endowment the result is similar with an odds ratio of 1.05 and $p$ value of .49.

## 5.4 Learning

Phillips et al. (1991) find that when subjects played several rounds their behavior fell in line with standard theory, as opposed to in a one-shot situation. To identify whether subjects learned to avoid the SCE in this experiment I compare estimates for early and late rounds. The rounds are identical in expectation; there should be no income effect because only one round is paid. Table 6 shows a regression in which early (1–10) and late (11–20) rounds have separate estimates of SCE coefficient. Because the first 19 subjects were only given 12 rounds, the second regression splits the sample into first and second halves. The second half starts at either 7 or 11 depending on the number of total rounds. The first specification, split after the tenth round, is preferred because it captures the idea that subjects learned for 10 rounds; the second regression is added to show the results are similar. If anything, the SCE is larger in later rounds, indicating that subjects do not learn to avoid the SCE.

Table 6: Learning

| | Early vs. Late | First vs. Second Half |
|---|---|---|
| Continue | | |
| Sunk x Type 4, Round $\leq 10$ | 1.200*** | |
| | (4.54) | |
| Sunk x Type 4, Round $> 10$ | 1.253*** | |
| | (4.60) | |
| Sunk x Type 4, First Half | | 1.210*** |
| | | (4.63) |
| Sunk x Type 4, Second Half | | 1.233*** |
| | | (4.48) |
| Observations | 3329 | 3329 |

Exponentiated coefficients; $t$ statistics in parentheses
Type, period, and attrition controls included. 63 groups.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

## 6 Discussion

### 6.1 H1: The Sunk Cost Effect

The primary hypothesis of this research tests for a Sunk Cost Effect—that subjects are more likely to continue an unprofitable endeavor when they have devoted greater costs to it. Table 2 shows we can reject the null that there is no SCE. Subjects are 21.9% more likely to continue for a change in sunk costs equal to the median.

The magnitude of the SCE found in this paper is large compared to most previous findings in economics but similar to the findings in psychology and Just and Wansink (2011). Two significant differences between this study and most economic field experiments are the length of time between the sunk cost and the decision and the responsibility for the amount of sunk costs. This study, as well as penny auctions, demands immediate action following a sunk cost, whereas using a water treatment product could be significantly delayed. A literature review by Roth et al. (2015), which includes hypothetical questions, suggests that the SCE diminishes over time. Field experiments generate random prices conditional on willingness to pay in order to control for selection. If responsibility for the sunk costs is a necessary component of the SCE, which would be a feature of any real purchase, field experiments need a different method to vary sunk costs.

### 6.2 H2: Reference Dependence

Realization Utility and Prospect Theory may explain SCE behavior without the need for a separate SCE. Differences in reference points in this experiment arise through framing. The effectiveness of framing is shown by the difference in behavior between those with no endowment and those with some endowment in

Table 3, implying that subjects also use reference points in decision-making. Table 4 shows that the amount of endowment remaining predicts behavior better than sunk costs. The fact that subjects behave differently with different endowments and that the endowment remaining has predictive success are evidence in favor of reference point theories.

Table 5 shows that accounting for loss and gain domain does not fully capture the SCE. The second regression favors Prospect Theory over Realization Utility because subjects are not more likely to quit when they can not realize a gain; they may be more likely to continue. While Prospect Theory predicts a reverse SCE in gain territory, the third regression of Table 5 does not find the SCE in gain territory. This study is underpowered for detecting the SCE in gain territory alone. There is strong evidence that reference points affect decisions in this setting. The evidence supports Prospect Theory but does not show a need for a separate theory to explain the SCE. Once position is accounted for, model fit is not notably improved by incorporating sunk costs.

### 6.3 H3: Learning

Table 6 shows that there is not a significant reduction in the estimate of the SCE as subjects gain experience, indicating that even after several rounds they do not learn to avoid the SCE. This may, however, be due to the limited number of repetitions relative to the potential hundreds in a setting such as penny auctions.

### 6.4 An Unprofitable Course

The field experiments in Africa (Ashraf et al. 2010; Berry et al. 2015; Cohen et al. 2015) test for increased usage of a product they believe to be of benefit to the user; the course of action is already profitable. Psychology expresses the SCE as applying to an unprofitable course of action (Arkes and Blumer 1985), so the SCE may not exist when there is already a profit motive. It was profitable to continue for three Types in this study, which only existed to give subjects an incentive to sink costs. There may be a significant reverse SCE for decisions that are already profit maximizing, shown in Table B1, consistent with concave utility. When all Types, profit maximizing and suboptimal, are pooled there is a significant reverse SCE.

## 7 Conclusion

This paper presents new laboratory evidence in favor of the existence of the Sunk Cost Effect. It is among the few studies to use real incentives and an unambiguous setting where subjects are responsible for their sunk costs. It uses a within-subject design to detect the SCE. Three hypotheses were tested: existence of the SCE, reference-dependent theories, and learning. There is

evidence in favor of the SCE, and its magnitude is economically meaningful. I estimate a 21.9% increase in the likelihood of continuing an unprofitable action at the median level of sunk costs relative to no sunk costs. Subjects do not appear to learn to avoid the SCE after several rounds of experience.

Prospect Theory and Realization Utility are both potential explanations of the SCE that are reference-dependent. They both predict increased risk-seeking behavior when in loss territory, which is correlated with sunk costs. I find that accounting for the loss/gain domain reduces the estimated SCE; however, the SCE is still significant. The amount of endowment remaining predicts behavior better than sunk costs, although variation in reference points has a less powerful between subjects design. I find that subjects do not quit more frequently when they are beyond recovery, as predicted by Realization Utility. I do not find evidence of the SCE in gain territory, though the study is underpowered for this test. A future study should incorporate within-subject variation in reference points to determine if the evidence supports the SCE or Prospect Theory in gain territory. If the SCE does not exist in gain territory then the SCE encompassed within Prospect Theory.

While this study finds evidence of the SCE, it leaves open questions as to why the SCE is present here and not in other incentivized studies. Potential mediators for the SCE are time between the sunk cost and the action, gain/loss domain, profitability of the course of action, and responsibility for the sunk cost. This study and Just and Wansink (2011) measure behavior immediately after costs are sunk, whereas the field experiments to date have a considerable delay. Psychologists apply the SCE to cases where it is unprofitable to continue. I found that when it is profitable, subjects display the reverse SCE. This study includes responsibility for the sunk costs, which is rare in economics studies because that means the treatment cannot be randomly assigned. If responsibility is required for the SCE, field studies must find a different and endogenous way to generate sunk costs. It is unclear if randomized discounts leave subjects sufficiently responsible for the amount they pay.

**Acknowledgements** Thank you to Martin Dufwenberg, Paul Ferraro, Charles Noussair, Stan Reynolds, and members of the ESA for guidance and suggestions.

## References

Arkes, H. R. (1996). The Psychology of Waste. *Journal of Behavioral Decision Making 9*(3), 213–224.

Arkes, H. R. and P. Ayton (1999). The sunk cost and Concorde effects: Are humans less rational than lower animals? *Psychological Bulletin 125*(5), 591–600.

Arkes, H. R. and C. Blumer (1985). The Psychology of Sunk Cost. *Organizational Behavior and Human Decision Processes 35*(1), 124–140.

Arkes, H. R. and L. Hutzel (2000). The role of probability of success estimates in the sunk cost effect. *Journal of Behavioral Decision Making 13*(3), 295–306.

Ashraf, N., J. Berry, and J. M. Shapiro (2010). Can Higher Prices Stimulate Product Use? Evidence from a Field Experiment in Zambia. *American Economic Review 100*(5), 2383–2413.

Augenblick, N. (2016). The Sunk-Cost Fallacy in Penny Auctions. *Review of Economic Studies 83*(1), 58–86.

Barberis, N. and W. Xiong (2012). Realization utility. *Journal of Financial Economics 104*(2), 251–271.

Bellemare, C., L. Bissonnette, and S. Kröger (2014). Statistical Power of Within and Between-Subjects Designs in Economic Experiments. *Working Paper #8583. Bonn, Germany: IZA* (8583).

Berry, J., G. Fischer, and R. P. Guiteras (2015). Eliciting and Utilizing Willingness-to-Pay: Evidence from Field Trials in Northern Ghana.

Brockner, J. (1992). The Escalation of Commitment to a Failing Course of Action: Toward Theoretical Progress. *Academy of Management Review 17*(1), 39–61.

Camerer, C. F. and R. a. Weber (1999). The econometrics and behavioral economics of escalation of commitment: a re-examination of Staw and Hoang's NBA data. *Journal of Economic Behavior & Organization 39*(1), 59–82.

Cohen, J., P. Dupas, and S. Schaner (2015). Price Subsidies, Diagnostic Tests, and Targeting of Malaria Treatment: Evidence from a Randomized Controlled Trial. *American Economic Review 105*(2), 609–645.

Eyster, E. (2002). Rationalizing the Past: A Taste for Consistency. *Nuffield College, Oxford, Job-Market Paper.*.

Fiegenbaum, A. and H. Thomas (1988). Attitudes toward Risk and the Risk-Return Paradox : Prospect Theory Explanations. *The Academy of Management Journal 31*(1), 85–106.

Fox, F. V. and B. M. Staw (1979). The trapped administrator: effects of job insecurity and policy resistance upon commitment to a course of action. *Administrative Science Quarterly 24*(3), 449–471.

Friedman, D., K. Pommerenke, R. Lukose, G. Milam, and B. a. Huberman (2007). Searching for the sunk cost fallacy. *Experimental Economics 10*(1), 79–104.

Frydman, C., N. Barberis, C. Camerer, P. Bossaerts, and A. Rangel (2014). Using neural data to test a theory of investor behavior: An application to realization utility. *Journal of Finance 69*(2), 907–946.

Genesove, D. and C. Mayer (2001). Loss aversion and seller behavior: Evidence from the housing market. *Quarterly Journal of Economics 116*(4), 1233–1260.

Haita-Falah, C. (2017). Sunk-cost fallacy and cognitive ability in individual decision-making. *Journal of Economic Psychology 58*, 44–59.

Hendricks, A. (2012). SoPHIE - Software Platform for Human Interaction Experiments. *University of Osnabrueck, Working Paper*.

Herrmann, P. N., D. O. Kundisch, and M. S. Rahman (2015). Beating irrationality: Does delegating to IT alleviate the sunk cost effect? *Management Science 61*(4), 831–850.

Ho, T.-H., I. P. L. Png, and S. Reza (2017). Sunk Cost Fallacy in Driving the World's Costliest Cars. *Management Science*.

Just, D. R. and B. Wansink (2011). The Flat-Rate Pricing Paradox: Conflicting Effects of "All-You-Can-eat" Buffet Pricing. *The Review of Economics and Statistics 93*(1), 193–200.

Kahneman, D. and A. Tversky (1979). Prospect Theory - An Analysis Of Decision Under Risk. *Econometrica 47*, 263–292.

Liang, A. R.-D., C.-L. Lee, and W. Tung (2014). The role of sunk costs in online consumer decision-making. *Electronic Commerce Research and Applications 13*(1), 56–68.

Loomes, G. and R. Sugden (1982). Regret Theory : An Alternative Theory of Rational Choice Under Uncertainty. *The Economic Journal 92*(368), 805–824.

Mcafee, R. P., H. M. Mialon, and S. H. Mialon (2010). Do sunk costs matter? *Economic Inquiry 48*(2), 323–336.

Molden, D. C. and C. M. Hui (2011). Promoting De-Escalation of Commitment: A Regulatory-Focus Perspective on Sunk Costs. *Psychological Science 22*(1), 8–12.

Otto, a. R. (2010). Three Attempts to Replicate the Behavioral Sunk-Cost Effect: A Note on Cunha and Caldieraro (2009). *Cognitive Science 34*(8), 1379–1383.

Phillips, O. R., R. C. Battalio, and C. A. Kogut (1991). Sunk and Opportunity Costs in Valuation and Bidding. *Southern Economic Journal 58*(1), 112–128.

Raftery, A. E. (1995). Bayesian Model Selection in Social Research. *Sociological Methodology 25*, 111–1163.

Roth, S., T. Robbert, and L. Straus (2015). On the sunk-cost effect in economic decision-making: a meta-analytic review. *Business Research 8*(1), 99–138.

Schoorman, D. F. and P. J. Holahan (1996). Psychological Antecedents of Escalation Behavior: Effects of Choice, Responsibility, and Decision Consequences. *Journal of Applied Psychology 81*(6), 786–794.

Schulz-Hardt, S., B. Thurow-Kröning, and D. Frey (2009). Preference-based escalation: A new interpretation for the responsibility effect in escalating commitment and entrapment. *Organizational Behavior and Human Decision Processes 108*(2), 175–186.

Soman, D. (2001). The mental accounting of sunk time costs: why time is not like money. *Journal of Behavioral Decision Making 14*(3), 169–185.

Soman, D. and A. Cheema (2001). The Effect of Windfall Gains on the Sunk-Cost Effect. *Marketing Letters 12*(1), 51–62.

Soman, D. and J. T. Gourville (2001). Transaction Decoupling: How Price Bundling Affects the Decision to Consume. *Journal of Marketing Research 38*(1), 30–44.

Staw, B. M. (1976). Knee-deep in the big muddy: a study of escalating commitment to a chosen course of action. *Organizational Behavior and Human Performance 16*(1), 27–44.

Staw, B. M. and H. Hoang (1995). Sunk Costs in the NBA: Why Draft Order Affects Playing Time and Survival in Professional Basketball. *Administrative Science Quarterly 40*(3), 474–494.

Strough, J., C. M. Mehta, J. P. McFall, and K. L. Schuller (2008). Are older adults less subject to the sunk-cost fallacy than younger adults?: Short report. *Psychological Science 19*(7), 650–652.

Sugden, R. (1993). An Axiomatic Foundation for Regret Theory. *Journal of Economic Theory 60*(1), 159–180.

Thaler, R. H. (1980). Toward a positive theory of consumer choice. *Journal of Economic Behavior & Organization 1*, 39–60.

Thaler, R. H. (1985). Mental Accounting and Consumer Choice. *Marketing Science 4*(3), 199–214.

Tversky, A. and D. Kahneman (1981). The Framing of Decisions and the Psychology of Choice. *Science 211*(4481), 453–458.

Tversky, A. and D. Kahneman (1992). Advances in Prospect-Theory - Cumulative Representation of Uncertainty. *Journal of Risk and Uncertainty 5*(4), 297–323.

Zeelenberg, M. and E. van Dijk (1997, nov). A reverse sunk cost effect in risky decision making: Sometimes we have too much invested to gamble. *Journal of Economic Psychology 18*, 677–691.

## A Proof of Optimal Strategy

This analysis will assume a risk neutral agent who seeks to maximize expected profits. There is no budget constraint and an unlimited number of periods in each round. Subjects are told the true distribution of the four Types, equal probability, therefore I assume correct beliefs.

Types can take values $i \in 1, 2, 3, 4$. There is a cost to continue for each Type, $c_i$, and a probability of winning the prize after paying, $p_i$. Let $R$ be the prize and $E$ be the endowment at the start of each period.

Let $v(i, E)$ be the optimal value for each Type $i$ with endowment $E$.

The Bellman Equation takes the form:

$$v(i, E) = max\{E, p_i(R + E - c_i) + (1 - p_i)\sum_{j=1}^{4} \frac{1}{4} v(j, E - c_i)\}, i \in 1, 2, 3, 4 \quad (1)$$

Where the endowment $E$ is the value of quitting in this period and the rest represents the expected payoff from continuing in this period. The endowment is a constant whether the agent continues or not, therefore this value can be pulled out of the maximization function. That is, $v(i, E) = E + \tilde{v}(i)$, where $\tilde{v}(i)$ satisfies

$$\tilde{v}(i) = max\{0, -c_i + p_i R + (1 - p_i)\sum_{j=1}^{4} \frac{1}{4} \tilde{v}(j)\} \quad (2)$$

Therefore $v(i, E)$ is equal to the current endowment plus a term $\tilde{v}(i)$ that reflects possible gains from continuing.

Given that $v(i, E) = E + \tilde{v}(i)$, the optimal decision for each Type is independent of the level of the endowment and therefore independent of prior sunk costs. Independence follows because a change in $E$ changes the quit and continue payoffs on the RHS of (1) by the same amount.

We can use a "guess-and-verify" method to determine the optimal policy given the four Types:

| Type | Cost | Probability of Winning |
|---|---|---|
| 1 | 50 | 10% |
| 2 | 50 | 30% |
| 3 | 100 | 10% |
| 4 | 300 | 10% |

Table A1: Possible types of draws.

We guess that quit is optimal for Type 4 (so that $\tilde{v}(4) = 0$) and continue is optimal for $\in 1, 2, 3$. If this is correct, then

$$\tilde{v}_1 = -50 + 75 + .9 * (\frac{1}{4})(\tilde{v}_1 + \tilde{v}_2 + \tilde{v}_3)$$
$$\tilde{v}_2 = -50 + 225 + .9 * (\frac{1}{4})(\tilde{v}_1 + \tilde{v}_2 + \tilde{v}_3)$$
$$\tilde{v}_3 = -100 + 75 + .9 * (\frac{1}{4})(\tilde{v}_1 + \tilde{v}_2 + \tilde{v}_3)$$

Solving yields

$$\tilde{v}_1 = 143.21$$
$$\tilde{v}_2 = 288.97$$
$$\tilde{v}_3 = 93.21$$

If we likewise assume the agent continues for every Type, we solve:

$$\tilde{v}_1 = -50 + 75 + .9 * (\frac{1}{4})(\tilde{v}_1 + \tilde{v}_2 + \tilde{v}_3 + \tilde{v}_4)$$
$$\tilde{v}_2 = -50 + 225 + .9 * (\frac{1}{4})(\tilde{v}_1 + \tilde{v}_2 + \tilde{v}_3 + \tilde{v}_4)$$
$$\tilde{v}_3 = -100 + 75 + .9 * (\frac{1}{4})(\tilde{v}_1 + \tilde{v}_2 + \tilde{v}_3 + \tilde{v}_4)$$
$$\tilde{v}_4 = -300 + 75 + .9 * (\frac{1}{4})(\tilde{v}_1 + \tilde{v}_2 + \tilde{v}_3 + \tilde{v}_4)$$

Which yields

$$\tilde{v}_1 = -87.5$$
$$\tilde{v}_2 = 62.5$$
$$\tilde{v}_3 = -137.5$$
$$\tilde{v}_4 = -337.5$$

These values imply $\tilde{v}_4 = 0$, confirming the proposed optimal policy.

## B Additional Tables and Figures

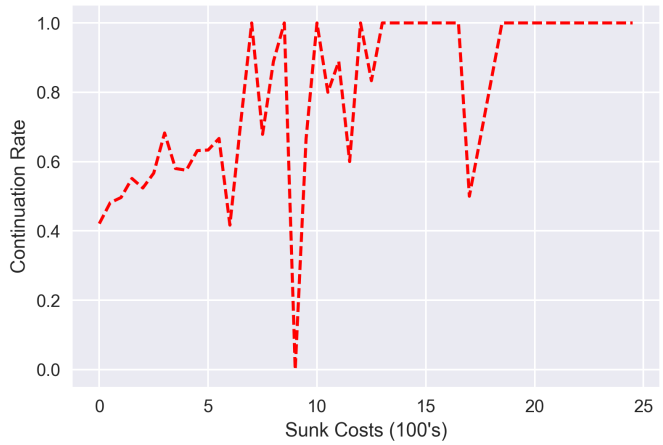


Fig. B1: Average continuation rate by sunk costs.

There are relatively few subjects who have large sunk costs. For example, the dip at 900 sunk costs in Figure B1 only has two subjects. To make the plot less sensitive, I group sunk costs by hundreds (e.g. 100 and 150 are combined) and calculate continuation rates by individual in Figure B2.


Fig. B2: Average continuation rate by sunk costs, smoothed.

Reference-Dependent theories predict a change in behavior based on the reference point, in this case the amount of the endowment remaining. Figure B3 calculates continuation rates like Figure B1, but grouping on the amount remaining rather than sunk costs.

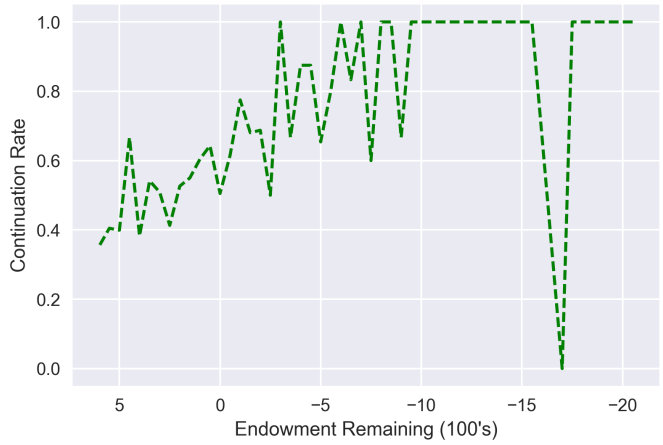


Fig. B3: Average continuation rate by endowment remaining.

Realization Utility has no bite when subjects can no longer realize a gain, which is the case for any subject with an amount remaining below -750. Figure B4 plots the continuation rates for only subjects who reach -750 remaining endowment. These subjects have higher continuation rates than the other part of the sample. This plot shows that these subjects do not dramatically reduce their continuation rates after passing the -750 threshold.

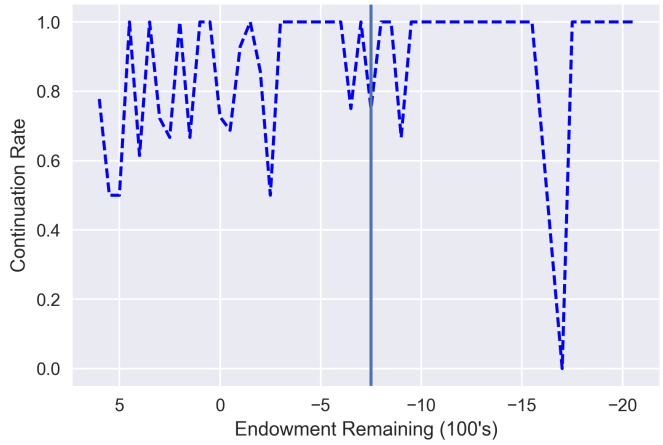


Fig. B4: Average continuation rate by endowment remaining for subjects who go beyond recovery.

Subjects in the no endowment treatment had higher continuation rates that the other two endowment groups. Figure B5 shows average continuation rates by endowment type.

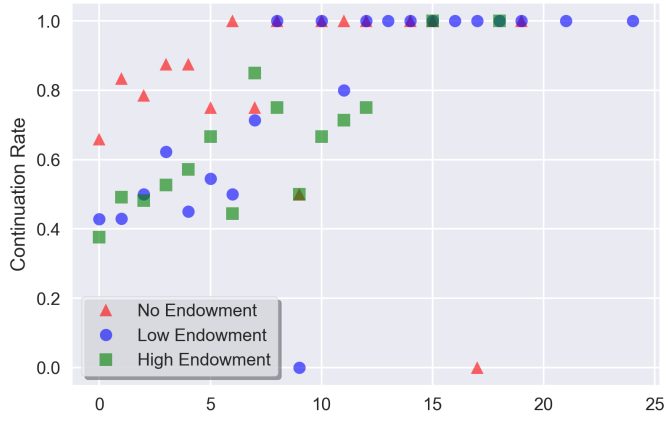


Fig. B5: Average continuation rate by endowment type.

The analysis in this paper focuses only on Type 4 decision because continuing for that Type is suboptimal. While the SCE may affect decisions that are already optimal, that is not the circumstance in which it is typically applied (Arkes and Blumer 1985). Table B1 shows that the SCE does not appear for other Types. The regressions use specifications

analogous to Table 2, with attrition indicators for their own respective Types. The low odds ratios come in part because subjects rarely quit for Types 1 and 2. Quitting as sunk costs rise, the reverse SCE, is predicted by concave utility functions.

Table B1: Other Types

| | Type 1 | Type 2 | Type 3 | Combined |
|---|---|---|---|---|
| Continue | | | | |
| Sunk x Type 1 | 0.907** | | | |
| | (-3.03) | | | |
| Sunk x Type 2 | | 0.834*** | | |
| | | (-5.08) | | |
| Sunk x Type 3 | | | 0.984 | |
| | | | (-0.50) | |
| Sunk | | | | 0.894* |
| | | | | (-1.97) |
| Observations | 3329 | 3329 | 3329 | 3329 |

Exponentiated coefficients; $t$ statistics in parentheses
Type, period, and attrition controls included. 63 groups.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

## C Instructions For Participants

This experiment was conducted using computers; instructions were embedded into the program rather than presented separately.

Consent

You are invited to participate in an economics experiment regarding decision-making. If you choose to participate, you will make many decisions that will impact your earnings. You are eligible to participate because you are a student at the University of Arizona and you are over 18 years of age.

If you choose to participate, your actions will be recorded but no information will be linked to you as an individual. A random number will be generated as an ID for you. The experiment will last about one hour and twenty minutes, and you may choose to withdraw from the experiment at any time. There are no known risks from participation. Your earnings in the experiment will be paid to you confidentially at the end. You will also have the option to take part in a continuation of the experiment in which you will receive emails. This is optional, but if you participate your email will not be disclosed to other parties.

By participating you:

1) Warrant that you have read and understand the above.
2) Warrant that your participation is voluntary.
3) Give permission to use your information and the data collected for research purposes.

*Next Page*

Welcome

Thank you for choosing to play this game. You will have to opportunity to earn money based on the decisions you make. Throughout the game you will earn points, and at the end these points will be turned into cents. Therefore 100 points will earn you $1.

*Next Page*

Thank-you for participating. During the session, please raise your hand if you have a question or do not understand the directions. In addition to your earnings from the experiment,

you will get an additional 1,200 points for completing the experiment.

*The last sentence depends on endowment type. This is an example for a person with 0 endowment in each round. One round is drawn from the Single Agent and one from the Partner Treatment (noted later). High endowment subjects receive 600 at the beginning of each round, and two round are chosen for payment. High endowment subjects do not receive additional points at the end. Low endowment subjects receive 400 per round, and therefore get an additional 400 (1200 - 800) in additional points at the end. The expected earnings for each subject is the same, but the payments are framed differently.*

*Next Page*
You will play three games in this experiment. Each game has several rounds. One round from each game will be chosen at random at the end of the experiment to determine your payment.

Which of the following is true about which rounds determine your earnings for the experiment?
Within a game, each round is equally likely
Within a game, rounds in which you earn a lot of points are more likely
Within a game, rounds in which you earn a lot of points are much less likely
*Subjects were forced to answer questions correctly before they could move on.*

*Subjects followed a link to have a copy of the instructions open while they answer quiz questions and complete throughout the experiment.*

*Next Page*
Instructions: Lottery Game
In this game you have the opportunity to win points which can later be turned into money. Each round will have a prize, which is some amount of points. You will choose to bid or not bid on that prize. You will start with no points in each round *(wording depends on endowment type)*, but this does not limit how much you can bid. When you bid, there is some probability that you will win the prize. If you do not win, you still have to pay the amount you bid and you are given another opportunity to bid or not bid.
You can keep bidding as many times as you like, but each bid costs you. Once you choose to stop bidding, that round is over and you start a new one. Each round is independent from the other.
For example, suppose that in round 1 the prize is 750 points. The bid is 300 and the probability of winning is .1, or 10%.
If you quit, your earnings are 0.
If you bid and win, your earnings are 750-300=450.
If you bid and do not win, then you will have the chance to bid again or quit. If you quit, your earnings are -300. Suppose the next bid is 50 with a probability of .1. If you bid and win, your earnings are 750-300-50=400. If you bid and do not win, then you will have the chance to bid again or quit. You can continue to do this as many times as you like.

As soon as you win or quit, the round is over. You may bid as many times as you like, but remember that each bid costs you whether you win or not. The possible bids are 50 with a 10% chance of winning, 300 with a 10% chance of winning, 50 with a 30% chance of winning, or 100 with a 10% chance of winning. These are randomly determined with equal probability. Your actions do not affect the bids or probabilities.
*Each link was specific to the treatment type. Subjects with a high endowment saw examples consistent with a high endowment.*

*Next Pages: Quiz, one question per page. Participants had to answer every question correctly to move on. They could raise their hand to ask for help if they had difficulty getting the right answer.*
If the prize in the round is 750 and you bid 300 and win, how much do you earn for that round?

If the prize in the round is 750 and you bid 300 and lose, then quit, how much do you earn for that round? (enter a negative number to represent negative earnings)

Suppose the prize in the round is 750. The first bid is 300 and you choose to bid but lose. Then the next bid is 50, and you choose to bid and you win. How much do you earn for that round?

Suppose the prize in the round is 750. You bid several times: you bid 300, 50, 50, 50, 300, 300, and 300 and lose each time, then bid 50 and win, what are your total earnings? (enter a negative sign for a loss).

If you have bid three times on a prize and lose each time, can you keep bidding?
- Yes, you can keep bidding until you win or quit
- No, you can only bid three times

You start the round with 0. You bid several times, the first bid is 300, then 50, then, 50, then 300. You still have not won. The next bid is 50, are you able to bid?
- Yes, you can keep bidding until you win or quit
- No

*Next Page*
The possible bids are 50 with a 10% chance of winning, 300 with a 10% chance of winning, 50 with a 30% chance of winning, or 100 with a 10% chance of winning. These are randomly determined with equal probability. Your actions do not affect the bids or probabilities.
*Each of the four possible states were color-coded for easier recognition.*

*Next Page: Main Experiment*
Lottery Game
You are now starting the first round of this game. Remember that you will play several rounds; one round will be randomly selected to be part of your final payment for the experiment.

*Example*
First Bid

In this round the prize is 750. The amount you must pay to bid for the prize is 300, which will give you a 0.1 chance of winning.

Would you like to bid or quit?
- Bid
- Quit
*She selects bid. If she were from a group that started with the high endowment, it would have also included: You are starting with 600 points.*

*Next page: If she loses*
You bid, but did not win the prize.

*Next page*
Second Bid

So far you have bid a total of 300. In this round the prize is 750.

The amount you must pay to bid for the prize is 50, which will give you a 0.3 chance of winning.

Would you like to bid or quit?
- Bid
- Quit

*This continues until she wins or quits.*

*End of the round.*
Earnings

This round you have earned 100 points. This round may be randomly selected to count towards your final payment. You will now start a new round.
*Since she started with 0, won 750, and paid 650, she earns a net total of 100. It was possible to earn negative amounts in the rounds.*

*Another Page: If she quit after spending 950*
Earnings

This round you have earned -950 points. This round may be randomly selected to count towards your final payment. You will now start a new round.

*Note: There were additional experiments run after this. One was a "Partners" edition in which subjects were paired with each other and took turns making decisions. The data from that part are too sparse to use because subjects could tolerate fewer rounds and the first subject, who acted as the treatment, was very conservative which resulted in very few data points for the subject of interest. Another experiment followed, which was a replication of Haita-Falah (2017) with additional instructions, however, numerous subjects complained that they did not understand. Subjects were also given the opportunity to play the "At Home" game, where they could login to a website and earn money. Subjects could elect to participate, facing a 50/50 chance of having to pay. Not enough participants chose to participate to analyze the data.*

How did you play?
If you are willing to indicate your gender, please do so below.
- Male
- Female
- Prefer not to answer

In the first game you played, you made many decisions- choosing to bid or quit. Would you briefly describe how you made this decision? What things were important to you? As a reminder, the bids were 50 with a 30% chance, 50 with a 10% chance, 100 with a 10% chance, and 300 with a 10% chance.
*Subjects' responses included justification that characterized the SCE, Realization Utility, Prospect Theory, and concave utility (reverse SCE). No single theme was dominant.*

*Next page*
Earnings

Your Earnings
Rounds have been drawn at random. Your earnings for the Single Lottery Game are: 100

Your Earnings
Rounds have been drawn at random. Your earnings for the Partner Lottery Game are: 650

Your Earnings
Rounds have been drawn at random. Your earnings for the Asset Game are: 480

Your Earnings
You also get 1,200 points for participating.

*Next page*
Final Earnings

Your earnings for this experiment are: 2430
For the first game, which you played on your own: 100
For the second game, which you played with a partner: 650
For the third game: 480.
And you earn an additional 1200 for participating.

You chose to participate in the "at home" portion, and nothing has been deducted from your earnings.

For a total of 2430. Please raise your hand and Collin will come around to give you your earnings. Thanks!

*For convenience, subject earnings were rounded up to the nearest dollar amount.*