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Essays on Decision Making under Uncertainty

A dissertation submitted in partial satisfaction of
the requirements for the degree Doctor of Philosophy in Economics

by

Santiago Ignacio Sautua

2015

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ABSTRACT OF THE DISSERTATION

Essays on Decision Making under Uncertainty

by

Santiago Ignacio Sautua

Doctor of Philosophy in Economics

University of California, Los Angeles, 2015

Professor Moshe Buchinsky, Co-chair

Professor William R. Zame, Co-chair

This dissertation consists of three chapters about decision making under uncertainty.

Chapter 1: “Testing between Models of Smoking Risk Perceptions”

Research in social and health psychology reports that smokers systematically underestimate the personal smoking risk. I build a model that captures potential determinants of smoking risk perceptions to investigate how smoking may cause an underestimation of the risk. The model is based on the premise that smokers have an incentive to be optimistic: because quitting may be hard, they find it reassuring to think that smoking is not so risky. Drawing upon the theoretical framework, I suggest two empirical tests of the model—one using survey data and another based on a laboratory experiment.

Chapter 2: “Does Uncertainty Cause Inertia in Decision Making? An Experimental Study of the Role of Regret Aversion and Indecisiveness”

Previous research has shown that in many situations there is clear inertia in individual decision making—that is, a tendency for decision makers to choose a status quo option. The status quo option may be the result of a previous choice, or may simply be the option designated as the “default.” While inertia may simply reflect the fact that individuals view the status quo option as optimal, there are other factors that may explain this observed behavior. I conduct a laboratory experiment to thoroughly investigate two potential determinants of inertia in uncertain environments: (i) regret aversion and (ii) indecisiveness. A decision maker may experience regret when the outcome of a choice compares unfavorably to the outcome that would have occurred had she made a different choice. Alternatively, a decision maker may be indecisive among the options if she does not know the probability distributions over the relevant outcomes. I use a between-subjects design, with varying conditions, to identify the effects of regret aversion and indecisiveness on choice behavior. In each condition, participants choose between two simple real gambles, one of which is assigned to be the status quo. I find that inertia is quite large and that both mechanisms are equally important.

Chapter 3: “Risk, Ambiguity, and Diversification”

Attitudes toward risk influence the decision to diversify among uncertain options. Yet, because in most situations the probability distributions over outcomes are unknown, attitudes toward ambiguity may also play an important role. In a simple laboratory experiment, I investigate the effect of ambiguity on the decision to diversify. Participants have the opportunity to diversify between gambles; in one condition, all gambles are risky, whereas in the other all gambles are

ambiguous. I find that diversification is more prevalent and more persistent under ambiguity than under risk. Moreover, excess diversification under ambiguity is driven by participants who stick with a status quo gamble when diversification is not feasible. This behavioral pattern cannot be accommodated by major theories of choice under ambiguity.

The dissertation of Santiago Ignacio Sautua is approved.

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2015

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CHAPTER 1

Testing between Models of Smoking Risk Perceptions

1 Introduction

Research in social and health psychology reports that smokers systematically underestimate the personal likelihood of experiencing smoking-related health problems.¹ This phenomenon of systematic underestimation of the personal risk is labeled *optimistic bias* in the literature. The interpretation of this finding suggested by this literature is that it is *because* they smoke that smokers underestimate the risk. While lack of information, misinformation and cognitive defects in the judgment of smoking risks have been widely documented, regardless of smoking behavior (U.S. FTC 1981, cited in Goodin 1989; Chapman et al. 1993; Borland 1997), they cannot explain the significant differences in risk perceptions among smokers, ex-smokers, and nonsmokers. Even though there appear to be no differences in the amount of factual knowledge about the effects of smoking (Mc Master and Lee 1991), smokers tend to adhere to significantly more rationalizations and self-exempting beliefs than do ex-smokers and nonsmokers (Mc Master and Lee 1991; Chapman et al. 1993).

This fact suggests that smokers may play down the risk *intentionally* (albeit not always consciously). This conjecture, however, still remains to be supported with compelling evidence. The fundamental flaw in the social and health psychology literature is that it appeals to a plain comparison of smokers' risk perceptions to nonsmokers' to conclude the existence of an optimistic bias; but actually such comparison cannot distinguish a model in which

¹Some examples are Hansen and Malotte (1986), McCoy et al. (1992), McKenna et al. (1993), Chapman et al. (1993), Schoenbaum (1997), Weinstein (1998), Arnett (2000) and references therein, and Weinstein et al. (2005).

smokers are optimistic *because* they smoke from one in which they simply hold lower risk perceptions based on the information they judge relevant, and hence they smoke.

In other words, the referred literature has not provided conclusive evidence of an optimistic bias in smokers' personal risk perceptions. There are reasons to believe that some individuals could legitimately perceive their personal smoking risk to be lower than for others. One could think that individuals are aware of differentiating factors that make the occurrence of a smoking-related illness in one group of people more likely than in another group (such as genetic predisposition, smoking history, other risky behaviors, and environment), and they use such concepts of risk-relevant factors when inferring their own risk (Hahn and Renner 1997). From this viewpoint, those who legitimately perceive their risk to be lower are more likely to smoke, and this could be the reason why smokers report lower personal risks. Thus, by simply looking at (reported) smoking risk perceptions and smoking behavior we are not actually able to establish whether there is indeed an optimistic bias among smokers. A key question arises: how can we tell if there is an optimistic bias among smokers?

The contribution of this paper is to provide an economic approach to address this question. In order to tackle this issue, first it is necessary to consider why smokers could be optimistic when forming their beliefs and what the main mechanisms governing the manipulation of beliefs are. One hypothesis is that smokers may be tempted to think that smoking is actually not that risky for themselves because this increases the discounted expected utility of smoking for the following years, which in turn boosts their current felicity via a higher anticipatory utility. That is, smokers feel happier today if they (partially) disregard potential smoking-related detrimental effects because they find it reassuring to think that smoking is not so dangerous. Based on this hypothesis, in this paper I build a model in which forward-looking individuals choose not only their cigarette consumption but *also* their personal smoking risk perceptions, and those who smoke may end up *choosing* to be optimistic about their personal risk. The model provides a microfoundation of personal

smoking risk perceptions by capturing the main underlying mechanisms that influence the incentives to manipulate risk perceptions. By explicitly addressing these mechanisms, the model yields testable implications that can be used to distinguish it from a standard model with bayesian decision makers in which beliefs are constructed *only* upon available information and hence are not manipulated.² Secondly, I suggest two empirical tests—one using survey data and another based on a laboratory experiment—to carry such implications to the data and evaluate the plausibility of this model compared to the standard one.

In the model, even though the smoker may be tempted to manipulate her beliefs in order to raise her current well-being, her ability to do so is limited. There is a cost of maintaining false beliefs because a rational individual acknowledges that being optimistic about the smoking risk may induce smoking decisions that lead to poor health outcomes. We could think of this cost as a self-deception cost. *Optimal* smoking risk perceptions trade-off the incentive to be optimistic so as to increase expected future utility against the costs of poor health outcomes that result from decisions made based on optimistic beliefs. Unlike in the standard model, optimal risk perceptions depend not only on available information, but also on smoking benefits, the intensity of withdrawal effects, the individual’s perceived severity of potential health losses for the following years and the price of cigarettes.

In this context, three comparative statics are analyzed in detail, namely the response of smoking risk perceptions to: (i) an increase in the price of cigarettes, (ii) a more vivid representation of potential health losses, and (iii) a negative taste shock. An important aspect of the analysis is that the *sign* of a particular response will depend, in turn, on the responsiveness of the (anticipated) cigarette consumption schedule to the factor being

²It is worth emphasizing the stark contrast between both processes of belief formation. Under bayesian decision theory agents construct their beliefs *only* upon available information. In contrast, in this model, despite knowing the medical smoking risks, the smoker may *decide* to believe that smoking is not that risky because she finds it reassuring to think that she will not suffer health problems. Then, her risk perception is not determined solely by the information available to her; rather, it is also influenced by her desire to disregard the risk.

changed. The basic intuition is that the ease with which the individual can change her smoking behavior affects her incentives to play down the risk; in particular, the more difficult it is to cut consumption—due to large withdrawal effects, for instance, the more difficult it is to avoid health costs based on own actions, and hence the stronger the incentive to (partially) disregard the personal likelihood of suffering those costs so as to relieve the stress produced by thinking about them. The empirical tests of the model draw on these three comparative statics.

Testing this model is important because it has at least two policy implications that are absent in a standard model that rules out the possibility of an optimistic bias. First, unlike a canonical model, this one shows that the perceived *magnitude* of potential health problems is a determinant of the perceived *likelihood* of suffering those problems. However, it also shows that it is unclear that enhancing people’s perception of the seriousness of potential health problems will lessen (or eliminate) *each* smoker’s optimistic bias, if present. As mentioned in the above paragraph, the impact will depend on the responsiveness of the individual’s cigarette consumption. Second, it is shown that when final consumption is sufficiently sensitive, an increase in the price of cigarettes reduces the optimistic bias; hence, such price increase induces a reduction in consumption that is *larger* than it is in the standard model, where prices affect consumption directly—but not indirectly through risk perceptions. This result is relevant for policy purposes, because it suggests that cigarette taxes may be an even more useful policy instrument than they are usually believed to be: not only may taxes reduce cigarette consumption directly, but they may also help to mitigate the distortions in consumption produced by belief manipulation.

In modeling belief manipulation, this paper is most closely connected to the work by Brunnermeier and Parker (2005), who also develop a theoretical model in which individuals choose consumption and beliefs; however, they do not explicitly address the ultimate determinants of belief manipulation and they do not provide sharp testable implications of their

model. Conceptually, the work presented here is also related to the cognitive-dissonance economics mini-literature, whose most salient papers are Akerlof and Dickens (1982), Dickens (1986), and Rabin (1994). These theoretical papers also approach belief formation in different contexts as a choice problem, incorporating the general trade-off involved in belief manipulation.³

The rest of the paper is organized as follows. Section 2 sets up the model and discusses it in detail: it describes its building blocks and the individual's optimization problem, and it characterizes the individual's choices of cigarette consumption and smoking risk perceptions. Section 3 analyzes the testable implications of the model that relate smoking risk perceptions to the price of cigarettes, the individual's perceived severity of potential health losses for the following years, and smoking benefits. Section 4 discusses two empirical tests based on these comparative statics. Section 5 concludes.

2 The Model

The model studies the smoking decisions of a representative individual at a finite number of periods. The individual is boundedly rational (in the sense of Simon (1978)). Concretely, this implies that in each period, the individual chooses only its current consumption level, rather than making a complete contingent lifetime plan that maximizes the present value of lifetime utility. Due to cognitive limitations, in making these choices the agent considers

³Akerlof and Dickens (1982) study workers' decisions regarding the purchase of safety equipment in hazardous occupations; workers base their decisions on how risky they think their jobs are. They are torn between two dissonant cognitions: that they are smart people, but they have chosen a dangerous job. Then, they may decide to believe their job is safe to avoid this tension.

Dickens (1986) studies crime decisions in a context in which individuals can manipulate their beliefs about the value of a crime after they decide whether or not to commit it, which helps them overcome the unsettling doubts about how wise their decision was.

Rabin (1994) studies how cognitive dissonance influences moral concerns, thereby affecting both prevalent beliefs about morality and the level of immoral activities in a society. Rabin argues that there is a psychic cost of convincing oneself that a morally dubious activity is actually moral, since this conflicts with our disinterested consciences.

only first-order consequences of her decisions on her well-being, that materialize (or could materialize) either immediately or in a relatively short period that follows the smoking decision. Specifically, the effects of cigarette consumption on her utility at age $A = A_1, \dots, \bar{A}$ can be divided into three components, all of them dependent on the current consumption level s_A . Such components are: (i) the current benefits of smoking, denoted by $B_A(s_A)$; (ii) the potential withdrawal effects, denoted by $C_A(s_A)$; and (iii) the potential physical losses for the following years derived from current consumption, represented by $L_A(c_A)$. In addition, there is a fourth basic element that is relevant for smoking decisions, and which constitutes the focus of the paper. Since the health losses are probabilistic, when making smoking decisions the individual considers not only the *severity* of the smoking-related illnesses (i.e., $L_A(s_A)$) but also the *perceived likelihood* that those illnesses will be suffered, denoted by p_A . I also refer to $\{p_A : A = A_1, \dots, \bar{A}\}$ as (smoking) *risk perceptions*. Next, I describe in detail these building blocks of the model.

2.1 Building Blocks

2.1.1 Smoking Benefits

Smoking benefits are given by the pleasure derived from both the nicotine content of cigarettes and stimuli conditioned to cigarette consumption, such as the enjoyment of positive affective states and the relief from negative ones. Thus smoking plays the role of reducing negative affect (such as feelings of distress, fear, shame or disgust) on the one hand and increasing positive feelings (such as excitement, relaxation, improvement of mood and better concentration) on the other.⁴ Smoking benefits at age A are captured by $B_A(s) = \xi_A b(s)$, where ξ_A represents a taste shock at age A and $b(\cdot)$ denotes the ‘stable’ component of benefits

⁴The specialized literature from psychology and medicine has identified several smoking motives and has distinguished various types of smoking behavior on the basis of such motives (see, for instance, Lujic et al. 2005).

over time. The function $b(\cdot)$ satisfies: $b(0) = 0$; $b'(s) > 0$ and $b''(s) \leq 0$ for all $s \geq 0$. Taste shocks follow a random walk: $\xi_A = \xi_{A-1} + \epsilon_A$, where $E(\epsilon_A) = 0$ and $E(\epsilon_A^2) = \sigma^2$.

2.1.2 Withdrawal Effects

The withdrawal effects, which are usually referred to as adjustment costs in the economics literature on addictions (e.g. Jones 1999, Suranovic et al. 1999), occur only when consumption is *reduced* from the habitual consumption level. They reflect the pharmacological addiction associated with the pure nicotine effects of cigarettes. In this setting, at age A habitual consumption is given by the consumption level of the previous period s_{A-1}^* . In addition, the intensity of the withdrawal effects is affected by the stock of past consumption, $S_A := \sum_{a=A_1}^{A-1} s_a$: the larger the stock, the stronger the withdrawal effects. Thus, the adjustment cost function C_A satisfies

$$\begin{aligned} C_A &= C_A(s; S_A) \quad \forall s \in [0, s_{A-1}^*) \\ C_A &= 0 \quad \forall s \geq s_{A-1}^*, \end{aligned}$$

and has the following properties for all $s \in [0, s_{A-1}^*)$: $C_s < 0$, $C_S > 0$, $C_{ss} < 0$.⁵ For simplicity, in this model the individual is assumed to *know* the potential withdrawal effects that she would suffer if she cut back consumption. Notice that this still allows for uncertainty in future adjustment costs. However, the implications of such uncertainty on smoking risk perceptions and cigarette consumption are not considered in this paper.⁶

⁵There is no a priori reason for a particular sign to C_{ss} . Suranovic et al. (1999) model lifetime consumption decisions considering three cases. An adjustment cost that rises at an increasing rate, $C_{ss} > 0$, implies that small reductions in cigarette consumption below the habitual level will have relatively small withdrawal effects. It is not so painful to reduce consumption slightly. In contrast, an adjustment cost that rises at a decreasing rate, $C_{ss} < 0$, implies that small reductions in consumption below the habitual level will produce relatively large withdrawal effects. In the third case, adjustment costs change at a decreasing rate for consumption levels near zero but an increasing rate for consumption levels near the habitual level. In this case, small smoking reductions are relatively painless but the costs rise rapidly with additional cut-backs. For further reductions near zero, adjustment costs rise slowly.

⁶Orphanides and Zervos (1995) study consumption decisions of individuals who do not know the ad-

2.1.3 Health Losses

With respect to the physical costs of smoking, it is assumed that at any age the magnitude of *potential* health losses for the following years increases with the level of current consumption, and it does so at a nondecreasing rate: $\frac{\partial L_A(s)}{\partial s} > 0$, $\frac{\partial^2 L_A(s)}{\partial s^2} \geq 0$.⁷ Without loss of generality, $L_A(0)$ is set to zero. The severity of potential health problems at age A will be larger if the individual smoked at age $A-1$, while it will remain the same if she did not smoke. Formally,

$$L_A(s) = I_{[s_{A-1}^* > 0]} \mu L_{A-1}(s) + (1 - I_{[s_{A-1}^* > 0]}) L_{A-1}(s), \quad (1)$$

where $\mu > 1$. The individual is assumed to be aware of this fact regarding the evolution of losses over time. In other words, she has ‘intellectual knowledge’ of the damage. However, she cannot perfectly foresee the actual severity of health losses for the following years. Rather, she must make her best effort to figure out the seriousness of the smoking-related illnesses she could experience during the next years. Such exercise requires the smoker to construct a mental and corporal representation of the illnesses, which is assumed to be biased downwards.⁸ At age A , the smoker’s estimate of the severity of potential harmful effects of

dictiveness of the good. To make their consumption plans, individuals form subjective beliefs about the likelihood that they will become addicted if they consume this good. If they consume, they have the chance to learn about the addictiveness and hence they update their beliefs accordingly, in a bayesian fashion. An individual becomes addicted when the stock of past consumption exceeds some threshold. Those who learn their propension to become addicted before reaching this threshold start to cut back consumption and manage to avoid the addiction. On the contrary, those who learn their propension after reaching the critical consumption level cannot avoid the addiction.

⁷Potential health losses for the following years at age A , $L_A(s)$, could be conceived of as the sum of discounted instantaneous losses over the time period between A and $A+1$. That is,

$$L_A(s; s_{A-1}^*) = \int_A^{A+1} e^{-r(t-A)} l(s_t; s_{A-1}^*) dt,$$

where r is the discount rate and $l(.,.)$ represents the potential damage for each instant t . Thus, in the model $s = \int_A^{A+1} s_t dt$ and $s_{A-1}^* = \int_{A-1}^A s_t dt$.

⁸Note that *involuntary underestimation* of the magnitude of potential injuries, as assumed here, differs significantly in nature from *voluntary discounting* of future health costs. Although both lead to a lower

smoking for the following years is

$$\hat{L}_A(s) = (1 - \gamma) \left[\eta_{A-1} L_{A-1}(s) + (1 - \eta_{A-1}) \hat{L}_{A-1}(s) \right] + \gamma L_A(s), \quad (2)$$

where $\gamma \in (0, 1)$ and η_{A-1} is a Bernoulli random variable whose value is one if the agent had health problems at age $A - 1$ and zero otherwise.⁹ To estimate the next potential losses, the agent considers her recent experience regarding health problems as a reference point. As the injuries are probabilistic, the individual may not have suffered health problems at age $A - 1$. If she did not suffer injuries, she simply constructs her current estimate upon the previous estimate, while if she did suffer health problems, she can base her current estimate on the magnitude of the experienced losses.¹⁰ In any case, the individual then adjusts this reference magnitude upwards (towards the actual losses $L_A(s)$) because she has a correct qualitative idea of the evolution of health losses over time, as pointed out before.

The parameter γ captures the vividness of the representation of the physical losses constructed by the individual. The larger is γ , the more vivid is this representation, hence the closer is the perceived severity of potential injuries to the actual severity.

value of health losses, it is important to distinguish between them from a policy perspective. While it may be desirable to correct the underestimation of future health losses due to its involuntary nature, there is no compelling reason to induce people to change the subjective ‘weight’ they voluntarily assign to future smoking costs.

⁹Kahneman et al. (1997) distinguish *decision utility* from *experienced utility*. The former is the weight of an outcome in a decision, while the latter is subjective hedonic quality, as in Bentham’s (1789) usage. Based on this distinction, the authors discuss, among other concepts, the one of *predicted utility*, which refers to beliefs about the experienced utility of outcomes. Thus, in the language of Kahneman et al. (1997), $\hat{L}_A(c)$ constitutes the predicted disutility (or health cost) of smoking for the next years.

¹⁰In this model, personal experience conveys new *hedonic* information; it provides the individual with first-hand evidence of the intensity and depth of the damage. As Weinstein (1989) argues, this is the main reason why its lessons are uniquely persuasive and salient. Weinstein (1989, 44) clearly summarizes the findings in the psychology literature (e.g. Averill 1987; Horowitz 1980) regarding the influence of personal victimization on the perceived severity of a health threat: “Personal experience of harm may be associated with persistent, vivid, unpleasant images or even physical sensations that increase the salience of the threat and the perceived severity of victimization.”

2.1.4 Perceived Risk

Finally, in addition to quantifying the magnitude of the losses, the smoker has to judge the probability of suffering such losses. Recall that η_A is a Bernoulli random variable that takes on the value 1 if a health shock occurs. Specifically,

$$\eta_A = \begin{cases} 1 & \text{with prob } \pi_A \\ 0 & \text{with prob } 1 - \pi_A \end{cases}.$$

The evolution of π_A captures the cumulative nature of the smoking risk: the actual risk that the individual of age A faces will be higher than that of the previous period if she smoked in the last period, while it will remain the same if she did not smoke. Formally,

$$\pi_A = I_{[s_{A-1}^* > 0]} \alpha \pi_{A-1} + (1 - I_{[s_{A-1}^* > 0]}) \pi_{A-1}, \quad (3)$$

where $\alpha > 1$. For expositional convenience, the agent is assumed to *know* the true probability of suffering health problems at a given age, π_A . Concretely, at each age she learns the latter on the basis of new publicly available information concerning the potential health problems for a smoker with her background characteristics and smoking history. Although this assumption may appear somewhat unrealistic,¹¹ it enables me to abstract from issues concerning information processing in order to focus on a *motivational* account of the belief formation process. In psychological terms, the concept of motivation refers to “any wish, desire, or preference that concerns the outcome of a given reasoning task” (Kunda 1990, p.

¹¹For instance, in one poll many people did not know that smoking was the *main* cause of lung cancer, bronchitis and emphysema (U.S. FTC 1981, cited in Goodin 1989). Besides, many smokers hold some erroneous beliefs about smoking which simply reveal misinformation (Chapman et al. 1993). On the other hand, there is ample evidence indicating that, even though they may have correct qualitative information, individuals have great difficulty in understanding numerical risk estimates (see Weinstein 1998 and references therein). Besides, the psychology literature has questioned the idea that individuals use statistics such as odds and percentages in making smoking decisions (e.g. Borland 1997). Therefore, in real-life situations people may find serious problems in processing information about smoking risks.

2). In this context, the agent may be *willing* to believe that the smoking risk is smaller than the true one, because he finds it reassuring to think that it is unlikely that he will suffer health problems. Therefore, in sharp contrast with models analyzing belief formation in a typical bayesian framework, in this model the individual forms her beliefs based not only on available information but also on her preferences over beliefs. In this respect, one of the central features of the model is that the perceived risk p_A will not necessarily coincide with the true one, π_A , *even when issues such as imperfect information or cognitive limitations in information processing are absent.*

2.2 The Individual's Problem

2.2.1 Overview

At each age, the agent derives utility from cigarettes and a composite good, whose consumption level is denoted by y_A . Smoking utility depends on benefits B_A , withdrawal effects C_A and health losses L_A . The agent's realized total utility at each age is assumed to be additively separable in the cigarettes and the composite good¹²:

$$U(s_A, y_A) = u[B_A(s_A), C_A(s_A), \eta_A L_A(s_A)] + v(y_A).$$

u and v satisfy the following properties: $u_B > 0$, $u_C < 0$, $u_L < 0$, $v_y > 0$. This means simply that smoking benefits raise utility while withdrawal effects and health losses decrease it, and total utility is increasing in the amount of the composite good. Notice that u summarizes *all* the relevant effects of smoking on utility for the following years (i.e. between ages A and $A + 1$), as perceived at age A : it captures both the short-run effects embedded in benefits and adjustment costs and also future potential effects (for the next years) through

¹²This separability assumption is usual in the economics literature on addictions. See, for instance, Becker and Murphy (1988), Suranovic et al. (1999), and Gruber and Koszegi (2001).

the impact on health. Thus, $u[., ., .]$ should be interpreted as the present (discounted) value of smoking s_A cigarettes between ages A and $A + 1$, conditional on the value of η_A .

Given the individual's perceived risk and her estimate of the severity of potential losses, their subjective expected utility at age A can be expressed as

$$EU(s_A, y_A) = p_A u[B_A(s_A), C_A(s_A), \hat{L}_A(s_A)] + (1 - p_A) u[B_A(s_A), C_A(s_A), 0] + v(y_A). \quad (4)$$

At each age, *given her perceived risk*, prices, and income, the individual chooses her current consumption of cigarettes s_A and composite good y_A to maximize (4), subject to her budget constraint. The latter is given by $q_A s_A + y_A \leq I_A$, where I_A denotes income at age A , q_A denotes the price of cigarettes at age A , and the price of the composite good has been normalized to 1. The solution to this problem is given by demand schedules $s_A^*(p_A; \gamma, \xi_A, S_A, \eta_{A-1}, q_A, I_A)$ and $y_A^*(p_A; \gamma, \xi_A, S_A, \eta_{A-1}, q_A, I_A)$. Hence, expected indirect utility, which I shall call *well-being*, is given by¹³

$$\begin{aligned} W(p_A; \gamma, \xi_A, S_A, \eta_{A-1}, q_A, I_A) &= p_A u[B_A(s_A^*), C_A(s_A^*), \hat{L}_A(s_A^*)] \\ &\quad + (1 - p_A) u[B_A(s_A^*), C_A(s_A^*), 0] + v(y_A^*). \end{aligned} \quad (5)$$

Notice that perceived risk p_A impacts well-being directly through anticipation of flow utility (as summarized by u) and indirectly through its effect on the agent's cigarette consumption (as summarized by s_A^* , the optimal demand schedule). A central aspect of this model is that perceived risk p_A is *endogenous*: the agent does not necessarily take the true probability of suffering health problems π_A at face value because she is aware that she can affect her well-being through belief manipulation. That is, by downplaying the risk, the agent

¹³I borrow this label from Brunnenmeier and Parker (2005), who also study the choice of optimal beliefs among forward-looking individuals. In that paper, however, the definition of well-being is a little bit different because individuals choose contingent consumption plans for their entire lifetime. So well-being is defined as the expected time-average of indirect utility flows.

can affect the direct impact of beliefs on well-being and increase expected utility. Importantly, she also acknowledges that altering her beliefs will have consequences on her cigarette consumption decision, and she internalizes such consequences when making her choice of p_A . This way she also considers the indirect effect of beliefs on well-being. The appeal of this latter feature of the decision-making process is that it makes consumption decisions consistent with beliefs, as in the standard model where beliefs are not chosen. Optimal smoking risk perceptions, p_A^* , trade-off the incentive to be optimistic so as to increase expected future utility against the costs of poor health outcomes that result from decisions made based on optimistic beliefs. Consequently, optimal beliefs p_A^* maximize well-being. Specifically, I assume every feasible belief p_A to have the following structure:

$$p_A = (1 - \theta_A) p_{A-1}^* + \theta_A \pi_A, \quad (6)$$

where p_{A-1}^* (the perceived risk at age $A - 1$) constitutes the reference risk at age A and $\theta_A \in [0, 1]$ is the weight that the agent places on the true probability. So actually the agent chooses $\theta_A \in [0, 1]$ to maximize well-being. It is assumed that $p_{A_0} < \pi_{A_1}$, i.e., the agent's original prior is biased downwards. Together with the assumption regarding the evolution of π (see 3), this ensures that beliefs will never be biased upwards; here the interest is to assess under what conditions risk perceptions will be biased *downwards*, compared to the standard model in which $p_A = \pi_A$.¹⁴ So even though the individual forms her risk perception based on the information encompassed by π_A , in this model she is able to manipulate the importance she attaches to such information. In particular, the desire to believe that smoking is not so

¹⁴In principle, this restriction appears inconsistent with Viscusi's (1992) finding that smokers *overestimate* smoking risks. He analyzes a national telephone survey of more than 3000 people age sixteen or older, where respondents were asked: "Among 100 cigarette smokers, how many of them do you think will get lung cancer because they smoke?" Viscusi found that the majority of smokers and nonsmokers in the sample greatly overestimated the probability of getting lung cancer. They also overestimated overall mortality rates from smoking and loss of life expectancy from smoking. There is, however, an important difference between Viscusi's approach and my approach. While Viscusi studies people's perceptions of the risk *for a random smoker*, I analyze *personal* risk perceptions. Thus, the fact that people overestimate the average risk is compatible with underestimation of their own risk.

risky in order to increase well-being may induce the smoker to downplay the importance of the risk information, which will result in a perceived risk that is lower than the actual risk. If $p_{A-1}^* < \pi_A$ and $\theta_A < 1$, then $p_A < \pi_A$ and the individual is said to have an *optimistic bias* in her smoking risk perception.¹⁵

Next, I study both the optimal consumption decision and the choice of optimal beliefs in detail.

2.2.2 Optimal Consumption Given Beliefs

As mentioned before, $s_A^*(p_A; \gamma, \xi_A, S_A, \eta_{A-1}, q_A, I_A)$ and $y_A^*(p_A; \gamma, \xi_A, S_A, \eta_{A-1}, q_A, I_A)$ solve

$$\begin{aligned} & \text{Max}_{(s_A, y_A)} EU(s_A, y_A) \\ & \text{s.t. } s_A \geq 0 ; y_A \geq 0 ; q_A s_A + y_A \leq I_A, \end{aligned} \tag{7}$$

where $EU(s_A, y_A)$ is defined in (4). Reexpress the latter as

$$EU(s_A, y_A) = -p_A \Delta u_A(s_A) + u[B_A(s_A), C_A(s_A), 0] + v(y_A),$$

where $\Delta u_A(s_A) := u[B_A(s_A), C_A(s_A), 0] - u[B_A(s_A), C_A(s_A), \hat{L}_A(s_A)]$. That is, $\Delta u_A(s_A)$

¹⁵ A comparison of this model with the framework developed in Viscusi (1989) is in order. Considering a multivariate (static) outcome situation with n possible outcomes, Viscusi (1989, p. 239) defines the perceived probability p_i^* of outcome i as

$$p_i^* = \frac{\gamma q_i + \xi p_i}{\gamma + \xi},$$

where q_i denotes the prior probability of outcome i , ξ denotes the number of trials observed by the individual, p_i represents the fraction of trials which are outcome i , and γ is a parameter of the prior distribution corresponding to the informational content of the individual's prior beliefs. Viscusi (1989, p. 240) mentions two possible reasons why individuals may not take stated probabilities (like p_i) at face value. "First, the individual may be legitimately suspicious of supposedly 'hard' probabilities, particularly if he does not have full confidence in the experiment being performed. The second possibility is that this behavior may reflect an inherent aspect of individual's information processing whereby individuals act as if risk information is imperfect." Note that in the present paper the rationale for individuals' manipulation of smoking risks differs significantly from that provided by Viscusi.

) denotes the differential utility enjoyed in the ‘good’ state (in which health losses are not realized) relative to that derived in the ‘bad’ state (in which health losses occur). Notice that $\Delta u_A(0) = 0$, while $\Delta u_A(s_A) > 0$ if $s_A > 0$.

The F.O.C. for s_A is

$$\frac{\partial EU(s_A, y_A)}{\partial s_A} = u_{B_A} B'_A(s_A) + u_{C_A} C'_A(s_A) + p_A u_{\hat{L}_A} \hat{L}'_A(s_A) = \lambda_A q_A, \quad (8)$$

where λ_A is the Lagrange multiplier associated to the budget constraint.

This equation characterizes an interior solution $s_A^*(p_A; \gamma, \xi_A, S_A, \eta_{A-1}, q_A, I_A)$. Thus, appealing to the Implicit Function Theorem we obtain

$$\frac{\partial s_A^*}{\partial p_A} \leq 0 ; \frac{\partial s_A^*}{\partial \xi_A} \geq 0 ; \frac{\partial s_A^*}{\partial S_A} \geq 0 ; \frac{\partial s_A^*}{\partial \gamma} \leq 0 ; \frac{\partial s_A^*}{\partial q_A} \leq 0 ;$$

also, $s_A^*|_{\eta_{A-1}=1} \leq s_A^*|_{\eta_{A-1}=0}$.

On the other hand, a corner solution arises if $\frac{\partial EU(s_A, y_A)}{\partial s_A} < \lambda_A q_A$ for all $s_A \geq 0$. That is,

$$s_A^* = 0 \Leftrightarrow u_{B_A} B'_A(s) + u_{C_A} C'_A(s) < \lambda_A q_A - p_A u_{\hat{L}_A} \hat{L}'_A(s). \quad (9)$$

The RHS represents the perceived full marginal cost of smoking in this model, whereas the LHS denotes the marginal ‘benefits’ of smoking, broadly defined (that is, it includes both the additional pleasure derived from one more cigarette and the avoided withdrawal symptoms that would take place if cigarette consumption were reduced). So provided that the perceived full marginal cost of smoking is sufficiently large relative to its benefits for any consumption level, the individual will optimally decide not to smoke.

2.2.3 Optimal Smoking Risk Perceptions

Optimal beliefs maximize well-being, as defined in (5). Reexpress the latter as

$$W(p_A; \gamma, \xi_A, S_A, \eta_{A-1}, q_A, I_A) = -p_A \Delta u_A(s_A^*) + u[B_A(s_A^*), C_A(s_A^*), 0] + v(y_A^*).$$

Thus, θ_A^* solves¹⁶

$$\begin{aligned} & \text{Max}_{\theta_A} W(p_A; \gamma, \xi_A, S_A, \eta_{A-1}, q_A, I_A) \\ & \text{s.t. } \theta_A \in [0, 1] \ ; \ p_A = p_{A-1}^* + \theta_A(\pi_A - p_{A-1}^*). \end{aligned} \quad (10)$$

Replacing p_A in the objective function with the expression given by the constraint, the F.O.C. for θ_A is

$$\begin{aligned} \frac{\partial W(p_A, \cdot)}{\partial \theta_A} &= (\pi_A - p_{A-1}^*) \left\{ -\Delta u_A(s_A^*) + [u_{B_A} B'_A(s_A^*) \frac{\partial s_A^*}{\partial p_A} + u_{C_A} C'_A(s_A^*) \frac{\partial s_A^*}{\partial p_A}] \right. \\ &\quad \left. + p_A u_{\hat{L}_A} \hat{L}'_A(s_A^*) \frac{\partial s_A^*}{\partial p_A} \right\} \\ &= 0. \end{aligned} \quad (11)$$

This equation characterizes an interior solution $\theta_A^*(\gamma, \xi_A, S_A, \eta_{A-1}, q_A, I_A)$. Two kinds of situations arise: one in which $\pi_A = p_{A-1}^*$ and another one in which $\pi_A > p_{A-1}^*$. Consider first the scenario in which $\pi_A = p_{A-1}^*$. Remember that the assumptions of the model imply that $p_{A-1}^* \leq \pi_{A-1} \leq \pi_A$.¹⁷ Therefore, for this scenario to arise, we must have $p_{A-1}^* = \pi_{A-1} = \pi_A$.

¹⁶In this model the choices of s_A^* and θ_A^* are made sequentially only for expositional convenience. Alternatively, the individual's problem can be set up as

$$\begin{aligned} & \text{Max}_{(s_A, y_A, \theta_A)} EU(s_A, y_A, \theta_A) \\ & \text{s.t. } s_A >= 0 \ ; \ y_A >= 0 \ ; \ q_A s_A + y_A \leq I_A \ ; \\ & \theta_A \in [0, 1] \ ; \ p_A = p_{A-1}^* + \theta_A(\pi_A - p_{A-1}^*) \ . \end{aligned}$$

The solution to this problem is mathematically equivalent to the one discussed in the main text.

¹⁷The first inequality is implied by (6) and the second one by (3).

This means two things: (i) the first equality indicates that the individual decided not to play down the risk at age $A - 1$; (ii) appealing to (3), the second equality indicates that the individual did not smoke at age $A - 1$. The consequence of having $\pi_A = p_{A-1}^*$ on the choice of θ_A is that *any* $\theta_A \in [0, 1]$ is optimal. So, in particular, *the individual has no reason to play down the true risk at age A* . This is intuitive: one would expect that, if the individual did not underestimate the risk in the previous period and did not smoke either, she would be inclined not to underestimate the risk also at age A , because as a consequence of not having smoked at age $A - 1$, the expected health cost at age A remains the same (see (1) and (3)).

Consider now the scenario in which $\pi_A > p_{A-1}^*$.¹⁸ In addition, suppose s_A^* is an interior solution to (7).¹⁹ There are three terms in the expression between brackets that capture the trade-off facing the individual of age A at the moment of making her decision on θ_A . The first two summarize the *marginal benefits* of underestimating the personal smoking risk, whereas the third term captures the corresponding *marginal cost*. The first term, which is negatively signed, expresses the marginal effect that a change in θ_A would have on well-being if smoking behavior were unchanged, i.e., if s_A^* remained the same in spite of the manipulation of beliefs. This term can be interpreted as the anticipatory (net) *disutility* of smoking in case a health shock occurs, given a consumption level s_A^* . In the context of the choice of beliefs at age A , such disutility is anticipatory because thinking about the possible *future* health consequences of smoking has an impact on the individual's *current* well-being; in particular, it produces uneasiness in the individual that has to take a stand on the risk. This provides the agent with incentives to believe that smoking is not so risky to relieve her conscience. Thus, all other things equal, she will be tempted to choose a smaller θ_A^* .

The second term between brackets is also negatively signed. It captures the anticipatory

¹⁸Appealing to the discussion in the above paragraph, this means that either the individual underestimated the risk at age $A - 1$ or she did not smoke at age $A - 1$ (or both).

¹⁹Below I discuss the individual's risk perception choice when she anticipates being a non-smoker at age A , so that s_A^* is a corner solution to (7).

utility effects of a change in θ_A on benefits and withdrawal symptoms, *taking into account the induced change in smoking behavior*. Consider, for instance, an increase in θ_A . The individual realizes that, due to the larger perceived risk, she will decide to consume less cigarettes, and hence she will enjoy smaller benefits and she will suffer the associated withdrawal effects as well. The anticipation of these effects discourages the agent to take the personal risk too seriously. Therefore, all other things equal, this provides her with incentives to choose a smaller θ_A^* .

The third term, which is positively signed, captures what I shall call the *self-deception cost*. Since belief manipulation influences smoking behavior when s_A^* is an interior solution to (7), there is a positive cost of maintaining false beliefs: the individual acknowledges that being optimistic introduces an *avoidable* distortion in cigarette consumption that may lead to worse outcomes. That is, downward-biased beliefs will induce more cigarette consumption, which could in turn produce more severe health losses in the next years and hence a lower utility. The presence of this self-deception cost poses a psychological obstacle to self-deception, thus discouraging the individual from choosing a smaller θ_A^* .²⁰

The above discussion analyzes the trade-off embedded in the individual's decision regarding θ_A when the chosen θ_A^* is interior and s_A^* is interior as well. Still supposing that s_A^* is interior, two interesting additional cases are given by the two possible corner solutions to (10). The individual will choose $\theta_A^* = 1$ when the marginal self-deception cost outweighs the marginal benefit of underestimation for every θ_A . Formally, $\theta_A^* = 1$ if and only if $\frac{\partial W(p_A, q_A, I_A)}{\partial \theta_A} > 0$ for all $\theta_A \in [0, 1]$; that is,

$$\theta_A^* = 1 \Leftrightarrow p_A u_{\hat{L}_A} \hat{L}'_A(s_A^*) \frac{\partial s_A^*}{\partial p_A} > \left| \left[u_{B_A} B'_A(s_A^*) \frac{\partial s_A^*}{\partial p_A} + u_{C_A} C'_A(s_A^*) \frac{\partial s_A^*}{\partial p_A} \right] - \Delta u_A(s_A^*) \right|.$$

²⁰Even though Rabin (1994) formally introduces a psychic cost of maintaining false beliefs, the alleged cause of its emergence is different from the one discussed here. This is due to the different nature of smoking behavior and moral behavior. Rabin (1994, p. 178) argues that manipulating beliefs about the morality of an activity is difficult because “to some degree, our beliefs reflect our ‘true’, disinterested consciences.”

So even though perceived health losses are not sufficiently severe for the individual not to smoke at age A , they are severe enough—relative to smoking benefits and withdrawal effects—to discourage belief manipulation; the individual chooses $\theta_A^* = 1$ (which implies that $p_A = \pi_A$) because he considers that playing down the risk would entail too large a potential health cost by inducing a larger consumption. This situation deserves an important remark: smoking risk perceptions in a standard model, where p_A is *constrained* to be π_A , can actually be reinterpreted as *chosen* beliefs associated to the corner solution $\theta_A^* = 1$. Thus, according to this reinterpretation, in the standard model the individual *decides* that playing down the risk is not worthwhile because the implied distortion in consumption entails too severe a potential health cost. So, importantly, the standard model can be subsumed under the model of smoking risk perceptions presented in this paper.

In contrast to the above situation, the individual will choose $\theta_A^* = 0$ when the marginal benefit of underestimation outweighs the marginal self-deception cost for every θ_A . It is worth going back to the two components of the marginal benefit of underestimation that appear in (11) to better understand when this situation can arise. Notice that the analysis will hinge on how severe the individual thinks potential health losses are. One possibility is that perceived health costs are quite small relative to smoking benefits and withdrawal effects. In this case, incorporating the new risk information at age A to any extent induces a smaller consumption, and the foregone smoking benefits and the withdrawal effects combined outweigh the reduction in potential health losses. Thus incorporating new risk information only reduces well-being. Another possibility is that perceived health losses are large, but the need for reassurance that underlies underestimation—captured by the term $-\Delta u_A(s_A^*)$ in (11)—is so strong that it outweighs the large self-deception cost. So in this extreme case the individual maximizes current well-being by completely ignoring the new risk information. For example, he could refuse to watch TV advertisements or listen to radio advertisements that highlight the seriousness of potential health consequences, and thus deliberately avoid

thinking about the risk. In Section 3 I will resume the analysis of this extreme situation when I discuss how risk perceptions may vary as potential health losses are perceived more vividly.²¹

Finally, consider now the choice of an individual who anticipates that he will not smoke at age A whatsoever, so that now s_A^* is a corner solution to (7). In this case, well-being is

$$W(p_A; \gamma, \xi_A, S_A, \eta_{A-1}, q_A, I_A) = u[0, C_A(0; S_A), 0] + v(y_A^*).$$

That is, the individual's well-being does not depend on the perceived smoking risk because manipulating beliefs will not change her smoking behavior. As a result, the individual is indifferent among all values of $\theta_A \in [0, 1]$. So, in particular, *she has no reason to play down the true risk.*²² This result has an interesting corollary regarding how this model compares to a standard model of smoking. Consider a current smoker who is planning to quit: this situation is represented by an individual whose smoking decisions satisfy $s_{A-1}^* > 0$ and $s_A^* = 0$. In a standard model in which beliefs are constrained to be the true risks, the individual chooses not to smoke at age A because, *given* her belief π_A , the full cost of smoking is sufficiently large. This consumption decision is captured by (9). In contrast, in this model the individual could *choose* any belief $p_A \in [p_{A-1}^*, \pi_A]$, but she chooses $p_A = \pi_A$ because there is no need for reassurance about the personal risk given that she anticipates that she will not smoke. Importantly, both models are consistent with the same smoking behavior and risk perception. Consequently, surveys that report that people who plan to quit judge their smoking risk higher than do people who do not plan to quit (e.g. Weinstein

²¹It may seem unlikely that the individual will completely disregard the new information. Indeed, there is evidence from the psychology literature indicating that motivated biases are constrained by available evidence, in the sense that individuals do not completely ignore reality when forming biased beliefs (Kunda 1990). In line with this evidence, the extreme case discussed here can be thought of as an approximation of a more realistic situation in which the individual attaches a very small weight (sufficiently close to zero) to the new risk information.

²²Notice that, in terms of the characterization of the chosen belief, this situation is analogous to that in which $\pi_A = \hat{p}_{A-1}$, which was discussed before.

et al. 2005) cannot actually distinguish between this model and the standard one.

3 Comparative Statics

The above discussion highlights that the main insight of the model is that, in general, personal risk perceptions depend not only on available risk information, but also on the perceived severity of potential health losses, smoking benefits and withdrawal effects. This is a significant departure from the standard model, which assumes that beliefs depend only on available risk information. The dependence of risk perceptions on these factors offers the opportunity to examine some comparative statics indicating how smoking risk perceptions at age A , p_A , respond to changes in the relevant parameters. Specifically, assuming an interior solution to both the consumption and the belief choice problems, in this section I discuss the following comparative statics: (i) $\frac{\partial \theta_A^*}{\partial q_A}$; (ii) $\frac{\partial \theta_A^*}{\partial \gamma}$; (iii) $\frac{\partial \theta_A^*}{\partial \xi_A}$.²³ For expositional convenience and to ease intuition, from now on I assume:

$$(a1) \quad u[B_A(s_A), C_A(s_A), \eta_A \hat{L}_A(s_A)] = B_A(s_A) - C_A(s_A) - \eta_A \hat{L}_A(s_A)$$

(a2) $v(y_A) = ay_A$. This assumption eliminates income effects, which are probably very small for small price changes in many addictive goods.²⁴

$$(a3) \quad \frac{\partial^2 L_A(s)}{\partial s^2} = 0.$$

$$(a4) \quad \frac{\partial^2 s_A^*(p_A, \dots)}{\partial \gamma \partial p_A} \leq 0, \quad \frac{\partial^2 s_A^*(p_A, \dots)}{\partial \xi_A \partial p_A} \geq 0.$$

This means that s_A^* is more sensitive to the perceived risk the better the perception of health losses (higher γ) and the weaker the taste for smoking (lower ξ_A).

Due to the complexity of the mechanisms driving the formation of risk perceptions, the responses of risk perceptions to changes in the parameters of interest do not have an unam-

²³ Another comparative static is $(\theta_A^*|_{\eta_{A-1}=1} - \theta_A^*|_{\eta_{A-1}=0})$. However, I do not discuss it in the text for two reasons: first, the intuition is analogous to that of $\frac{\partial \theta_A^*}{\partial \gamma}$; second, the proposed test of the model discussed in Section 4 hinges on the other three comparative statics but not on this one.

²⁴ Gruber and Koszegi (2001) make the same assumption.

biguous sign. An important aspect of the analysis is that the sign of a particular response will depend, in turn, on the responsiveness of the (anticipated) cigarette consumption schedule to the parameter being changed. For example, the magnitude of $\frac{\partial s_A^*(p_A, \dots)}{\partial q_A}$ —which tells us how responsive to the price cigarette consumption is—is a crucial determinant of the sign of $\frac{\partial \theta_A^*}{\partial q_A}$. The basic intuition is that the ease with which the individual can change her smoking behavior affects her incentives to play down the risk; in particular, the more difficult it is to cut consumption (due to large withdrawal effects, for instance), the more difficult it is to avoid health costs based on own actions, and hence the stronger the incentive to (partially) disregard the personal likelihood of suffering those costs so as to relieve the stress produced by thinking about them. Next, I discuss each of the comparative statics in detail.

1) The response of risk perceptions to an increase in the price of cigarettes

Suppose q_A rises from q_A^0 to q_A^1 . Let θ_A^0 (resp. θ_A^1) denote the solution to (10) when the price is q_A^0 (resp. q_A^1). Appealing to (11), we know that $\frac{\partial W(\theta_A^0, q_A^0, I_A)}{\partial \theta_A} = 0$. We want to establish under what conditions $\frac{\partial W(\theta_A^0, q_A^1, I_A)}{\partial \theta_A} \geq \frac{\partial W(\theta_A^1, q_A^0, I_A)}{\partial \theta_A} = 0$, which implies that $\theta_A^1 \geq \theta_A^0$. Let us examine (11), making the dependence on q_A more explicit:

$$\begin{aligned} \frac{\partial W(\theta_A^0, q_A^0, I_A)}{\partial \theta_A} &= (\pi_A - p_{A-1}^*) \{ -\hat{L}_A(s_A^*(q_A^0)) \\ &\quad + [B'_A(s_A^*(q_A^0)) - C'_A(s_A^*(q_A^0)) - p_A \hat{L}'_A(s_A^*(q_A^0))] \frac{\partial s_A^*(q_A^0)}{\partial p_A} \} \\ &= 0 \end{aligned}$$

Now consider the change in price. If q_A were equal to q_A^1 rather than q_A^0 , in general we would have $s_A^*(q_A^1) \leq s_A^*(q_A^0)$. Consider first the case in which $s_A^*(q_A^1)$ is very similar to $s_A^*(q_A^0)$, i.e., s_A^* is slightly responsive to price; for instance, this could be due to large withdrawal costs C_A that reflect a relatively strong addiction. In this case, the marginal benefits of underestimation will outweigh the marginal costs. The intuition is as follows.

With the higher price and the associated slightly smaller consumption, there is a slightly weaker incentive to hide the risk, because the already smaller consumption induced by the higher price effectively entails less severe health losses. This means that $\hat{L}_A(s_A^*(q_A^1))$ is slightly smaller than $\hat{L}_A(s_A^*(q_A^0))$. However, cutting consumption is very painful (large C'_A); this means that $C'_A(s_A^*(q_A^1)) \gg C'_A(s_A^*(q_A^0))$. This significantly reinforces the incentive to hide the risk, thus offsetting the previous effect. So when withdrawal effects are sufficiently large, the individual finds it extremely difficult to change her smoking behavior in spite of the price increase, and she will be more willing to play down the risk so as to sustain her deep-seated behavior and feel more comfortable with it. Formally, we will have that $\frac{\partial W(\theta_A^0, q_A^1, I_A)}{\partial \theta_A} \leq \frac{\partial W(\theta_A^0, q_A^0, I_A)}{\partial \theta_A} = 0$ and hence $\theta_A^1 \leq \theta_A^0$: facing a larger price, the individual will decide to place a smaller weight on new risk information and hence her perceived risk will be *lower*.

In contrast, consider now the case in which s_A^* is very responsive to price because C_A is small. Since cutting consumption in response to the higher price is much easier, the individual can already feel more comfortable with her behavior by directly reducing consumption—which reduces the severity of potential losses, and thus there will be much less effective need for reassurance about the risk. Then in this case we will have $\theta_A^1 \geq \theta_A^0$: the individual will decide to place a larger weight on new risk information and hence her perceived risk will be *higher*.

Note that, in this model, the price of cigarettes affects final cigarette *consumption* through both a direct channel and an indirect channel. The former consists of the impact of the price on consumption given beliefs; the latter consists of the impact of the price on consumption that occurs via the influence of the price on beliefs. More formally, we can write final cigarette consumption as $s_A^*(p_A^*(\theta_A^*(q_A)); q_A)$, where the notation is intended to highlight both channels of influence.²⁵ Hence, the response of final consumption to a change in price is given by

²⁵Remember that in Section 2.2.2 we expressed the cigarette consumption schedule as

$\frac{\partial s_A^*(p_A^*(\theta_A^*(q_A)); q_A)}{\partial q_A} = \frac{\partial s_A^*}{\partial q_A} \Big|_{p_A=p_A^*} + \frac{\partial s_A^*}{\partial p_A^*} \frac{\partial p_A^*}{\partial \theta_A^*} \frac{\partial \theta_A^*}{\partial q_A}$. When the consumption schedule is slightly sensitive in general, both $\frac{\partial s_A^*}{\partial q_A} \Big|_{p_A=p_A^*}$ and $\frac{\partial s_A^*}{\partial p_A^*}$ are negligible; therefore, final consumption is slightly sensitive to the change in price.

This contrasts with the case in which the consumption schedule is highly sensitive. In this case, both $\frac{\partial s_A^*}{\partial q_A} \Big|_{p_A=p_A^*}$ and $\frac{\partial s_A^*}{\partial p_A^*}$ are negative and large; moreover, as discussed above, $\frac{\partial \theta_A^*}{\partial q_A}$ is positive. Therefore, $\frac{\partial s_A^*(p_A^*(\theta_A^*(q_A)); q_A)}{\partial q_A}$ is negative and large, meaning that final consumption is very responsive to a change in price. In particular, consider an increase in q_A as discussed above, and compare the reaction of final consumption in this model with that in the standard model, where p_A^* is constrained to equal π_A . Due to this feature, in the standard model there is no indirect effect of the price on consumption. This implies that, when final consumption is highly sensitive, the reduction in consumption in this model is *larger* than that in the standard model. This result is relevant for policy purposes, because it suggests that taxes may be an even more useful policy instrument than they are usually believed to be: not only may taxes reduce consumption directly, but they may also help to mitigate the distortions in consumption produced by belief manipulation. This is one reason why it is important to test whether this model is a more accurate description of smoking behavior than the standard model is. Some possible tests of the model are discussed in Section 4.

2) The response of risk perceptions to a more vivid representation of potential health losses

An increase in γ , which represents a better perception of the seriousness of potential losses, appears to be a hard experiment to think about in practice. However, it can be linked to a concrete example with reference to a set of public health campaigns that were originally conducted in Australia, Canada and UK, and later in several other countries. The campaign

$s_A^*(p_A; \gamma, \xi_A, S_A, \eta_{A-1}, q_A, I_A)$. Now we are looking at final consumption, that is, consumption given optimal beliefs p_A^* : $s_A^*(p_A^*; \gamma, \xi_A, S_A, \eta_{A-1}, q_A, I_A)$. Here parameters other than q_A are suppressed for expositional convenience.

conducted in Australia, consisting of two stages (1997 and 2006), is the most emblematic and salient. The basic premise of this campaign was that featuring chilling images about smoking-related health issues clarifies the health threats, as these images convey much more arousing information than the one that most people have acquired simply by reading and hearing about the risks. The view of the specialists involved in the 1997 National Tobacco Campaign was that the communication challenge of a campaign of this kind is to “translate the specific knowledge about smoking into ‘felt’ experience, rather than cognitive appreciation of risk” (Hill et al. 1998, p. 7).

The mass-media led National Tobacco Campaign, launched by the Australian government in 1997 to promote smoking cessation, included a set of television and radio advertisements. The TV ads were devised to personally involve the smoker by taking them on a journey through their own body (Hill et al. 1998). Thus, one of them featured fatty deposits being squeezed by a surgeon’s gloved hand from a human aorta; other ads depicted harsh images of people affected by lung cancer, emphysema and stroke. A second stage of the campaign, initiated in 2006, consisted of the inclusion of government-mandated graphic warning labels in cigarette packages; these labels warned smokers that smoking also causes other diseases such as peripheral vascular disease and mouth and throat cancer.²⁶ These advertisements featuring chilling images of some negative consequences of smoking could directly help individuals (and especially smokers) to imagine these consequences more vividly. In terms of the model, this amounts to an increase in γ , which would reduce the gap between the perceived magnitude of the damage and the actual magnitude.

Suppose γ rises from γ^0 to γ^1 . Let θ_A^0 (resp. θ_A^1) denote the solution to (10) when γ equals γ^0 (resp. γ^1). We know that $\frac{\partial W(\theta_A^0, q_A, I_A)}{\partial \theta_A} \big|_{\gamma=\gamma^0} = 0$. We want to establish under what conditions $\frac{\partial W(\theta_A^0, q_A, I_A)}{\partial \theta_A} \big|_{\gamma=\gamma^1} \geq \frac{\partial W(\theta_A^0, q_A, I_A)}{\partial \theta_A} \big|_{\gamma=\gamma^0} = 0$, which implies that $\theta_A^1 \geq \theta_A^0$. Again, let

²⁶All the materials related to the National Tobacco Campaign can be found at www.quitnow.info.au.

us look at (11):

$$\begin{aligned}
\frac{\partial W(\theta_A^0, q_A, I_A)}{\partial \theta_A} \Big|_{\gamma=\gamma^0} &= (\pi_A - p_{A-1}^*) \{ -\hat{L}_A(s_A^* |_{\gamma=\gamma^0}; \gamma^0) \\
&\quad + [B'_A(s_A^* |_{\gamma=\gamma^0}) - C'_A(s_A^* |_{\gamma=\gamma^0}) - p_A \hat{L}'_A(s_A^* |_{\gamma=\gamma^0}; \gamma^0)] \frac{\partial s_A^*}{\partial p_A} \Big|_{\gamma=\gamma^0} \} \\
&= 0.
\end{aligned}$$

Recall that the magnitude of the term $\hat{L}_A(s_A^* |_{\gamma=\gamma^0}; \gamma^0)$ captures the extent to which the individual needs reassurance about her own risk. Notice that γ —the perceived severity of health losses—affects this term through two channels. It has a direct effect—holding consumption s_A^* constant, with a higher γ making losses look more severe. It also has an indirect effect that operates through the anticipated adjustment of s_A^* to the higher γ . In particular, since in general we have that $s_A^* |_{\gamma=\gamma^1} \leq s_A^* |_{\gamma=\gamma^0}$, the anticipated reduction in consumption entails a reduction in the *effective* health losses faced by the individual. Thus the net effect of a higher γ on perceived health costs is driven by two opposite forces; which one prevails will crucially depend on the ability of the individual to cut consumption as he imagines losses more vividly.

Consider first the case in which s_A^* is slightly responsive to γ , again possibly because C_A (and C'_A) is very large. Here the direct effect dominates, so a higher γ is finally associated to larger perceived losses. A higher ability to construct a vivid representation of potential losses makes the individual more uneasy about smoking; and given that smoking behavior is hard to change, this feeling creates a stronger need for reassurance about the risk. However, perceiving potential losses more vividly also makes self-deception more costly, which is captured by $-p_A \hat{L}'_A(s_A^* |_{\gamma=\gamma^1}; \gamma^1) \frac{\partial s_A^*}{\partial p_A} \Big|_{\gamma=\gamma^1} > -p_A \hat{L}'_A(s_A^* |_{\gamma=\gamma^0}; \gamma^0) \frac{\partial s_A^*}{\partial p_A} \Big|_{\gamma=\gamma^0}$.²⁷ This discour-

²⁷To see this, first notice that from (2) we have $\frac{\partial \hat{L}'_A}{\partial \gamma} \Big|_{s_A=s_A^*} = -[\eta_{A-1} L'_{A-1}(s) + (1 - \eta_{A-1}) \hat{L}'_{A-1}(s)] + L'_A(s)$. Using (1) as well, we get that $\frac{\partial \hat{L}'_A}{\partial \gamma} \Big|_{s_A=s_A^*, \eta_{A-1}=1} > 0$ and $\frac{\partial \hat{L}'_A}{\partial \gamma} \Big|_{s_A=s_A^*, \eta_{A-1}=0} > 0$, so that $\frac{\partial \hat{L}'_A}{\partial \gamma} \Big|_{s_A=s_A^*} > 0$. Now write $\frac{\partial \hat{L}'_A}{\partial \gamma} = \frac{\partial \hat{L}'_A}{\partial \gamma} \Big|_{s_A=s_A^*} + \frac{\partial \hat{L}'_A}{\partial s_A^*} \frac{\partial s_A^*}{\partial \gamma}$. We have just seen that the first term is posi-

ages the individual from further underestimating the risk. So there are two opposite forces governing the change in beliefs as health problems become more vivid. However, when C'_A is very large, the tension is resolved in favor of further risk underestimation. Smoking is now perceived as having worse consequences but it is still too painful to cut consumption; as a consequence, the stronger need for reassurance about the risk outweighs the also larger self-deception cost.²⁸ Thus in this case $\frac{\partial W(\theta_A^0, q_A, I_A)}{\partial \theta_A} \big|_{\gamma=\gamma^1} < \frac{\partial W(\theta_A^0, q_A, I_A)}{\partial \theta_A} \big|_{\gamma=\gamma^0} = 0$ and hence $\theta_A^1 \leq \theta_A^0$: with a larger value of γ , the individual will decide to place a smaller weight on new risk information and hence her perceived risk will be *lower*.²⁹

In contrast, the smaller C'_A , the more the trade-off underlying belief manipulation is inclined towards a less optimistic risk perception. In this case, the second channel through which γ affects perceived losses—the indirect channel—dominates. When C'_A is small enough, so that s_A^* is very responsive to γ , the individual will react to the greater perceived seriousness of health costs by reducing her consumption in the first place; hence *effective* health costs will be smaller. Thus the need for reassurance will weaken. This, combined with the larger self-deception cost, will encourage the individual to take the risk more seriously. So in this

tive, while (a3) implies that the second term is zero. Hence $\frac{\partial \hat{L}'_A}{\partial \gamma} > 0$. This means that $\hat{L}'_A(s_A^*|_{\gamma=\gamma^1}; \gamma^1) > \hat{L}'_A(s_A^*|_{\gamma=\gamma^0}; \gamma^0)$. Also, by (a4) we have that $-\frac{\partial s_A^*}{\partial p_A} \big|_{\gamma=\gamma^1} \geq -\frac{\partial s_A^*}{\partial p_A} \big|_{\gamma=\gamma^0}$. Putting these two last inequalities together yields the inequality presented in the text.

²⁸More formally, when C_A is very large, s_A^* is not only slightly responsive to γ but also slightly responsive to p_A . This implies that the increase in the marginal self-deception cost associated to the higher γ , as captured by the difference between $-p_A \hat{L}'_A(s_A^*|_{\gamma=\gamma^1}; \gamma^1) \frac{\partial s_A^*}{\partial p_A} \big|_{\gamma=\gamma^1}$ and $-p_A \hat{L}'_A(s_A^*|_{\gamma=\gamma^0}; \gamma^0) \frac{\partial s_A^*}{\partial p_A} \big|_{\gamma=\gamma^0}$, is relatively small. In other words, the increase in the self-deception cost is of second order. In contrast, the increase in the marginal benefit of underestimation, as captured by the difference between $\hat{L}_A(s_A^*|_{\gamma=\gamma^1}; \gamma^1)$ and $\hat{L}_A(s_A^*|_{\gamma=\gamma^0}; \gamma^0)$, is a first-order effect; this effect is reinforced by a large difference between $C'_A(s_A^*|_{\gamma=\gamma^1})$ and $C'_A(s_A^*|_{\gamma=\gamma^0})$. Hence, overall the increase in the marginal benefit of underestimation outweighs the increase in the marginal cost.

²⁹Gold (2008) provides experimental evidence that sometimes the more serious an event's consequences, the greater the optimism for that event. Gold (2008, p. 194) suggests the following mechanism for such effect: "...the greater the event threat, the more reassurance about their risk individuals would require, the more likely they would therefore be to distort their reasoning, and the greater the unrealistic optimism that would result." This is precisely the mechanism just described. It is worth noting, however, that the discussion emphasizes the role that withdrawal effects play in it by making smoking behavior difficult to change. As argued in the next paragraph, further risk underestimation for more serious events is unlikely when withdrawal effects are sufficiently small.

case we will have $\theta_A^1 \geq \theta_A^0$: the individual will decide to place a larger weight on new risk information and hence her perceived risk will be *higher*.

As mentioned before, the dependence of personal risk perceptions on the perceived seriousness of health losses is one of the main insights of this model. In other words, this means that the evaluation of one of the dimensions of the expected health damage—the value of health losses—influences the evaluation of the other dimension—the probability of the health losses. This feature is absent in the standard framework based on rational expectations. However, the channel modeled here is not the only one through which this feature could arise. The fact that an individual’s risk perception may be directly affected by how severe she thinks potential illnesses are has already been suggested by the psychology literature on judgment under uncertainty. This literature argues that individuals use various heuristics to judge risks. In particular, Tversky and Kahneman (1974) argue that the assessment of the probability of a negative event may be strongly influenced by the ability to imagine the sufferings associated with that event vividly, since such ability affects the application of the availability heuristic to judge the risk.³⁰ Notice that this mechanism is purely *unmotivated*, i.e., risk judgment is not affected by any intention the individual may have to play down the risk.

The model presented here is consistent with the idea that individuals apply the availability heuristic to evaluate personal smoking risks, as described by Tversky and Kahneman (1974). However, the model subsumes this judgment heuristic under a *motivated* evaluation process, which is ultimately permeated by the individual’s incentives to underestimate the risk. This is an important distinction. It means that, on top of the *mechanical* difficulties that individuals may find in applying the availability heuristic to judge their personal risks,

³⁰Availability is a clue for assessing frequency or probability which consists of evaluating the frequency of a class or the probability of an event by the ease with which instances or occurrences can be brought to mind. As an example, Tversky and Kahneman (1974, p. 1128) consider the evaluation of the risk involved in an adventurous expedition, pointing out that “the risk may be grossly underestimated if some possible dangers are either difficult to conceive of, or simply do not come to mind.”

there is a *desire* —which may of course be subtle—to believe that smoking is not that risky. Importantly, the discussion in this section has highlighted that when smoking is a very deep-rooted behavior, such desire to play down the risk may counteract the effect of a better perception of health losses. This prediction distinguishes this model from one in which *only* the availability heuristic affects risk perceptions. In the latter, $\frac{\partial p_A^*}{\partial \gamma}$ is *always positive* (or at least nonnegative), because a better perception of losses directly tackles the mechanical limitations to belief formation. On the contrary, this model predicts that $\frac{\partial p_A^*}{\partial \gamma}$ will be negative if C_A is so large that s_A^* is slightly responsive to γ . This difference is important to devise tests of the present model. I exploit this point in the Section 4, when I discuss such tests.

3) The response of smoking risk perceptions to a negative taste shock

Suppose ξ_A decreases from ξ_A^0 to ξ_A^1 . Let θ_A^0 (resp. θ_A^1) denote the solution to (10) when ξ_A equals ξ_A^0 (resp. ξ_A^1). We know that $\frac{\partial W(\theta_A^0, q_A, I_A)}{\partial \theta_A} \big|_{\xi_A=\xi_A^0} = 0$. We want to establish under what conditions $\frac{\partial W(\theta_A^0, q_A, I_A)}{\partial \theta_A} \big|_{\xi_A=\xi_A^1} \geq \frac{\partial W(\theta_A^0, q_A, I_A)}{\partial \theta_A} \big|_{\xi_A=\xi_A^0} = 0$, which implies that $\theta_A^1 \geq \theta_A^0$. Again, let us look at (11), now making the dependence on ξ_A more explicit:

$$\begin{aligned} \frac{\partial W(\theta_A^0, q_A, I_A)}{\partial \theta_A} \big|_{\gamma=\xi_A^0} &= (\pi_A - p_{A-1}^*) \{ -\hat{L}_A(s_A^*(\xi_A^0)) \\ &\quad + \left[B'_A(s_A^*|_{\xi_A=\xi_A^0}; \xi_A^0) - C'_A(s_A^*(\xi_A^0)) - p_A \hat{L}'_A(s_A^*(\xi_A^0)) \right] \frac{\partial s_A^*}{\partial p_A} \big|_{\xi_A=\xi_A^0} \} \\ &= 0. \end{aligned}$$

Since $\xi_A^1 < \xi_A^0$, we have that $s_A^*(\xi_A^1) < s_A^*(\xi_A^0)$. The decrease in the taste for cigarettes will generate a significant reduction in the consumption schedule. This is due to the fact that the negative taste shock attacks the roots of the habit directly, given that it is the liking of smoking that ultimately drives the behavior.³¹ The planned reduction in consumption will make effective losses smaller, which will alleviate the need for reassurance about the risk.

³¹It is still true, however, that the effect of the negative taste shock on the consumption schedule may be mitigated by strong withdrawal effects; this means that even though the pleasure of smoking is weaker, it is not so easy to cut consumption if the *physical* addiction to cigarettes is strong.

This effect will be stronger the smaller is C_A . When C_A is small enough, the individual will decide to take the risk more seriously as a result of the negative taste shock. That is, we will have $\theta_A^1 \geq \theta_A^0$: the individual will decide to place a larger weight on new risk information and hence her perceived risk will be *higher*.

4 Suggested Tests of the Model

This section draws on the comparative statics discussed above to suggest two tests that could be conducted to assess the empirical validity of the model. The first test stems from a survey intended to estimate the response of smoking risk perceptions to an increase in the price of cigarettes. The second test is a laboratory experiment intended to estimate the response of risk perceptions to: (i) a more vivid representation of losses, and (ii) a negative taste shock.

Test 1: smoking risk perceptions and the price of cigarettes

The aim of this test is to establish whether or not personal smoking risk perceptions respond to an increase in the price of cigarettes. The model presented here predicts that risk perceptions are affected by the price of cigarettes, and whether an increase in the latter raises or decreases the perceived risk among smokers depends on how sensitive to the price their cigarette consumption is. Such sensitivity of consumption crucially depends on the taste for smoking and potential withdrawal effects. Nonsmokers' risk perceptions are unaffected by the price, and hence an increase in the latter does not alter risk perceptions. In contrast, in the standard model both smokers' and nonsmokers' risk perceptions are unaffected by the price of cigarettes. Thus, three basic inputs are needed to carry out the test: personal smoking risk perceptions of smokers and nonsmokers, a measure of the taste for smoking and potential withdrawal effects among smokers, and a change in the price of cigarettes. These can be collected in a survey that exploits an effective increase in price via an increase in

cigarette taxes.³²

The basic strategy would be to interview a randomly chosen group of individuals, including both smokers and nonsmokers, before the tax increase, and then interview a comparable group (also randomly chosen) after the tax increase. Within each group, smokers would report their age and answer some questions intended to capture the intensity of their physical addiction: whether they are occasional or daily smokers, how many years they have been smoking, what their habitual consumption has been and, among daily smokers, how many cigarettes they currently smoke per day. Although it is very likely that the physical addiction to cigarettes (C_A in the model) will be highly correlated with the taste for smoking (B_A in the model), the model distinguishes between these two components of smoking utility. One important difference that stems from the model is that the physical addiction is relatively persistent, while the intrinsic taste for smoking is affected by shocks over time. If some individuals with similar consumption histories systematically differ in their intrinsic liking of smoking (because they have experienced different shocks), then they will not be actually comparable. At least conceptually, this is important because the empirical strategy relies on the assumption that individuals who are interviewed after the tax increase are comparable to those who have similar consumption histories and are interviewed before the tax increase; if this were true, the different prices would constitute the only systematic difference in the determinants of smoking risk perceptions across groups. Given that the taste for smoking is not directly observable, a rough measure would be given by the answer to a question about them; an example is a question included in the surveys conducted in the context of the International Tobacco Control Policy Evaluation Project (ITC). Specifically, that question asks smokers to rank their liking of the habit in a scale from 1 to 5.³³

Similarly, the model predicts that risk perceptions are influenced by the occurrence of

³²For instance, the state of California is considering a ballot measure that would raise the cigarette tax by \$1 per pack to fund cancer research and prevention efforts.

³³See <http://www.itcproject.org/research>

health shocks. In practice, the causal link between smoking and the occurrence of the health problem cannot be established; so the model should be interpreted as saying that if the individual can be fairly sure to attribute the shock to smoking, then the shock will influence her risk perception. In order to address the potential issue of systematic differences in the realization of shocks across individuals, they can be asked whether they have experienced any of several smoking-related illnesses; so that if such differences exist, they can be controlled for in the analysis.

Another potentially important control variable is education. It could be correlated with the individuals' familiarity with information about smoking risks and it could affect their ability to judge personal risks using a given amount of information; in addition, as education is likely to be correlated with individuals' social environments and the effective influence of peer effects, it could also affect the intrinsic taste for smoking.

To fix ideas, suppose there are N *smokers* in the sample. Let C identify individuals in the control group (those who are interviewed before the tax increase) and let T identify individuals in the treatment group (those who are interviewed after the tax increase). Suppose that, within group g ($g = C, T$), K subgroups of smokers can be formed based on age range, consumption history, health history, and educational attainment. Let p_{gk} denote the average perceived risk among smokers of group g and subgroup k . With the survey data, we can compute $\Delta p_k := (p_{Tk} - p_{Ck})$, $k = 1, \dots, K$, which is intended to capture the effect of the price increase on average risk perceptions of smokers in subgroup k . The model presented in this paper predicts that $\Delta p_k \leq 0$ for subgroups characterized by a strong addiction, while $\Delta p_k \geq 0$ for subgroups characterized by a weak addiction. In addition, the model predicts that among *nonsmokers*, $\Delta p = 0$. In contrast, the standard model predicts that, among smokers, $\Delta p_k = 0$ for all k , and $\Delta p = 0$ among nonsmokers as well. These hypotheses can

be assessed by performing tests of means for each subgroup of smokers and for nonsmokers.³⁴

Test 2: smoking risk perceptions, perceived severity of health losses, and the taste for smoking

The aim of this test is to find out whether or not personal smoking risk perceptions respond to: (i) a more vivid representation of potential health losses, and (ii) a negative taste shock. The model presented here predicts that risk perceptions are affected by the perceived severity of losses and the taste for smoking. As with the price of cigarettes, whether a better perception of losses (increase in γ) or a negative taste shock (decrease in ξ) induce higher risk perceptions among smokers depends on how sensitive to these factors individual cigarette consumption is. Such sensitivity of consumption crucially depends on potential withdrawal effects, which capture the intensity of the physical addiction. As discussed in Section 3, there is still another channel through which γ affects risk perceptions, namely the use of heuristics to judge risks, à la Tversky and Kahneman (1974). In that model, risk perceptions of all individuals never decrease (and in general increase) as γ increases, and they are unaffected by ξ . Notice that this implies that the model presented here is consistent with an increase in perceived risk among nonsmokers as γ increases. In contrast, in the standard model both smokers' and nonsmokers' risk perceptions are unaffected by an increase in γ or a decrease in ξ .

The suitable setting to assess these effects is the laboratory. One possible experiment has the following basic features. Experimental subjects are randomly assigned to four groups: the first one is the control group (C), while the other three represent three treatment groups ($T1$, $T2$, and $T3$). All experimental subjects are asked questions intended to measure their degree of risk aversion; this measure may be useful as a control variable in analyzing the data.

³⁴We could also compute the average treatment effect for the entire population of smokers as $\sum_{k=1}^K (\frac{N_k}{N}) \Delta p_k$, where N_k is the number of smokers in subgroup k . However, since in the present model Δp_k is expected to be positive for some subgroups and negative for others, the sign of the overall treatment effect is ambiguous.

In addition, as in Test 1, they report their age and education level, and answer questions regarding their consumption and health histories. After the corresponding treatment has been implemented, perceived risks are elicited from individuals in each group. As in Test 1, suppose that, within group g ($g = C, T1, T2$, and $T3$), K subgroups of smokers can be formed based on age range, consumption history, health history and educational attainment, N_k being the number of smokers in subgroup k . Let p_{gk} denote the average perceived risk among smokers of group g and subgroup k . The details of the treatments are as follows:

Group C

These individuals are only asked to report personal smoking risks.

Group T1

Experimental subjects receive purely *factual* information about the potential health consequences of smoking that is publicly available from specialized sources. In other words, they are provided only with general descriptions, statistics and relevant likelihoods that can help them judge their *actual* personal risk π . For expositional convenience, in the model individuals were assumed to know π , but in practice some of them may not know, use or process correctly factual information that is in the public domain.

Group T2

In addition to receiving the same factual information that individuals in $T1$ are given, subjects in this group are provided with *graphic* information illustrating the health effects to which the factual information refers. That is, the images they will look at do not convey novel risk information beyond what is encompassed in the statistical information; instead, they are intended to stimulate a more vivid representation of potential health problems. These images would be like the ones used in the smoking-cessation campaign conducted in Australia that was briefly described above. In terms of the model in this paper, the graphic information raises γ among individuals in this group.

Group $T3$

In addition to receiving both the factual and graphic information that individuals in $T2$ are given, Group $T3$'s experimental subjects are provided with information intended to negatively affect their taste for smoking. In terms of the model in this paper, this can be interpreted as a decrease in ξ . There are two ways of affecting the taste for smoking. One of them is to provide information that is intended to make smoking seem intrinsically less attractive, without any reference to potential health issues. For instance, many nonsmokers would agree that the smokers' skin and clothes usually smell bad after smoking; also, that smoking causes bad breath and affects appearance, e.g. teeth aspect. A second approach exploits the fact that smoking is ultimately associated to the enjoyment of positive affective states and the relief from negative ones. So the idea would be to evoke such connection between smoking and affective states, and then emphasize substitute means of accompanying good feelings (such as excitement or relaxation) or coping with negative feelings (such as distress or fear).

The predictions of the different models are as follows:

(i) $(p_{T1} - p_C) > 0$ indicates that individuals are not using or processing correctly factual information about smoking risks that is publicly available.

(ii) The model in this paper predicts:

$$\begin{aligned} (p_{T2k} - p_{T1k}) & \begin{cases} \geq 0 & \text{if subgroup } k \text{ is characterized by a weak addiction} \\ \leq 0 & \text{if subgroup } k \text{ is characterized by a strong addiction} \end{cases} \\ (p_{T3k} - p_{T2k}) & \begin{cases} \geq 0 & \text{if subgroup } k \text{ is characterized by a weak addiction} \\ \leq 0 & \text{if subgroup } k \text{ is characterized by a strong addiction} \end{cases} \end{aligned}$$

(iii) If *only* the mechanism discussed by Tversky and Kahneman (1974) were present, we would have

$$(p_{T2k} - p_{T1k}) > 0 \quad \text{for all } k = 1, \dots, K$$

$$(p_{T3k} - p_{T2k}) = 0 \quad \text{for all } k = 1, \dots, K$$

(iv) The standard model predicts:

$$(p_{T2k} - p_{T1k}) = 0 \quad \text{for all } k = 1, \dots, K$$

$$(p_{T3k} - p_{T2k}) = 0 \quad \text{for all } k = 1, \dots, K$$

5 Conclusions

This paper presents an economic approach to test whether there is an optimistic bias in smokers' risk perceptions. It develops a model in which forward-looking individuals choose both cigarette consumption and smoking risk perceptions; the latter are optimally chosen in that they trade-off the incentive to be optimistic so as to increase the expected future utility of smoking against the costs of poor health outcomes that result from decisions made based on optimistic beliefs. The model provides a microfoundation of personal smoking risk perceptions by capturing the main underlying mechanisms that govern the incentives to manipulate risk perceptions. By explicitly addressing these mechanisms, the model yields testable implications that can be used to distinguish it from a standard model with bayesian decision makers in which beliefs are constructed *only* upon available information and hence are not manipulated.

Three comparative statics are analyzed in detail, namely the response of smoking risk perceptions to: (i) an increase in the price of cigarettes, (ii) a more vivid representation of potential health losses, and (iii) a negative taste shock. These yield at least two policy implications that are absent in the standard model. First, the perceived *magnitude* of potential health problems is shown to be a determinant of the perceived *likelihood* of suffering those problems. However, enhancing people's perception of the seriousness of potential health problems will lessen (or eliminate) a smoker's optimistic bias only if her cigarette consumption is sufficiently sensitive. Second, when cigarette consumption is sufficiently responsive,

an increase in the price of cigarettes induces a reduction in consumption that is *larger* than it is in the standard model; this is especially relevant for cigarette taxation policies. Drawing on the testable implications, the paper also discusses two empirical tests to assess the validity of the model.

Variations on the approach presented here may also be useful to analyze risk perceptions associated to activities other than smoking, where potential deleterious effects on health are also involved; more generally, it may be useful to study processes of belief formation in broader contexts. That is, the approach may be helpful for further work that aims to understand whether people are optimistic in different environments, and what mechanisms govern the incentives to be optimistic in those environments. Having a better understanding of how people form their beliefs in different contexts is key to better understand economic outcomes and, importantly, for policy purposes, so further work on the nature and determinants of optimism would make a contribution in this respect.

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CHAPTER 2

Does Uncertainty Cause Inertia in Decision Making? An Experimental Study of the Role of Regret Aversion and Indecisiveness

1 Introduction

In many decision situations there is a *status quo* option, which may be the result of a previous choice, or may simply be the option designated as the “default” (i.e., the alternative that ensues if no action is taken). *Inertia*—the tendency to stick with the status quo—has been widely documented.¹ Two commonly cited drivers of inertia in *uncertain* environments are the decision makers’ perception that a default option comes with an implicit endorsement from the default setter (Madrian and Shea 2001), and decision avoidance when there is a large number of alternatives (Dean 2008) or when individuals find it hard to understand the options (Thaler and Sunstein 2008). Yet, two theories of choice under uncertainty suggest two other important mechanisms: (i) *regret aversion* and (ii) *indecisiveness*. A person may experience regret when the outcome of a choice compares unfavorably to the outcome that would have occurred had she made a different choice. On the other hand, a person may be indecisive among the options if she does not know the probability distributions over the relevant outcomes. These two mechanisms might induce substantial inertia even if the choice involves two simple options, there is no scope for value inference, and physical switching costs

¹Samuelson and Zeckhauser (1988) use the term *status quo bias* to refer to this phenomenon. Inertia has been shown to affect several important real-life decisions. These are organ donation (Johnson and Goldstein 2003), the choice of electrical service provider (Hartman et al. 1991), car insurance (Johnson et al. 1993), health insurance (Samuelson and Zeckhauser 1988), investment portfolio (Agnew et al. 2003), contractual choice in health clubs (DellaVigna and Malmendier 2006), and retirement savings (Samuelson and Zeckhauser 1988; Madrian and Shea 2001; Choi et al. 2004; Cronqvist and Thaler 2004). In his 2009 survey of findings from behavioral economics in the field, DellaVigna regarded inertia as “one of the most robust results in the applied economics literature of the last ten years” (DellaVigna 2009, p. 322).

are negligible.

In a laboratory experiment, I investigate whether uncertainty generates inertia in incentivized choices through regret aversion and indecisiveness. The first mechanism is captured by Reference-Dependent Subjective Expected Utility (Sugden 2003; Kőszegi and Rabin 2006, 2007) (henceforth R-D SEU). This theory assumes that people encode outcomes as gains and losses relative to a reference point; it also implies that in certain situations people perceive the status quo option as the reference point. If after switching an individual learns that she would have achieved a better outcome had she retained the status quo, she will experience a sensation of loss. Thus, she will regret having switched. A regret-averse individual that anticipates this possibility may stick with the status quo simply to avoid experiencing regret.²

On the other hand, the hypothesis that indecisiveness may cause inertia in choice under uncertainty is the core of Knightian Decision Theory (Bewley 2002) (henceforth KDT). This theory is based on the premise that *ambiguity* may induce an incomplete preference. This premise implies that an individual may be indecisive between some options when she does not know the probability distributions over outcomes. KDT predicts that an indecisive individual will stick with the status quo when the status quo is not clearly dominated by any other option.

The experiment features a between-subjects design with several conditions. In each condition, I randomly (and privately) assign participants one of two possible tickets to play an individual lottery. Right before the lottery is resolved, I allow participants to switch tickets if they so desire. If they switch, they will receive a small bonus in addition to what

²Note that regret and disappointment are distinct emotions. Regret is “a psychological reaction to making a wrong decision, where wrong is determined on the basis of actual outcomes rather than on the information available at the time of the decision” (Bell 1985, p. 2). By contrast, people experience disappointment if, given a choice, the realized state of the world “compares unfavorably to a state that they expected could possibly happen” (Abeler et al. 2011, p. 471). In the setting on which I focus in this paper, regret and disappointment have different implications for choice behavior. For evidence that anticipated disappointment affects incentivized choices in other settings, see Abeler et al. (2011) and Gill and Prowse (2012).

they get from the lottery. At this point, they make a private keep-or-switch decision, and then they play their individual lottery. In each condition, participants play a different lottery.

The lotteries differ along two dimensions. First, they differ in the degree of uncertainty: some lotteries are ambiguous—participants do not know the winning probabilities of the tickets, and some are fair—participants know that the winning chance of either ticket is 0.5. Second, the lotteries differ in participants’ knowledge about the counterfactual outcome: in some lotteries, participants anticipate that they will learn what the outcome would have been had they played with the rejected ticket; in other lotteries, they know that this information will not be available. By manipulating the degree of uncertainty of the lotteries, I am able to assess the effect of ambiguity-driven indecisiveness on inertia. By manipulating participants’ knowledge about the counterfactual outcome, I affect the potential for regret after a switch that results in a failure to win; hence, I can assess the effect of anticipated regret on inertia.

The experiment is divided into two parts. First, I use a baseline condition to test if regret aversion and indecisiveness *jointly* create inertia; then, I use additional conditions to investigate the *individual* effect of each mechanism. To carry out the joint test, I use an ambiguous lottery in which participants learn the counterfactual outcome. In the baseline condition, I randomly assign each participant either a Red Ticket or a Blue Ticket. In a room next door, an assistant sets up a bag with 10 red and blue balls. Participants know that the bag contains 8 balls of one color and 2 of the other color, but the assistant is the only person in the lab who knows which is the dominant color. At the end of the session, she will draw a ball in front of each participant. The assistant does not see a participant’s ticket until after drawing a ball. A ticket pays the prize if its color matches the color of the ball drawn. Right before the lottery is resolved, I inform participants that they can switch tickets for a small bonus. Then they make the keep-or-switch decision and play the lottery.

As I show, all theories of choice under uncertainty make sharp predictions for choice behavior in this setting. The experimental design enables a clear separation between the set

of theories that predict that participants will switch tickets and the set of theories that predict that participants will not switch. Most theories imply that the Alternative Ticket clearly dominates the Original Ticket as it offers a bonus, and hence predict that participants will switch tickets. By contrast, because the winning chances with either ticket are ambiguous, KDT implies that participants will be indecisive. Indecisiveness is *not* resolved with a small switching bonus. As a result, participants should stick with the Original Ticket. R-D SEU, in turn, implies that individuals perceive a switch that results in a failure to win as regrettable, as they would have won had they not switched. A small switching bonus is insufficient to override the influence of anticipated regret. Hence, R-D SEU also predicts that participants will not switch tickets.

Seventy-percent of participants from the baseline condition keep the Original Ticket. Using a control condition that accounts for potential confounds (such as inattention and carelessness, among others), I demonstrate that most of the inertia is jointly driven by regret aversion and indecisiveness. The baseline condition, however, does not distinguish between the two mechanisms of interest. To disentangle the individual effects, I then tweak the baseline in additional conditions.

To assess whether anticipated regret generates inertia, I face participants with a fair lottery in which the counterfactual outcome is known. Because the lottery is fair, indecisiveness cannot play a role in choice behavior. To investigate whether ambiguity-driven indecisiveness produces inertia, I face participants with a choice between two ambiguous tickets, each corresponding to a different lottery. Since only the chosen lottery is resolved, the counterfactual outcome is unknowable. This feature shuts down the regret channel posed by R-D SEU. Then, in another condition, I make a concession to a broader conception of regret, by which it is not necessary to *know* the counterfactual outcome to experience regret. Using the additional conditions, I find that both mechanisms are individually significant and that they generate about the same amount of inertia.

Overall, anticipated regret and indecisiveness induce a strong reluctance to switch to the Alternative Ticket when the opportunity to switch is a surprise. I find, however, that when either ticket is known to have a winning chance of 0.5, inertia greatly diminishes if participants *anticipate* the opportunity to switch tickets. This finding is predicted by R-D SEU under the hypothesis that reference points are determined by plans (Kőszegi and Rabin 2006, 2007). The result suggests that the plan to use the Original Ticket, rather than mere possession of it, leads regret-averse individuals to refuse to switch.

This paper contributes to at least three bodies of literature. First, the hypothesis that *anticipated* regret affects choice behavior has received support from psychology studies using hypothetical choices (for a review, see Zeelenberg and Pieters 2007); there is, however, little work that examines real choices among uncertain options. Most closely related to my paper are the studies by Bar-Hillel and Neter (1996) and van de Ven and Zeelenberg (2011). Bar-Hillel and Neter (1996) show that many participants from a series of lotteries refuse to switch tickets despite being offered a switching bonus. Although the authors attribute inertia to anticipated regret, the amount of inertia does not seem to depend on knowledge about the counterfactual outcome. While Bar-Hillel and Neter’s design cannot rule out superstitious beliefs (Risen and Gilovich 2007), my design controls for this potential confound. Building upon Bar-Hillel and Neter’s design, van de Ven and Zeelenberg (2011) show that asymmetry in feedback about the outcomes of the chosen and rejected tickets affects people’s willingness to switch tickets. Although van de Ven and Zeelenberg’s results are consistent with regret aversion, their account cannot explain my results with regard to the influence of anticipated regret on choice behavior.³ My design enables a clear distinction among different theories that explicitly incorporate regret aversion. In particular, I show that only R-D SEU predicts the effect of anticipated regret on inertia that I find in the experiment.⁴

³Specifically, van de Ven and Zeelenberg’s account cannot explain why (i) participants are reluctant to switch when they learn the outcome of *both* tickets (and hence feedback is symmetric), and (ii) inertia diminishes when the opportunity to switch tickets is anticipated.

⁴My paper is also complementary to Arlen and Tontrup (2014). Based on research in psychology (e.g.,

Second, my paper adds to the recent experimental research that tests Kőszegi and Rabin's (2006, 2007) hypothesis that reference points are shaped by plans (Sprenger 2010; Ericson and Fuster 2011). Most closely related to my work is the study by Ericson and Fuster (2011), who endow participants with a mug and randomize the probability that they will be allowed to exchange it for a pen. Each participant knows this probability from the beginning. The authors find that participants that are more likely to expect to keep the mug (as they have a low probability of being allowed to exchange) are more likely to retain the mug if given the opportunity to exchange. This finding suggests that it is the expectation of continued ownership, rather than ownership per se, that induces a reluctance to exchange. My approach is complementary in three respects. First, I test Kőszegi and Rabin's (2006, 2007) hypothesis in the domain of gambles, rather than using a choice between two certain options. Second, by manipulating whether or not participants know that they will have the opportunity to switch tickets, I am able to test the hypothesis when the choice set is a surprise. Third, I assess whether the plan to keep the status quo might create inertia by influencing the potential for regret after a switch. Regret does not play a role in Ericson and Fuster's (2011) setting. Our studies find converging evidence on the importance of plans in shaping reference points.

Finally, this paper contributes to our understanding of decision making under ambiguity. A large decision-theoretic literature implies that choice behavior in ambiguous environments could be inconsistent with SEU (Ellsberg 1961; Gilboa and Schmeidler 1989; Bewley 2002; Ghirardato et al. 2004; Klibanoff et al. 2005, 2012; Maccheroni et al. 2006). In particu-

Zeelenberg et al. 1998), the authors conjecture that people anticipate regret over parting with an entitlement whose future value is uncertain only when they feel responsible for the decision to trade their entitlement. Therefore, when entitlement-holders have the option to transact through institutions that divide responsibility for the transaction between multiple actors (such as agency relationships and voting), they should be significantly more willing to trade. The authors test this prediction in the laboratory and online. They assign participants one of two lottery tickets, each of which has a 50 percent winning chance; then they give participants the opportunity to exchange their ticket for the other ticket plus a small monetary bonus. The authors compare the propensity to trade when participants have to decide by themselves to situations in which participants can delegate the trading decision to an agent or to a majority vote. The proportion of participants who trade is substantially larger in the agency and voting conditions.

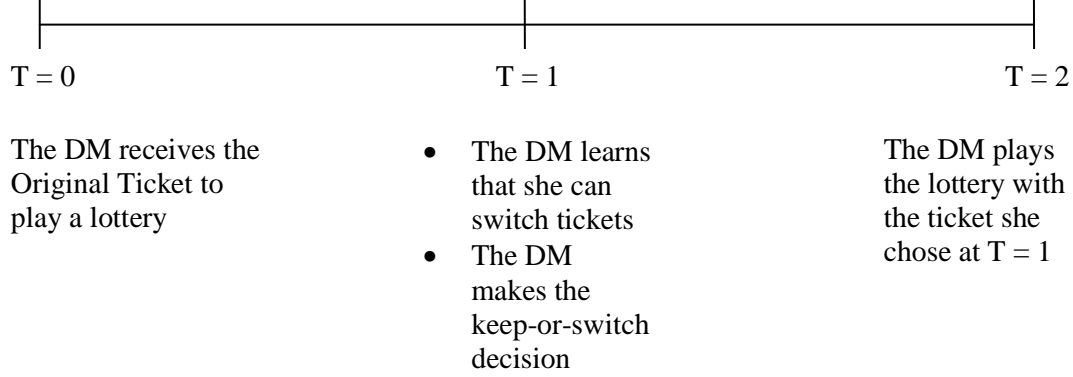
lar, Bewley (2002) forcefully argued that people might have an incomplete preference over ambiguous options, and hence might remain indecisive at times. He proposed a theory of choice (KDT) in which indecisiveness may lead to inertia when there is a status quo option. Despite its intuitive appeal, KDT has not been tested to date.⁵ In this paper I exploit an experimental design in which inertia stands as a behavioral marker of indecisiveness. I demonstrate that ambiguity-driven indecisiveness is real, and I separate its effect on choice behavior from that of anticipated regret.

2 Theoretical Framework

Consider the following decision situation that involves three stages. At $T = 0$, a decision maker (DM) receives one of two tickets to play a lottery that offers a prize of $\$x$ ($x > 0$). I shall refer to the ticket that the DM originally holds as the Original Ticket and to the remaining ticket as the Alternative Ticket. There are two possible states of the world: S and S^C . The Original Ticket pays the prize if state S occurs, while the Alternative Ticket pays the prize if state S^C occurs. At $T = 1$, shortly before the lottery is resolved, the DM has the opportunity to switch tickets. Switching tickets is costless; in addition, if she switches the DM will receive $\$b$ ($0 \leq b \leq x$) in addition to what she gets from the lottery. When the DM receives the Original Ticket at $T = 0$, she may or may not know that she will be able to switch tickets at $T = 1$. I shall say that the opportunity to switch is a *surprise* to the DM if she learns about it at $T = 1$. At $T = 1$ the DM must make a keep-or-switch decision. Finally, at $T = 2$ the lottery is resolved. Figures 1A and 1B illustrate the timing of the

⁵Cettolin and Riedl (2013) document choice behavior that is consistent with an incomplete preference over uncertain options, but do not provide a test of KDT. In their experiment, participants have to choose between an ambiguous gamble and a series of risky gambles. In any given choice situation, participants can avoid an active choice by selecting a fair chance device that eventually assigns them one of the two gambles. The authors find that most participants choose the chance device in at least two choice situations, and show that this behavior cannot be reconciled with standard theories assuming complete preferences. But since KDT does not make sharp behavioral predictions in the absence of a status quo, in principle it cannot be tested using Cettolin and Riedl's design.

FIGURE 1A --- TIMELINE WHEN THE OPPORTUNITY
TO SWITCH TICKETS IS A SURPRISE



decision situation. I shall say that the DM's choice displays *inertia* if the DM retains the Original Ticket at $T = 1$.⁶

Let $(S : y_S, S^C : y_{S^C})$ denote a gamble yielding outcome y_S if state S occurs and outcome y_{S^C} otherwise. Outcomes are nonnegative real numbers designating money. Let w be the DM's initial wealth (i.e., her wealth before participating in the lottery). Notice that both tickets can be expressed as gambles over final wealth (i.e., the DM's wealth after the lottery). The Original Ticket is the gamble $(S : w + x, S^C : w)$ and the Alternative Ticket is the gamble $(S : w + b, S^C : w + b + x)$. Figure 2 displays the keep-or-switch decision as a choice between these two gambles.

⁶In the empirical analysis from Section 3, I use the proportion of individuals who retain the Original Ticket in a given lottery as the relevant measure of the amount of inertia from that lottery.

FIGURE 1B --- TIMELINE WHEN THE OPPORTUNITY TO SWITCH TICKETS IS ANTICIPATED

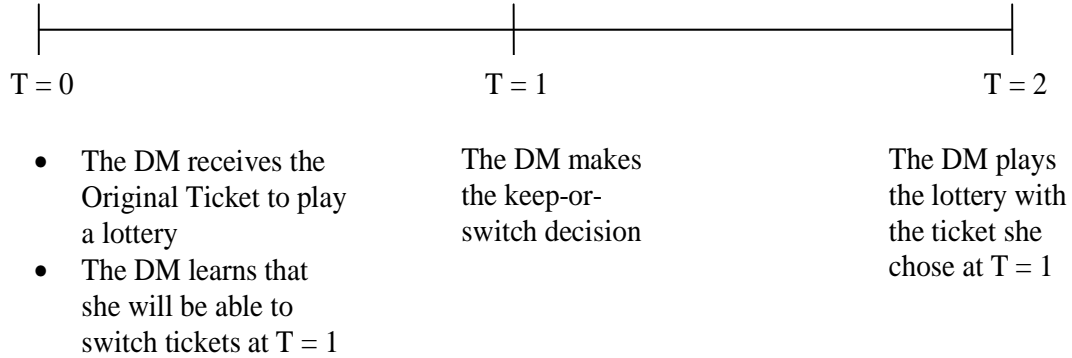
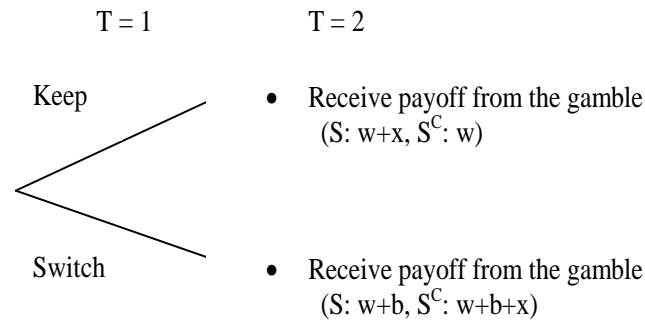


FIGURE 2 --- THE KEEP-OR-SWITCH DECISION



I assume that in this environment the DM holds *beliefs*. A belief $P(S)$ is a subjective probability that S will occur. I consider two sets of lotteries. Within the set of *fair* lotteries, the DM knows that the likelihood of S is 0.5—hence she holds the belief $P(S) = 0.5$. Within the set of *ambiguous* lotteries, the DM does not know the likelihood of S ; I assume that she just knows that the likelihood of S lies in a symmetric range around 0.5. Denote this range

by $[1 - p, p]$, where $0.5 < p \leq 1$.⁷ The DM is clueless about the probability distribution of the likelihood of S over the range $[1 - p, p]$. Some theories assume that the DM holds a single belief in ambiguous lotteries, while other theories assume that she holds multiple beliefs. If the DM holds a single belief, I assume that $P(S) = 0.5$.⁸ On the other hand, if the DM entertains multiple beliefs, I assume that the set of beliefs equals $[1 - p, p]$.

Now consider how the DM evaluates outcomes. A prize of x dollars added to wealth w yields a *consumption utility* of $m(w + x)$. The function $m(\cdot)$ is continuous and strictly increasing, and $m(0) = 0$. An outcome, however, need not be evaluated in isolation—that is, it need not yield *only* consumption utility. In particular, counterfactual outcomes constitute *reference levels* that might affect the overall utility of an outcome. An outcome that is greater than its reference level might be encoded by the DM as a gain, whereas an outcome that is smaller than its reference level might be encoded as a loss. Let $u(w + x|w + r)$ be the overall utility of $w + x$ dollars given a reference level of $w + r$ dollars:

$$u(w + x|w + r) = m(w + x) + \mu(m(w + x) - m(w + r)).$$

The function $\mu(\cdot)$ captures the *gain-loss utility* of $w + x$ dollars relative to the referent, $w + r$ dollars. The outcome $w + x$ is encoded as a gain relative to $w + r$ if $x > r$, and it is encoded as a loss if $x < r$. When gains and losses relative to the referent do not affect utility (i.e., $\mu(\cdot) \equiv 0$), we say that preferences are *reference-independent*. On the other hand, when preferences are *reference-dependent*, the function $\mu(\cdot)$ has the properties of the Kahneman-Tversky value function (Kahneman and Tversky 1979). Specifically, following Section II in Köszegi and Rabin (2006), I assume that $\mu(\cdot)$ satisfies the following properties:

⁷The symmetry assumption matches the experimental setting I describe in Section 3. This assumption is key to identifying the effects of regret aversion and indecisiveness on choice behavior.

⁸The DM could come to entertain such belief by applying the *principle of insufficient reason*: since she has no reason to view one state as more likely than the other, she could assign each state a probability of 0.5. (See Gilboa 2009, p. 14.) Also, $P(S) = 0.5$ is sometimes referred to as the ‘ignorance prior’ (see Fox and See 2003).

A0. $\mu(z)$ is continuous for all z , twice differentiable for $z \neq 0$, and $\mu(0) = 0$.

A1. $\mu(z)$ is strictly increasing.

A2. $\mu'_-(0)/\mu'_+(0) \equiv \lambda > 1$, where $\mu'_+(0) \equiv \lim_{z \rightarrow 0} \mu'(|z|)$ and $\mu'_-(0) \equiv \lim_{z \rightarrow 0} \mu'(-|z|)$.

A2 captures *loss aversion* for small stakes: the DM feels small losses around the reference level more severely than she feels equal-sized gains. The degree of loss aversion is captured by the coefficient λ .

The prize x is a small stake relative to the DM's wealth w , which matches the experimental setting I describe in Section 3. Because this feature of the prize implies that the function $m(\cdot)$ can be taken as approximately linear (Rabin 2000; Kőszegi and Rabin 2006, 2007), in what follows I assume that $m(w + x) = w + x$.

Last, the DM's beliefs and the utility she anticipates from different outcomes jointly determine how the DM evaluates the tickets. Reference levels might vary across states of the world for a given ticket. Thus, we can think of the reference point for that ticket as a gamble over state-contingent reference levels. Let $R_O \equiv (S : w + r_{O,S}, S^C : w + r_{O,S^C})$ and $R_A \equiv (S : w + r_{A,S}, S^C : w + r_{A,S^C})$ denote the reference points when the DM evaluates the Original Ticket and the Alternative Ticket. Notice that R_O and R_A might be different gambles. Given a belief $P(S)$ and a referent R_O , the utility of the Original Ticket is

$$\begin{aligned} U(\text{Original}|R_O) &= W(P(S)) u(w + x|w + r_{O,S}) + W(1 - P(S)) u(w|w + r_{O,S^C}) \\ &= [W(P(S)) + W(1 - P(S))] w + W(P(S)) x \\ &\quad + W(P(S)) \mu(x - r_{O,S}) + W((1 - P(S))) \mu(-r_{O,S^C}), \end{aligned} \tag{1}$$

where $W(\cdot)$ is some strictly increasing probability weighting function, with $W(0) = 0$ and $W(1) = 1$. Similarly, given a belief $P(S)$ and a referent R_A , the utility of the Alternative

Ticket is

$$\begin{aligned}
U(\textit{Alternative}|R_A) &= W(P(S)) u(w + b|w + r_{A,S}) + W(1 - P(S)) u(w + b + x|w + r_{A,SC}) \\
&= [W(P(S)) + W(1 - P(S))] (w + b) + W(1 - P(S)) x \\
&\quad + W(P(S)) \mu(b - r_{A,S}) + W(1 - P(S)) \mu(b + x - r_{A,SC}). \tag{2}
\end{aligned}$$

The general description of preferences encompasses all major theories of choice under uncertainty.⁹ The theories, however, differ in their assumptions about beliefs, reference points, and decision rules. Next, I specialize the general framework to indicate the prediction of each theory for the DM's choice behavior. I organize the discussion by dividing the set of theories into two groups: those that predict that the DM will always switch tickets, and those that predict that the DM will not switch in some lotteries.

2.1 Theories that Predict a Switch

Several theories of choice under uncertainty predict that the DM will switch tickets provided that switching is rewarded with a bonus (i.e., $b > 0$). These theories are Subjective Expected Utility (Savage 1954), Maxmin Expected Utility (Gilboa and Schmeidler 1989), Smooth Ambiguity Preferences (Klibanoff, Marinacci, and Mukerji 2005, 2012), Variational Preferences (Maccheroni, Marinacci, and Rustichini 2006), Prospect Theory (Kahneman and Tversky 1979), Regret Theory (Bell 1982; Loomes and Sugden 1982), and Disappointment Theory (Bell 1985; Loomes and Sugden 1986). Moreover, these theories predict that the DM will switch regardless of whether the possibility of switching is a surprise or is anticipated. The switching bonus b is the key parameter affecting the keep-or-switch decision. All theories imply that the DM would be indifferent between the tickets in the absence of a bonus ($b = 0$);

⁹Strictly speaking, although (1) and (2) are general enough to cover most theories, they do not exactly match utilities in models of ambiguity aversion. For expositional convenience, I prefer to stick to (1) and (2) and modify them once I get to describe the models of ambiguity aversion in the Appendix (Section 5.1.1).

a strictly positive switching bonus breaks indifference in favor of the Alternative Ticket.

The best-known theory within this set is Subjective Expected Utility (henceforth SEU). In this theory, preferences are complete and reference-independent. In all lotteries the DM holds a single belief ($P(S) = 0.5$). The probability weighting function equals the identity function. In the absence of a switching bonus, the tickets are ex-ante identical and hence the DM is indifferent between them. But when there is a bonus the DM strictly prefers the Alternative Ticket, and hence will switch tickets. In the Appendix (Section 5.1) I show that all the other theories I mentioned above make the same prediction as SEU.

2.2 Theories that Predict that the DM Will Not Switch

Two theories of choice under uncertainty imply that the DM's choice between tickets might display inertia—even in presence of a small switching bonus. These theories are Knightian Decision Theory (Bewley 2002) and Reference-Dependent Subjective Expected Utility (Sugden 2003; Kőszegi and Rabin 2006, 2007). KDT and R-D SEU, however, do *not* sharply predict that the DM will *never* switch. When the opportunity to switch is a surprise, R-D SEU predicts that the DM's choice will display inertia in any lottery; KDT, on the other hand, predicts that the DM will not switch only in ambiguous lotteries. When the option to switch is anticipated, R-D SEU predicts that the DM's choice will display inertia in any lottery only under a particular hypothesis about the reference point; KDT is vague with respect to ambiguous lotteries.

2.2.1 Knightian Decision Theory (KDT)

Preferences are reference-independent. When the lottery is ambiguous the DM entertains multiple beliefs. The probability weighting function equals the identity function. The DM

prefers the Original Ticket if and only if

$$U_{KDT}(Original) \geq U_{KDT}(Alternative) \quad \text{for all } P(S) \in [1 - p, p]. \quad (3)$$

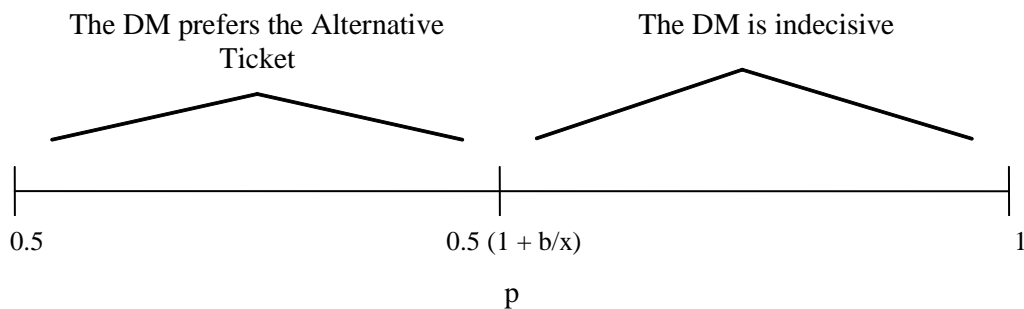
Conversely, the DM prefers the Alternative Ticket if and only if

$$U_{KDT}(Original) \leq U_{KDT}(Alternative) \quad \text{for all } P(S) \in [1 - p, p]. \quad (4)$$

That is, for a ticket to be preferred to the other, it must yield a higher consumption utility for *all* beliefs. When neither (3) nor (4) hold, the DM finds the tickets incomparable. I shall say that in this case the DM is *indecisive*. In the language of choice theory, indecisiveness is a manifestation of an *incomplete preference*. Notice that when the DM faces a fair lottery, she is able to compare the tickets and behaves as a SEU maximizer. In other words, indecisiveness could arise only in ambiguous lotteries. Next, I show exactly when the DM is indecisive, and I explain why the inability to compare the tickets may generate inertia.

Consider an ambiguous lottery. Simplifying (1) and (2), and combining them with (3), we conclude that the DM prefers the Original Ticket if and only if $1 - p \geq 0.5 (1 + \frac{b}{x})$. Conversely, putting (1), (2), and (4) together, we conclude that the DM prefers the Alternative Ticket if and only if $p \leq 0.5 (1 + \frac{b}{x})$. Notice that for the DM to prefer the Original Ticket, $1 - p$ must be at least 0.5 for any values of x and b . Since I assumed $p > 0.5$, it follows that the DM *never* prefers the Original Ticket when the lottery is ambiguous. The reason is simple: $1 - p < 0.5$ means that the Alternative Ticket might offer a larger winning probability than the Original Ticket does; in addition, the Alternative Ticket might offer a bonus. On the other hand, the DM *might* prefer the Alternative Ticket; given the assumption $p > 0.5$, she will if $0.5 < p \leq 0.5 (1 + \frac{b}{x})$. Figure 3 illustrates the DM's preference over tickets for different values of p .

FIGURE 3 --- THE DM'S PREFERENCE OVER
TICKETS IN KDT



Note: The figure illustrates the DM's preference over tickets in KDT for different values of p , given a switching bonus b that is smaller than the prize x .

Notice that in the absence of a switching bonus, the DM does not prefer the Alternative Ticket. Consequently, when there is no bonus the DM is indecisive: neither ticket is preferred to the other. Now consider the reservation bonus—the smallest value of b that induces a strict preference for the Alternative Ticket given a prize x . Let \tilde{b} denote the reservation bonus as a fraction of the prize x . We have $\tilde{b} \equiv (2p - 1)$. When $p = 0.51$, the DM requires a 2% bonus to switch tickets. Because \tilde{b} is increasing in p , a Knightian DM will require *at least* a 2% bonus to switch in *any* ambiguous lottery.¹⁰

A switching bonus smaller than 2% will leave the DM indecisive between the tickets. What will an indecisive DM choose? As it turns out, KDT makes a sharp prediction when the opportunity to switch tickets is a surprise. The theory, however, is vague when the DM becomes aware of the option to switch as soon as she receives the Original Ticket.

Choice Behavior when the Opportunity to Switch Is a Surprise

In Bewley's (2002) model, the DM makes a plan about a choice that will be put into practice later; she makes up her mind to pick a certain alternative among the ones that

¹⁰The DM's reservation bonus could be substantially larger than 2%. For example, for $p = 0.6$ the reservation bonus is 20%, for $p = 0.8$ it is 60%, and for the extreme case $p = 1$ it is 100%.

she *expects* to be available. Suppose that shortly before the choice is put into practice, an alternative that was previously unavailable and whose arrival was unexpected becomes feasible. In this scenario, the DM must decide whether to stick with the original plan or switch to the new alternative. To predict choice behavior, Bewley invoked the *Inertia Assumption*. This assumption states that “if any decision problem occurs by surprise, the decision maker changes his program only if the new program dominates the old one in the new situation” (Bewley 2002, p. 90). In other words, the DM will switch to the new alternative *only if* it is *strictly preferred* to the planned alternative. This implies that if the DM is indecisive, she will stick with her plan.¹¹ In the choice between tickets when the option to switch becomes available by surprise, there is clearly a unique initial plan—playing the Original Ticket, and a new unanticipated alternative—playing the Alternative Ticket. Therefore, as the DM is indecisive, KDT predicts that she will keep the Original Ticket.

Choice Behavior when the Opportunity to Switch Is Anticipated

Now suppose that as soon as the DM receives the Original Ticket, she learns that she will be able to switch tickets. Because the option to switch is expected, the DM could plan to play *either* ticket. Notice, however, that as the tickets are incomparable, the DM will be indecisive at the moment of making an initial plan. The same reason that motivates the Inertia Assumption—choices between incomparable alternatives would be arbitrary without the assumption—now restricts the predictive power of KDT. The model predicts that the DM will stick with her planned choice once she gets to make the keep-or-switch decision, but it does not predict the DM’s initial plan. Thus, KDT does not provide a testable implication when the DM anticipates the opportunity to switch.

¹¹Bewley (2002) notes that it would be equally rational to switch to the new alternative because the DM has no compelling reason to choose either option when she is indecisive. The Inertia Assumption is just “an extra assumption that is consistent with rationality” (Bewley 2002, p. 84).

2.2.2 Reference-Dependent Subjective Expected Utility (R-D SEU)

This theory combines two different basic models: Sugden (2003) and Kőszegi and Rabin (2006, 2007). The DM has a single belief. The probability weighting function equals the identity function. Preferences are complete and reference-dependent. The utility function, which features state-contingent gains and losses, is that of Sugden (2003).¹²

The reference point is the same for both tickets. I consider two competing hypotheses about how it is determined. On one hand, Sugden (2003) assumes that the referent is the ticket with which the DM is *endowed*—namely, the Original Ticket. This is the *endowment hypothesis*.¹³ On the other hand, Kőszegi and Rabin (2006, 2007) posit that the referent is the ticket that the DM *planned* to play between the time she first focused on the lottery and shortly before it is resolved. This is the *plan hypothesis*. When the opportunity to switch tickets is a surprise to the DM, her initial plan is to play the Original Ticket—the only one that was initially available to her. In this case, the plan hypothesis (like the endowment hypothesis) implies that the DM perceives the Original Ticket as the reference point.¹⁴ When instead the option to switch tickets is anticipated, the plan hypothesis (unlike the endowment hypothesis) implies that the DM’s reference point is the Alternative Ticket. (I show this below.)

¹²Taken at face value, Kőszegi and Rabin’s (2006, 2007) model predicts that the DM will switch tickets in any lottery provided that there is a switching bonus. This prediction hinges on the specification of the utility function, which differs from Sugden (2003). In Kőszegi and Rabin’s model, the DM compares outcomes across states of the world, rather than per states of the world. Yet, the main feature of Kőszegi and Rabin’s model is the specification of the reference point, rather than the specification of the utility function. This is the reason why, in the present setting, I regard RD-SEU as a blend of Sugden (2003) and Kőszegi and Rabin (2006, 2007).

¹³The hypothesis that mere ownership of a good results in the good becoming the DM’s reference point when she considers a keep-or-switch decision was originally put forward by Thaler (1980). Sugden (2003) extrapolates the original endowment hypothesis to a setting in which there is uncertainty, taking account of the fact that endowments can be state-dependent.

¹⁴The key premise behind this prediction is that the DM is not expecting to make a choice once she receives the Original Ticket. We can accommodate the surprise by assuming an expectation to face the choice set $\{\textit{Original Ticket}\}$ with near certainty and the choice set $\{\textit{Original Ticket}, \textit{Alternative Ticket}\}$ with very small probability. In this situation, the reference point is the Original Ticket independent of the set $\{\textit{Original Ticket}, \textit{Alternative Ticket}\}$ or what the DM could have expected to choose from such set (if she ever thought about it).

Choice Behavior when the Opportunity to Switch Is a Surprise

When the opportunity to switch tickets is a surprise, the DM's reference point is the Original Ticket: $R_O = R_A = R \equiv (S : w + x, S^C : w)$. This feature of the model has two implications: (i) a failure to win is more painful when it results from switching than when it results from not switching, and (ii) a win is more enjoyable when it follows a switch than when it stems from not switching.¹⁵ Because the DM perceives the Original Ticket as the reference point, the tickets are *asymmetric* in terms of their potential for regret and rejoicing. The asymmetry is clearly captured by the expressions for the utilities of tickets; simplifying (1) and (2), we obtain

$$\begin{aligned} U_{RD}(\text{Original}|R) &= w + 0.5 x \\ U_{RD}(\text{Alternative}|R) &= w + b + 0.5 x + [0.5 \mu(b - x) + 0.5 \mu(b + x)]. \end{aligned}$$

Since the Original Ticket is the referent, holding on to it yields only consumption utility. By contrast, in addition to yielding consumption utility, the Alternative Ticket might also involve a loss or a gain. On one hand, the DM anticipates that she would regret switching if she failed to win—because she *would* have won had she just held on to the Original Ticket. The utility loss from regret would be $\mu(b - x)$. On the other hand, the DM thinks that a win would bring special joy after switching—because she would *not* have won had she not switched. The utility gain from rejoicing would be $\mu(b + x)$. The DM believes that regret

¹⁵There is some psychological evidence on these two implications. The evidence comes from research on the role of counterfactuals in the *anticipation* of regret and rejoicing. (See Kahneman and Tversky 1982; Landman 1987; and Gleicher et al. 1990.) Using vignettes and hypothetical questions, this research has presented two key findings. First, people tend to *imagine* experiencing greater regret over negative outcomes that result from actions taken than over equally negative outcomes that stem from actions foregone. Second, people tend to *imagine* experiencing greater joy over positive outcomes following actions than over equally positive outcomes following failures to act. The finding about *anticipated* regret, however, contrasts with a finding about *experienced* regret reported by Gilovich and Medvec (1995). When people look in retrospect and express their biggest regrets in life, they tend to focus on their failures to act rather than on their actions. The model I describe here is concerned with how the anticipation of regret affects choice behavior, but does not speak to long-term feelings of regret.

and rejoicing are equally likely. Thus, when she evaluates the Alternative Ticket at the moment of the keep-or-switch decision, she weighs the potential loss and the potential gain accordingly.

Define $\Delta U_{RD}(R) \equiv U_{RD}(\textit{Alternative}|R) - U_{RD}(\textit{Original}|R)$. Then,

$$\Delta U_{RD}(R) = b + 0.5 [\mu(b - x) + \mu(b + x)].$$

First suppose that there is no switching bonus—so that the gain and the loss that might result from switching are of equal size (x). Since the DM is *regret-averse*, it follows that $[\mu(-x) + \mu(x)] < 0$ and hence $\Delta U_{RD}(R) < 0$: the DM strictly prefers sticking with the Original Ticket to switching.

Now suppose that switching is rewarded with a bonus. To pin down the reservation bonus \tilde{b} (again as a fraction of the prize), I make two additional assumptions. First, following Section IV of Kőszegi and Rabin (2006), the gain-loss utility function μ is piecewise-linear:

$$\mu(z) = \begin{cases} \eta z & \text{if } z \geq 0 \\ \eta \lambda z & \text{if } z < 0 \end{cases}.$$

The parameter $\eta > 0$ captures the relative weight on gain-loss utility, and $\lambda > 1$ is the coefficient of loss aversion. Second, following Sprenger (2010), $\eta = 1$; this assumption enables me to focus on the (relative) impact of the parameter λ on utility. With these assumptions, given the belief $P(S) = 0.5$,

$$\Delta U_{RD}(R) > 0 \text{ if and only if } b/x > \tilde{b},$$

where $\tilde{b} \equiv \frac{\lambda-1}{\lambda+3}$. A loss-averse DM with an extremely low degree of loss aversion ($\lambda = 1.1$)

requires a 2.4% bonus to switch tickets.¹⁶ Since \tilde{b} is increasing in λ , *any* loss-averse DM will require *at least* a 2.4% bonus to switch.¹⁷ When the opportunity to switch is a surprise and switching is rewarded with less than a 2.4% bonus, R-D SEU predicts that the DM will not switch.

Choice Behavior when the Opportunity to Switch Is Anticipated

Now consider the case in which the DM learns in advance about the opportunity to switch. Like in the previous case, the endowment hypothesis implies that the DM perceives the Original Ticket as the reference point. Therefore, the DM's choice behavior is the same as when the option to switch is a surprise. That is, she will stick with the Original Ticket if switching is rewarded with less than a 2.4% bonus.

The plan hypothesis posits that, in principle, the DM could plan to play either ticket. Her plan will determine her reference point at the moment of the actual keep-or-switch decision. If the DM plans to stick with the Original Ticket, her utility-maximizing behavior will be to follow through on her plan—provided that the bonus is a small fraction of the prize. Holding on to the Original Ticket is a consistent plan—in the words of Köszegi and Rabin (2006), it is a *personal equilibrium*. Alternatively, the DM could initially plan to switch. If she does, she will perceive the Alternative Ticket as her reference point at the moment of the keep-or-switch decision. Then, it will be optimal for her to pursue her plan to switch—switching is also a personal equilibrium for any $b \geq 0$.¹⁸ In sum, *either* plan is consistent in the absence of a switching bonus or when the bonus is small.

¹⁶A loss-averse DM with a lower degree of loss aversion is hardly distinguishable from one who is not loss-averse ($\lambda = 1$). The combination of parameters ($\eta = 1$, $\lambda = 1.1$)—together with the linearity of consumption utility—implies that losses are felt 1.05 times as severely as gains. A smaller λ would imply that losses are felt essentially as severely as gains.

¹⁷The reservation bonus could be substantially larger than 2.4%. For example, a DM with $\lambda = 1.5$ demands a 11% bonus to switch, and one with $\lambda = 3$ requires a 33% bonus. It is worth noting that the often-discussed empirical benchmark in the literature on loss aversion is ($\eta = 1$, $\lambda = 3$); that is, losses are felt on average twice as severely as gains (Tversky and Kahneman 1992; Köszegi and Rabin 2006, 2007; Sprenger 2010).

¹⁸To see why switching is also a consistent plan, write the reference point as $R' \equiv (S : w + b, S^C : w + b + x)$ and notice that $\Delta U_{RD}(R') = b - 0.5 [\mu(x - b) + \mu(-x - b)]$. Clearly, $\Delta U_{RD}(R') > 0$ for any $x > 0$, $b \geq 0$.

Suppose that switching is rewarded with less than a 2.4% bonus. Which plan will the DM make and pursue according to the plan hypothesis? Notice that the DM's *equilibrium* expected utility when she keeps the Original Ticket is $w + 0.5 x$, while her *equilibrium* expected utility when she switches is $w + b + 0.5 x$. The DM anticipates that she will attain the highest ex-ante expected utility if she plans to switch and then pursues this plan. Hence, playing the Alternative Ticket is her *preferred personal equilibrium* (Kőszegi and Rabin 2006). When the option to switch tickets and receive a bonus is anticipated, the plan hypothesis predicts that the DM will switch.

2.2.3 A Hybrid Model

KDT implies that inertia in ambiguous lotteries is caused by indecisiveness, while R-D SEU implies that inertia in any lottery is driven by anticipated regret. In practice, however, the DM might stick with the Original Ticket in an ambiguous lottery because she is both indecisive *and* regret-averse. In the Appendix (Section 5.2) I discuss a straightforward combination between KDT and R-D SEU that accommodates this richer pattern. When the option to switch tickets is a surprise and the switching bonus is small, the Hybrid Model predicts that the DM's choice will display inertia in any lottery. When instead the option to switch tickets is anticipated, the Hybrid Model predicts that the DM will not switch in lotteries with large ambiguity (i.e., when p is large). The model, however, does not make a sharp prediction if p is close to 0.5. Under the endowment hypothesis it still predicts that the DM's choice will display inertia, but under the plan hypothesis it is vague.

2.3 Differentiating between the Theories

Suppose that we could put a series of lotteries into practice to investigate whether indecisiveness and regret aversion cause inertia. Conceptually, I approach this investigation in two steps. First, I pick a baseline lottery to achieve a clean separation between the set of theories

TABLE 1 --- SUMMARY OF LOTTERIES AND PREDICTIONS FOR CHOICE BEHAVIOR

	Lottery			
	BASE	REG	END	IND
Type of lottery	Ambiguous	Fair	Fair	Ambiguous
Counterfactual outcome	Known	Known	Known	Unknowable
Option to switch tickets	Surprise	Surprise	Anticipated	Surprise
Switching bonus	1%	1%	1%	1%
Theories that predict inertia	R-D SEU, KDT, Hybrid	R-D SEU, Hybrid	R-D SEU, Hybrid	KDT, Hybrid
Mechanisms	Regret aversion (EH & PH)* Indecisiveness	Regret aversion (EH & PH)	Regret aversion (EH)	Indecisiveness

* EH: endowment hypothesis; PH: plan hypothesis

that predict a switch and the set of theories that predict that the DM will not switch. Thus, the baseline reveals whether regret aversion and indecisiveness *jointly* generate inertia. If they do, the second step is to pick a few other lotteries that identify the *individual* influence of each mechanism. Next, I describe a series of lotteries that will guide the empirical analysis of choice behavior. Table 1 summarizes the features of each lottery. The experiment I discuss in Section 3 puts these lotteries into practice.

2.3.1 Do Regret Aversion and Indecisiveness Jointly Generate Inertia?

The BASE Lottery (BASE for *baseline*) is an ambiguous lottery in which the DM learns the counterfactual outcome. To distinguish between the set of theories that predict a switch and the set of theories that predict that the DM will not switch, the BASE lottery must have two additional features. First, switching must be rewarded with a small bonus. Otherwise, most theories (the ones that never predict that the DM's choice will display inertia, and R-D SEU based on the plan hypothesis) imply that choice is indeterminate as the DM is

indifferent between the tickets. Second, the option to switch tickets must be a surprise. When instead this option is anticipated, KDT is vague; and R-D SEU based on the plan hypothesis is observationally equivalent to the theories that never predict that the DM's choice will display inertia. Therefore, I assume that the BASE lottery is ambiguous, the opportunity to switch tickets is a surprise, and switching is rewarded with a 1% bonus. SEU, Maxmin EU, Prospect Theory, Regret Theory, and Disappointment Theory all predict that the DM will switch tickets in the BASE lottery, while KDT and R-D SEU predict that the DM will not switch. Inertia reveals that the DM is indecisive, regret-averse, or both.

2.3.2 Separating the Effects of Regret Aversion and Indecisiveness

Suppose, in the remainder of this section, that the DM's choice in the BASE lottery displays inertia. The next step is to identify the underlying mechanisms.¹⁹ To this end, let me first illustrate the fundamental differences between KDT and R-D SEU with respect to the BASE lottery. These differences will guide the selection of lotteries that I will use to distinguish between indecisiveness and regret aversion.

According to KDT, the utility of an outcome with either ticket is unaffected by counterfactual outcomes. The DM's preference between tickets is affected only by the set of probability distributions $(P(S) : w + x, 1 - P(S) : w)$ and $(P(S) : w + b, 1 - P(S) : w + b + x)$ that the tickets generate over the outcomes. The fact that the lottery is ambiguous turns out to be crucial, as ambiguity prevents the DM from comparing the tickets. Ambiguity makes the DM indecisive; and it is indecisiveness—combined with the Inertia Assumption—that leads the DM to keep the Original Ticket. If the lottery were fair, she would be able to compare the tickets—and she would switch.

Compare to R-D SEU. Comparisons across tickets within states of the world result in a

¹⁹In this setting, it would be hard to achieve further separation within the set of theories that predict a switch. What makes further separation difficult is the fact that all these theories make the same prediction regardless of (i) whether the lottery is fair or ambiguous, (ii) whether the option to switch tickets is a surprise or is anticipated, and (iii) the value of the switching bonus.

preference for the Original Ticket. In particular, because the Original Ticket is the reference point, a failure to win after a switch would be regrettable, and regret aversion induces inertia. Importantly, the influence of this mechanism is unaffected by the fact that the BASE lottery is ambiguous. Although the DM does not know the likelihood of S , she holds the belief $P(S) = 0.5$. Her behavior would be the same if the lottery were fair.

Now consider one variation of the BASE lottery. The REG lottery (REG for *regret*) differs from the BASE lottery *only* in that it is a fair lottery. Because ambiguity is removed, KDT predicts that the DM will switch.²⁰ On the other hand, since the regret channel remains the same as in the BASE lottery, R-D SEU predicts that the DM will not switch. The Hybrid Model—which is reduced to R-D SEU in fair lotteries—also predicts that the DM will not switch. Then, inertia in the REG lottery identifies a regret-averse DM, which in principle is consistent with both R-D SEU and the Hybrid Model.

Suppose that the DM’s choice in the REG lottery displays inertia. According to R-D SEU, regret aversion causes inertia because the Original Ticket is perceived as the reference point. As we have seen, there are two different hypotheses as to *why* the Original Ticket is the DM’s reference point. The DM might perceive it as the referent just because she was endowed with it. Alternatively, she might perceive it as the referent because it is the ticket that she plans to play until she learns that switching is possible. To differentiate between the endowment hypothesis and the plan hypothesis, consider the END lottery (END for *endowment*). The END lottery differs from the REG lottery in just one feature: when the DM receives the Original Ticket, she learns that later she will be able to switch tickets. While the endowment hypothesis predicts that the DM’s choice will display inertia, the plan hypothesis predicts that the DM will switch. Therefore, the END lottery offers a clean test

²⁰Strictly speaking, it might be impossible to *eliminate* ambiguity altogether. To guarantee the removal of ambiguity from the REG lottery, we would need the DM to verify that the likelihood of S is indeed 0.5—but this might be infeasible in practice. Fortunately, the prediction of KDT that the DM will switch in the REG lottery still holds if the DM *believes* that the likelihood of S is 0.5. I will return to this point in Section 3 when I describe the experiment.

between the two hypotheses.

Now consider the IND lottery (IND for *indecisiveness*), another variation of the baseline lottery that I will use to investigate indecisiveness. Recall that in the BASE lottery the two tickets correspond to the same lottery. By contrast, in the IND lottery the DM must choose between two tickets that correspond to two *different* lotteries offering the same prize x . The Original Ticket, which allows the DM to play the Original Lottery, pays the prize with probability q . The Alternative Ticket, which allows the DM to play the Alternative Lottery, pays the prize with probability $1 - q$. (Thus, the Original Ticket is the gamble $(q : w + x, 1 - q : w)$ and the Alternative Ticket is the gamble $(q : w + b, 1 - q : w + b + x)$.) The DM does not know q , but she knows that it lies within the range $[1 - p, p]$. Like in the BASE lottery, the opportunity to switch tickets is a surprise. After the keep-or-switch decision, the chosen lottery is resolved, but the rejected lottery is *not* resolved.

The IND lottery has two key features. First, each ticket generates the same set of probability distributions over outcomes as its counterpart in the BASE lottery. In other words, ambiguity is the same as in the BASE lottery. This implies that the DM will maintain the same beliefs as in the BASE lottery. Second, because only the chosen lottery is resolved, the DM is aware that she will never know what the outcome would have been had she chosen the other ticket. This shuts down the regret channel. Notice the implications for choice behavior: KDT and the Hybrid Model predict that the DM's choice will display inertia, whereas R-D SEU predicts that the DM will switch. Thus, inertia in the IND lottery identifies an indecisive DM, which in principle is consistent with both KDT and the Hybrid Model.

The predictions for choice behavior can be summarized as follows. (See Table 1.) Inertia in the BASE and REG lotteries, but not in the IND lottery, is consistent with R-D SEU alone. Inertia in the BASE and IND lotteries, but not in the REG lottery, is consistent with KDT alone. Inertia in the BASE, REG, and IND lotteries is consistent with the Hybrid

Model. Last, if the REG lottery reveals that the DM is regret-averse, the END lottery distinguishes between the endowment hypothesis and the plan hypothesis. Inertia in the END lottery is consistent with the endowment hypothesis, while a switch is consistent with the plan hypothesis.

3 Experiment

3.1 General Aspects of the Design

Drawing upon the theoretical framework, I conducted a laboratory experiment on the campus of the University of California, Los Angeles. I ran the sessions at the Anderson Behavioral Lab, with students drawn from the laboratory’s subject pool. The experiment features a between-subjects design with seven conditions, each of which has around 50 participants. I carried out each condition through several sessions, with between three and twelve participants per session.

I conducted the experiment with paper-and-pencil. In each session, upon arrival at the lab, participants were seated at individual carrels; then I gave them a series of handouts containing general and specific instructions (which I also read aloud) and they filled out a few forms. Towards the end of the session participants made an incentivized choice.²¹ All payments from a given session (including a \$6 show-up fee) were made by the lab manager through a deposit to participants’ university accounts in the following two or three weeks. The sessions lasted between 30 and 35 minutes; I ran them with the help of one or two assistants, whom I introduced as I read the first portion of instructions.²²

²¹In all conditions but one (the BCR condition), participants made a single choice. In the BCR condition, one of the several choices was selected to be played out using the random-lottery method.

²²The assistants varied across sessions. The protocol could have been carried out with only one assistant per session, but in most sessions I used two to run the sessions faster. I told participants that the two assistants would proceed independently, and that each assistant would interact with roughly half of the participants in the session. (See instructions in the Appendix.) Therefore, in what follows I describe the protocol as if I had used a single assistant in all sessions.

The structure of a session was common to all conditions. At the beginning of the session, I endowed participants with one of two tickets to take part in an individual lottery that offered a \$10 prize. The lottery was to be resolved at the end of the session. After the first round of instructions, participants filled out a few questionnaires and received a reminder about the upcoming lottery. Before the lottery was resolved, I gave them the opportunity to switch tickets; switching was rewarded with a \$0.10 bonus. Finally, participants made the keep-or-switch decision privately and played the lottery. The conditions differed only in the particular characteristics of the lottery.

Table 2 summarizes some demographic characteristics of the pool of participants.²³ For each experimental condition, it shows the percentage of participants who previously participated in other experiments, are women, are Asian, are undergraduate students, pursue a major that is Math-intensive or intensive in formal logic, and are native English speakers.²⁴ For each of these observable characteristics, the last column of the table displays the result of a chi-square test of differences in proportions across conditions. Although some differences do exist, particularly in the proportions of undergraduate students and native English speakers, participants seem to be broadly balanced on observable characteristics. Table 3 summarizes the features of each condition; it also reports the main results in the last two rows. The Appendix contains more details about procedures, as well as full instructions and a sample of the forms that participants filled out.

²³Participants reported this information on one of the forms that they filled out.

²⁴For a classification of majors, see the Appendix (Section 5.3).

TABLE 2 --- DEMOGRAPHIC CHARACTERISTICS OF PARTICIPANTS

Variable*	Condition							Chi-Square Test p-value*
	BASE (N = 50)	TRUST (N = 51)	CONTROL (N = 49)	REG (N = 52)	END (N = 47)	IND (N = 48)	BCR (N = 49)	
Other Experiments	86%	82%	84%	78%	83%	67%	84%	0.251
Female	80%	80%	82%	82%	72%	75%	73%	0.796
Asian	62%	57%	61%	57%	60%	46%	43%	0.335
Undergraduate	92%	96%	94%	86%	93%	79%	71%	0.001
Math-Related Major	46%	33%	31%	33%	28%	44%	24%	0.217
English 1 st Language	60%	67%	67%	80%	81%	63%	82%	0.046

* The p-values are for chi-square tests of differences in proportions. For each variable, the null hypothesis is that the percentage of participants with the relevant characteristic is the same in all experimental conditions.

3.2 The Joint Effect of Regret Aversion and Indecisiveness on Choice Behavior

3.2.1 The Baseline

The BASE condition puts the BASE Lottery into practice. In a typical session, I showed participants an empty black bag sitting on the front desk. The assistant was standing behind the front desk while I read the first portion of instructions. I informed participants that the assistant would take the bag with her to the adjacent room and fill it with 10 red and blue balls in total. The bag would be used at the end of the session to play an individual lottery. I told participants that they would go, one at a time, to the adjacent room, where the assistant would randomly draw a ball from the bag in front of them. (I told participants that the balls would be drawn with replacement.)

TABLE 3 --- DESIGN FEATURES AND MAIN RESULTS

	BASE	TRUST	CONTROL	Condition		IND	BCR
	BASE	Robustness check of BASE condition	CONTROL	REG	END	IND	Robustness check of IND condition
Lottery	BASE	Robustness check of BASE condition	CONTROL	REG	END	IND	Robustness check of IND condition
Winning probabilities	Unknown; 0.2 or 0.8	Unknown; 0.2 or 0.8	Known; 0.5	Known; 0.5	Known; 0.5	Unknown; 0.2 or 0.8	Unknown; between 0 and 1
Prize	\$10	\$10	\$10	\$10	\$10	\$10	\$10
Switching bonus	\$0.10	\$0.10	\$0.10	\$0.10	\$0.10	\$0.10	\$0.10
Number of participants	50	51	49	52	47	48	49
Number of Keep choices	35	40	15	28	17	38	24
Percentage of Keep choices							
<i>Point estimate</i>	70%	78%	31%	54%	36%	79%	49%
<i>Confidence interval (95%)</i>	(57%, 83%)	(67%, 90%)	(18%, 44%)	(40%, 67%)	(22%, 50%)	(68%, 91%)	(35%, 63%)
Excess inertia*	39%	47%	---	23%	5%	48%	18%
Result**	$p < 0.001$	$p < 0.001$	---	$p = 0.009$	$p = 0.282$	$p < 0.001$	$p = 0.032$

* Excess inertia from a given condition is defined as the difference between the amount of inertia from such condition and the amount of inertia from the CONTROL condition.

** Results are from one-tailed tests of differences in proportions (null hypothesis: excess inertia is smaller than or equal to zero; alternate hypothesis: excess inertia is positive).

Then I told participants that there were two possible tickets to play the lottery—Red and Blue—and that they would be randomly assigned one of the tickets. Specifically, I informed participants that they would pick a closed envelope containing a ticket, and that half of the tickets were Red and the other half Blue. The Red Ticket would pay the \$10 prize if the assistant drew a red ball from the bag at the end of the session (and it would pay nothing otherwise). Conversely, the Blue Ticket would pay the \$10 prize if the assistant randomly drew a blue ball (and it would pay nothing otherwise).

Participants knew that the bag would contain 8 balls of one color and 2 balls of the other color; they did not know, however, which of the two possible compositions would be the

actual composition of the bag. In particular, I told participants that the assistant would pick one of the two possible compositions as she pleased. I emphasized that the assistant would set the bag without seeing any participant’s ticket and check the ticket only after drawing a ball.

After this first round of instructions, the assistant went to the adjacent room and stayed there until the end of the session. Once she had left the main room, I walked around holding a box with closed envelopes and asked each participant to pick an envelope.²⁵ Then, participants answered some demographic questions and filled out the first part of a 44-item “Big Five” personality questionnaire (John, Donahue, and Kentle 1991).²⁶ The questionnaire served two purposes. First, it allowed time for participants to adapt to the new reference point, in case preferences over gambles are reference-dependent. Becoming psychologically accustomed to the reference point might take some time (see, for instance, Strahilevitz and Loewenstein 1998). Second, the questionnaire also served as a decoy for the main decision of interest, which took place at the end of the session (see Ericson and Fuster 2011). This second role of the questionnaire was intended to attenuate experimental effects. After participants finished answering the first 22 questions, I reminded them about the instructions with regard to the lottery, to make sure they understood and also to make them focus on the upcoming lottery.

After they answered the second 22 questions, participants received a Decision Form. Through this form I informed them that they had the opportunity to switch tickets, if they so desired. The form also stated that if they switched, they would receive \$0.10 in addition to what they got from the lottery. Participants indicated whether they wanted to keep the Original Ticket or switch to the Alternative Ticket by checking the corresponding option.

²⁵After handing in the envelopes, I asked participants to check which ticket they had gotten. I allowed them to look inside the envelope whenever they wanted. The envelope remained on each participant’s desk until they grabbed it to play the lottery in the adjacent room.

²⁶This questionnaire was previously used by Ericson and Fuster (2011) in a related experiment about reference-dependent preferences.

Once they had made a decision, participants folded the Decision Form, placed it inside the envelope, and lined up to play the lottery.²⁷

I collected data from 50 participants. The proportion of participants from the BASE condition that displayed inertia was quite large: seventy percent kept the Original Ticket. At the 95% significance level, the probability of retaining the Original Ticket fell between 57% and 83%.

RESULT 1: A substantial proportion of participants from the BASE condition displayed inertia.

3.2.2 Accounting for Potential Confounds

Result 1 suggests that regret aversion and indecisiveness are jointly significant determinants of inertia. The BASE condition, however, might have failed to control for other determinants of inertia. Next I describe six potential confounds—divided into two groups—and I discuss two additional conditions that address them.

A. Lack of Trust in the Experimenter

A participant from the BASE condition could not *verify* that the tickets had in fact been randomly assigned and that the experimenter did not know her ticket. Hence, she might have been suspicious about the unexpected option to switch tickets and get a bonus. Mistrust could have created inertia. Thus, it is crucial to separate the inherent uncertainty about the composition of the bag (one of the deep parameters of interest) from a participant’s lack of trust in the experimenter.

I used the TRUST condition to test if lack of trust had affected choice behavior in the BASE condition. The TRUST condition is a variation of the baseline in which it is impossible to rig the lottery. In a typical session, I walked around the room holding a small bag that

²⁷Recall that all payments (including the \$0.10 bonus) were made through a deposit to participants’ university accounts rather than by cash. This procedure eliminated the potential cost of carrying \$0.10 after the session, which might have discouraged participants from switching tickets.

contained one red ball and one blue ball. Participants checked the bag out. Then, I asked them to randomly draw a ball from the bag, check the color without revealing it to anyone else, and put the ball back into the bag. Once I had left their carrels, they wrote the color down on a blank card, placed the card inside an empty envelope, and closed the envelope. Next, I told them that the card was a ticket to play an individual lottery, and I described the lottery—which was identical to the one from the baseline. The remainder of the session was exactly the same as in the BASE condition. Because each participant was the only person in the lab who knew her own ticket until the lottery was resolved, it was impossible to rig the lottery. This feature removed any potential influence of lack of trust on choice behavior.

I collected data from 51 participants. Seventy-eight percent retained the Original Ticket. A two-tailed test of differences in proportions fails to reject the null hypothesis that this percentage is equal to the one from the BASE condition ($p = 0.333$). This result indicates that participants from BASE believed that the lottery had not been rigged.

B. Other Factors

Carelessness. Participants might have failed to react to the \$0.10 switching bonus because \$0.10 was too small an incentive for them to care about the keep-or-switch decision.

Inattention. Because participants had to make an explicit choice to move on, the keep-or-switch decision was salient. Some participants, however, might not have paid enough attention and hence might have had a tendency to pick the first option that was listed on the Decision Form. I partially addressed this issue by randomizing the order of the options on the Decision Form across participants within a session. This feature of the design reduced the impact of inattention on choice behavior, but it failed to eliminate it.

Concern About the Experimenter’s or Assistant’s Judgment. Participants might have believed that switching for just \$0.10 would make them appear too greedy in front of the experimenter or the assistant. Thus, they might have kept the Original Ticket simply to

avoid this negative judgment.

Belief in Fate. If participants considered the tickets to be identical ex-ante, they might have thought that by switching tickets they would be “tempting fate”—that is, they might have had the “gut feeling” that a switch could reduce their chances of winning the lottery (Risen and Gilovich 2007). Inertia might have been driven by a profound aversion to switching that stems from the fear of tempting fate. The \$0.10 bonus may have been too small to override the influence of this superstitious belief.

Experimental Effects. Although the personality questionnaire served as a decoy for the keep-or-switch decision, it did not necessarily remove all potential experimental effects. For example, some participants might have believed that the experimenter expected people to switch because they were offered a monetary incentive to do so. Based on such belief, they might have construed the decision as a test of their conformity tendencies (Ross and Nisbett 1991). By refusing to switch, these participants might have wanted to show the experimenter that they “do not behave like most people”—for whom switching was supposed to be the normal choice.

I used the CONTROL condition to assess to what extent these other factors could have induced inertia in the BASE condition. The CONTROL condition identifies the amount of inertia that such factors create themselves when regret aversion and indecisiveness do not play a role.

In a typical session from the CONTROL condition, participants saw two transparent plastic cups and two identical ten-sided dice on their desks. I invited them to inspect these objects. Once they were done, I asked participants to place one die inside each cup. Each cup was placed in front of a sticker, which served as a label. One of the stickers had a Vertical Stripe, while the other had a Horizontal Stripe; they were otherwise identical. In some sessions, I told participants that they would use the die labeled with the Vertical Stripe to play a lottery at the end of the session; in other sessions I told participants that they

would use the die labeled with the Horizontal Stripe. I told them that the lottery worked as follows: they would grab the designated die from their carrel, go to the adjacent room, and roll the die in front of the assistant. If a number from 0 through 4 came out, they would win the \$10 prize; if a number from 5 through 9 came out, they would get nothing. Before they played the lottery, they received a Decision Form through which I gave them the option to use the other die. Switching dice was rewarded with a \$0.10 bonus.

The design has three key features. First, because I faced participants with a choice between two 50-50 gambles, they could not be indecisive. Hence, KDT predicts a switch.²⁸ Second, since I allowed participants to roll only one die, the counterfactual outcome was unknowable to a participant. This feature blocked the influence of anticipated regret. Hence, R-D SEU also predicts a switch. Third, other factors should all have exerted the *same* influence on choice behavior as they did in the BASE condition. Together, these three features make the CONTROL condition a suitable benchmark for the BASE condition. Therefore, *excess inertia* from BASE identifies the amount of inertia jointly driven by regret aversion and indecisiveness.

I collected data from 49 participants. Thirty-one percent retained the Original Die. A one-tailed test of differences in proportions rejects the null hypothesis that the percentage in BASE is smaller than or equal to the one in CONTROL in favor of the alternate hypothesis that the percentage in BASE is larger ($p < 0.001$). Moreover, excess inertia from BASE is quite large: it is 1.26 times as large as the amount of inertia found in CONTROL. This suggests that most of the inertia from the baseline was jointly driven by regret aversion and indecisiveness.²⁹

²⁸Although it was impossible for participants to make sure that the dice were identical, they did believe so. In a Post-Decision Questionnaire, I asked participants whether they thought the winning chance of the chosen die was higher than, lower than, or equal to the chance of the rejected die, or whether they could not tell. (Participants answered this question after the keep-or-switch decision but before playing the lottery.) Forty-five out of 49 participants replied that the chances were the same; 3 out the remaining 4 said that they could not tell, but still switched dice. This provides further support for the claim that participants were not indecisive in the sense of KDT.

²⁹The BASE condition has one shortcoming that cannot be resolved by a comparison with the CONTROL

RESULT 2: Most of the inertia from the BASE condition can be jointly attributed to regret aversion and indecisiveness.

The data from BASE, TRUST, and CONTROL indicate that anticipated regret and indecisiveness jointly affect the choice between tickets. The design, however, does not enable me to establish whether excess inertia from the BASE condition is driven by regret aversion, indecisiveness, or both. The following step is to assess the *individual* influence of these two mechanisms on the choice between tickets. Next, I examine the effect of regret aversion. Then, I turn to the effect of indecisiveness.

3.3 The Effect of Regret Aversion on Choice Behavior

The REG condition assesses the effect of regret aversion on choice behavior by putting the REG lottery into practice. In a typical session participants saw a transparent plastic cup and a ten-sided die on their desks, and were invited to inspect them.³⁰ Then I collected all the dice with a large plastic cup. Next, I asked the assistant to randomly pick one die from the large cup in front of participants. I also asked her to pick a transparent plastic cup (like the one that each participant had on her desk) from a pile of cups sitting on the front desk. I informed participants that they would play an individual lottery that the assistant would resolve at the end of the session. To resolve the lottery, the assistant would use the die and the cup that she had picked. I told participants that they would go, one at a time, to the adjacent room, where the assistant would roll the die (using the cup) in front of them.

Then I informed participants that there were two possible tickets to play the lottery—Odd condition. The design fails to fully control for the influence of the intrinsic preference over colors on choice behavior. To see why this might be a problem, consider the following decision rule that consists of two steps: (i) choose the ticket that maximizes the preference over gambles; (ii) if indecisive between the two tickets, pick the ticket with the most preferred color. Such a decision rule could artificially create inertia: those indecisive participants who happen to be assigned their preferred color end up keeping the Original Ticket. Yet, in the Appendix (Section 5.4) I show that excess inertia is too large to be driven by the preference over colors.

³⁰The dice and cups were identical to the ones used in a typical session from the CONTROL condition.

and Even—and that they would be randomly assigned one of the tickets. Specifically, I told participants that they would pick a closed envelope containing a ticket, and that half of the tickets were Odd and the other half Even. The Odd Ticket would pay the \$10 prize if an odd number (1, 3, 5, 7, or 9) came out when the assistant rolled the die (and it would pay nothing otherwise). Conversely, the Even Ticket would pay the prize if an even number (0, 2, 4, 6, or 8) came out (and it would pay nothing otherwise). After this first round of instructions, the assistant left the main room and the session proceeded as in the BASE, TRUST, and CONTROL conditions. In particular, participants made an unanticipated keep-or-switch decision before they got to play the lottery.

I collected data from 52 participants. Fifty-four percent kept the Original Ticket. A one-tailed test of differences in proportions rejects the null hypothesis that this percentage is smaller than or equal to that from CONTROL in favor of the alternate hypothesis that the percentage from REG is larger ($p = 0.009$). Thus, these data indicate that regret aversion is an individually significant determinant of inertia. In addition, excess inertia from REG is large: it represents 75% of the amount of inertia found in CONTROL.³¹

RESULT 3: A large proportion of participants from the REG condition displayed inertia as a result of regret aversion.

According to R-D SEU, regret aversion induced inertia in the REG condition because regret-averse participants perceived the Original Ticket as the reference point. This is consistent with both the endowment hypothesis and the plan hypothesis. The END condition distinguishes between the two hypotheses by putting the END lottery into practice.

The END condition features only one difference with respect to the REG condition. The twist is the following: as soon as I informed participants that they would randomly get either an Odd Ticket or an Even Ticket, I also announced that they would have the opportunity

³¹In the Appendix (Section 5.5) I discuss two robustness checks on excess inertia from the REG condition. I show that excess inertia is not affected by an ‘*illusion of control*’ (Langer 1975) or by *perceived ambiguity*.

to switch tickets (and receive a \$0.10 bonus) before they played the lottery. I told them that they would indicate their decision on a Decision Form shortly before the assistant resolved the lottery. Later on, as I reminded them about the upcoming lottery, I also reminded them about the option to switch tickets. Then the session proceeded as in the REG condition. If the endowment hypothesis describes the behavior of most regret-averse participants, the REG and END conditions should display about the same amount of inertia. By contrast, if the plan hypothesis fits the behavior of a significant proportion of regret-averse participants, inertia should drop in the END condition.

I collected data from 47 participants. Thirty-six percent kept the Original Ticket. A one-tailed test of differences in proportions rejects the null hypothesis that this percentage is greater than or equal to that of REG in favor of the alternate hypothesis that the percentage from END is strictly smaller ($p = 0.039$). Furthermore, almost all of the excess inertia from the REG condition vanished when participants could plan to switch tickets in advance. A one-tailed test of differences in proportions fails to reject the null hypothesis that the amount of inertia from the END condition is smaller than or equal to that from the CONTROL condition ($p = 0.282$).

RESULT 4: When participants could plan to switch tickets in advance, regret aversion no longer generated inertia.

3.4 The Effect of Indecisiveness on Choice Behavior

The IND condition assesses the effect of indecisiveness on choice behavior by putting the IND lottery into practice. In a typical session I showed participants two empty black bags sitting on the front desk. The bags were labeled Bag 1 and Bag 2. I informed participants that the assistant would take the bags with her to the adjacent room and would fill each bag with 10 red and blue balls in total. The bags would be used to play an individual lottery at

the end of the session. I told participants that they would go, one at a time, to the adjacent room, where the assistant would draw a ball from *one* of the bags in front of them. (I told participants that the balls would be drawn with replacement.)

I randomly assigned participants a ticket to play one of two possible lotteries. (They picked a closed envelope from a box as in BASE, TRUST, REG, and END.) They could receive a Red-1 Ticket or a Red-2 Ticket. If a participant ended up playing a Red-1 Ticket, the assistant would draw a ball from Bag 1; the participant would win the \$10 prize if the assistant drew a red ball. Conversely, if a participant ended up playing a Red-2 Ticket, the assistant would draw a ball from Bag 2; the participant would win the \$10 prize if the assistant drew a red ball.

Participants knew that one of the bags would contain 8 red balls (and 2 blue balls) and the other would contain 2 red balls (and 8 blue balls); they did not know, however, which bag would contain more red balls. In particular, I told participants that the assistant would set the bags as she pleased.³² I emphasized that the assistant would set the bags without seeing any participant's ticket. After this first round of instructions, the session proceeded as in the conditions I already discussed.

I collected data from 48 participants. Seventy-nine percent kept the Original Ticket. A one-tailed test of differences in proportions rejects the null hypothesis that this percentage is smaller than or equal to the percentage from CONTROL in favor of the alternate hypothesis that the percentage from IND is larger ($p < 0.001$). Also, excess inertia is 1.55 times as large as the amount of inertia found in CONTROL.

RESULT 5: A substantial proportion of participants from the IND condition displayed inertia as a result of indecisiveness.

Although the IND condition removes the possibility of experiencing regret after learning

³²I also announced that the assistant would never reveal the compositions of the bags, not even after resolving the lottery.

the counterfactual outcome—simply because the counterfactual outcome is unknowable, this condition fails to account for a broader conception of regret. Unlike what the conventional notion of regret states, it may not be necessary to *know* the counterfactual outcome to experience regret after a choice (Gilovich and Medvec 1995). If the DM switches tickets and fails to win, she could regret having switched just because she *might* have won had she not switched. The IND condition does not remove the influence of this kind of regret on choice behavior. It is possible, however, to set an *upper bound* on the amount of inertia driven by regret aversion in the IND condition. Inertia beyond this bound should be attributed to indecisiveness.

To bound the amount of inertia driven by regret aversion, I just need to make one straightforward assumption. I assume that the DM experiences less regret when the counterfactual outcome is unknowable than she does when the counterfactual outcome is known. This premise implies that the amount of inertia attributable to regret aversion in the IND condition cannot be larger than it is in the REG condition. Thus, if inertia from IND were entirely produced by anticipated regret and factors other than indecisiveness (like carelessness, belief in fate, etc.), the level of inertia would not exceed the one from REG. A one-tailed test of differences in proportions rejects the null hypothesis that inertia from IND is smaller than or equal to that from REG in favor of the alternate hypothesis that inertia from IND is larger ($p = 0.004$). This means that some (if not all) of the excess inertia from the IND condition must have been driven by indecisiveness.

3.5 Comparing The Effect of Regret Aversion with that of Indecisiveness

Thus far, the data indicate that both regret aversion and indecisiveness are significant determinants of inertia. A natural question is which mechanism, if any, causes more inertia.

To answer this question, however, I need to improve upon the IND condition to obtain a clean measure of the effect of indecisiveness. I will use the BCR condition (BCR for *broad conception of regret*) to obtain such measure. This condition is guided by an extension of R-D SEU that accommodates the broader conception of regret introduced in Section 3.4.

Consider a loss-averse DM whose reference point is the Original Ticket. Suppose that this DM would always regret switching tickets if she switched and failed to win—even if the counterfactual outcome were unknowable. Suppose, in addition, that this DM is bayesian, and hence judges the prior winning chance of either ticket to be 0.5. Now think about the utility loss that she would experience right after switching tickets and failing to win. Intuitively, the utility loss would increase with the probability that the DM would have won with the Original Ticket, *given* that she failed to win with the Alternative Ticket. A similar logic applies to the utility gain that would result from switching and winning the lottery. The utility gain would increase with the probability that the DM would have failed to win had she not switched, *given* that she won with the Alternative Ticket.

R-D SEU can be reinterpreted and extended in a way that fits the above description. In the model I described in Section 2.2.2, the counterfactual outcome is certain. After a switch, the DM learns what would have happened had she not switched. We can restate this feature introducing probabilities explicitly. If after a switch the DM fails to win, she learns that the Original Ticket would have won with probability 1—and hence experiences the full loss $\mu(b - x)$. On the other hand, if the DM wins with the Alternative Ticket, she learns that the Original Ticket would have won with probability 0—and hence experiences the full gain $\mu(b + x)$. When the counterfactual outcome is unknowable rather than known, gains or losses are weighed by their *posterior* probability of occurrence. Let $P(O \text{ wins} | A \text{ fails})$ denote the probability of a counterfactual win given a failure to win with the Alternative Ticket. Similarly, let $P(O \text{ fails} | A \text{ wins})$ denote the probability of a counterfactual failure to win given a win with the Alternative Ticket. As before, the utility of the Original Ticket

is $U(\text{Original}|R) = w + 0.5 x$; but now the utility of the Alternative Ticket is³³

$$\begin{aligned}
U(\text{Alternative}|R) = & w + b + 0.5 x \\
& + 0.5 [P(O \text{ wins}|A \text{ fails}) \mu(b - x) + P(O \text{ fails}|A \text{ fails}) \mu(b)] \\
& + 0.5 [P(O \text{ wins}|A \text{ wins}) \mu(b + x - x) \\
& + P(O \text{ fails}|A \text{ wins}) \mu(b + x)].
\end{aligned} \tag{5}$$

This extension of R-D SEU enables a precise characterization of the role of regret in the IND condition. Because the DM knows that one bag is ‘dominant red’ while the other one is ‘dominant blue,’ the outcome of the Alternative Ticket contains relevant information about the winning chance of both tickets. Being bayesian, the DM realizes that a failure to win with the Alternative Ticket suggests that a win would have been *more* likely with the Original Ticket. Similarly, she realizes that a win with the Alternative Ticket suggests that a win would have been *less* likely with the Original Ticket. Specifically, since one bag has 8 red balls and the other has 2 red balls, it follows that $P(O \text{ wins}|A \text{ fails}) = P(O \text{ fails}|A \text{ wins}) = 0.68$ and $P(O \text{ fails}|A \text{ fails}) = P(O \text{ wins}|A \text{ wins}) = 0.32$.³⁴

Compare to the CONTROL condition, in which the counterfactual outcome is also unknowable. The DM will regret switching dice if she uses the Alternative Die to resolve the lottery and fails to win. In the CONTROL condition, however, the outcome when the Alternative Die is used is uninformative about the counterfactual outcome, as both

³³Notice that if both tickets resulted in the same outcome (for example, in the IND condition), the DM would experience a gain of b because the Alternative Ticket pays the bonus.

³⁴To compute $P(O \text{ wins}|A \text{ fails})$, write $P(O \text{ wins}|A \text{ fails}) = P(O \text{ wins}|A \text{ fails}, O \text{ Bag dominant red}) P(O \text{ Bag dominant red}|A \text{ fails}) + P(O \text{ wins}|A \text{ fails}, O \text{ Bag dominant blue}) P(O \text{ Bag dominant blue}|A \text{ fails})$.

If the Original Bag is ‘dominant red,’ the winning chance of the Original Ticket will be 0.8; but if instead the Original Bag is ‘dominant blue,’ the winning chance will be 0.2. Now, it follows from Bayes’ Rule that $P(O \text{ Bag dominant red}|A \text{ fails}) = 0.8$. (I am assuming that the prior probability that the Original Bag is ‘dominant red’ is 0.5.) In turn, this implies that $P(O \text{ Bag dominant blue}|A \text{ fails}) = 0.2$. Replacing all the probabilities in the above equation, we get $P(O \text{ wins}|A \text{ fails}) = 0.68$.

outcomes are independent. In particular, $P(O \text{ wins} | A \text{ fails}) = P(O \text{ wins} | A \text{ wins}) = P(O \text{ fails} | A \text{ wins}) = P(O \text{ fails} | A \text{ fails}) = 0.5$. Assuming that $\mu(\cdot)$ is piecewise linear as in Section 2.2.2, it follows from equation (5) that the expected utility of the Alternative Ticket is smaller in IND than in CONTROL. Then, regret aversion might induce more inertia in IND than in CONTROL. If this were the case, excess inertia from IND would be contaminated by the influence of anticipated regret; hence, it would not cleanly identify the amount of inertia generated by indecisiveness. The BCR condition resolves this issue. Its key feature is that the Alternative Ticket yields the same expected utility to a regret-averse DM as it does in the CONTROL condition.

The BCR condition differs from the IND condition only in the way the compositions of the two bags are determined. In IND participants know that one bag is ‘dominant red’ while the other one is ‘dominant blue.’ By contrast, in BCR the compositions are *independent*. The assistant draws two numbers between 0 and 10 from a cup in front of participants; she draws the numbers with replacement.³⁵ She is the only person in the lab that knows these two numbers.³⁶ The first number determines the number of red balls in Bag 1; the second number determines the number of red balls in Bag 2. (Recall that each bag contains 10 red and blue balls in total.) Because the compositions of the bags are independent, the outcome of the Alternative Ticket is uninformative about the proportion of red balls in the original bag; then, $P(O \text{ wins} | A \text{ fails}) = P(O \text{ wins} | A \text{ wins}) = P(O \text{ fails} | A \text{ wins}) = P(O \text{ fails} | A \text{ fails}) = 0.5$. This implies that the expected utility of the Alternative Ticket to a regret-averse DM is the same in the CONTROL and BCR conditions. Hence, excess inertia from the BCR condition identifies the effect of indecisiveness.

I collected data from 49 participants.³⁷ Forty-nine percent retained the Original Ticket.

³⁵The cup contains 11 pieces of paper, each one featuring a different number between 0 and 10.

³⁶As in the IND condition, I told participants that the assistant would never reveal the compositions of the bags, not even after resolving the lottery.

³⁷Because in BASE, TRUST, CONTROL, R, END, and IND participants made a single incentivized decision, I could not check consistency of choice behavior at the individual level. In the BCR condition

Based on the above discussion, next I examine three hypotheses. First, I test whether regret aversion induced a stronger reluctance to switch in the IND condition than it did in the BCR condition. The original R-D SEU predicts that regret-driven inertia should be the same (and equal to zero) in both conditions; in contrast, extended R-D SEU is consistent with larger inertia in the IND condition. A one-tailed test of differences in proportions rejects the null hypothesis that inertia from IND is smaller than or equal to that from BCR in favor of the alternate hypothesis that inertia from IND is larger ($p = 0.001$). Second, I test whether the amount of regret-driven inertia from the IND condition is about the same as that from the REG condition.³⁸ If this were the case, the additional inertia from IND relative to that from BCR should equal excess inertia from REG. I cannot reject this hypothesis ($p = 0.606$).³⁹

RESULT 6: Although the counterfactual outcome is unknowable in the IND condition, regret aversion appears to have induced about the same amount of inertia as in the REG condition. This is not consistent with original R-D SEU, but it is consistent with an extension of R-D SEU that accounts for a broader conception of regret.

I added a price-list task to perform a basic consistency check. After participants made the keep-or-switch choice with a \$0.10 switching bonus, I collected their Decision Form. Then I asked them—again by surprise—to make a series of similar choices for different values of the switching bonus, ranging from \$0.20 to \$1 in steps of \$0.10. The series of choices was displayed in a table on Decision Form Part II (see the Appendix). I told participants that once they had made all their choices, I would randomly select the choice-that-counted by rolling a die in front of them. For an individual’s choice behavior to be considered consistent, the individual must feature a single switch point (if any). Reassuringly, only one participant had multiple switch points; I exclude this participant from the analysis. The analysis focuses exclusively on the keep-or-switch decision with a \$0.10 bonus. I do not use the price-list task for further analyses because it is unclear how to interpret switch points if individuals have expectations-based reference points. (See Section IV in Köszegi and Rabin (2006) for discussion.)

³⁸Notice that we should reinterpret excess inertia from REG in light of extended R-D SEU. Strictly speaking, excess inertia from REG identifies the effect of anticipated regret when the counterfactual is known, compared to a situation in which the counterfactual is unknowable but the two possible counterfactual outcomes are equally likely.

³⁹To test this hypothesis, I ran a linear regression of the keep-or-switch choice on dummy variables for CONTROL, REG, IND, and BCR: $y = \alpha_1 \text{CONTROL} + \alpha_2 \text{REG} + \alpha_3 \text{IND} + \alpha_4 \text{BCR}$, where y equals one if a participant kept the Original Ticket (and zero otherwise), and the dummy for Condition i equals one if a participant took part in Condition i (and zero otherwise). The coefficients from this regression capture the amount of inertia from each condition. The null hypothesis is $H_0 : \alpha_2 - \alpha_1 = \alpha_3 - \alpha_4$, which can be restated as $H_0 : \alpha_2 - \alpha_1 - \alpha_3 + \alpha_4 = 0$. Then, I carried out a standard asymptotic test that uses the delta method to compute the standard error of $\hat{\alpha}_2 - \hat{\alpha}_1 - \hat{\alpha}_3 + \hat{\alpha}_4$.

Finally, I test whether regret aversion and indecisiveness induced about the same reluctance to switch tickets. To this end, I compare inertia between the REG and BCR conditions. A two-tailed test of differences in proportions fails to reject the null hypothesis that the proportion of participants who kept the Original Ticket is the same in both conditions ($p = 0.625$).

RESULT 7: Regret aversion and indecisiveness generated about the same amount of inertia.

4 Conclusions

In a laboratory experiment, I investigated whether uncertainty creates inertia in real choices through anticipated regret and indecisiveness. I randomly assigned each participant one of two tickets to play an individual lottery; each participant then decided whether to keep the Original Ticket or switch to the Alternative Ticket (and receive a small bonus). In each condition, participants took part in a different lottery. The lotteries differed in the degree of uncertainty and in the potential to induce regret after a switch. Overall, I documented that inertia was quite large when the opportunity to switch tickets was a surprise. I showed that both anticipated regret and ambiguity-driven indecisiveness were significant determinants of the refusal to switch. In addition, both mechanisms had an equally strong effect. When participants knew that either ticket had a winning chance of 0.5, inertia was substantially lower if they anticipated the opportunity to switch. This finding supports Kőszegi and Rabin's (2006, 2007) hypothesis that reference points are shaped by plans.

Inertia driven by indecisiveness appears to reveal an aversion to ambiguity that is more basic than that described by Ellsberg (1961). In Ellsberg's classical 'two-color' problem, most people prefer to bet on an urn with 50 red and 50 black balls (the risky urn) than on an urn with 100 red and black balls in an unknown proportion (the ambiguous urn).

By contrast, in the experiment I reported here the two tickets from any of the ambiguous lotteries are equally ambiguous. Inertia reveals that the options need not be asymmetric in their degree of uncertainty to trigger ambiguity-averse behavior.

An interesting question for future research is how sensitive inertia is to the arrival of new information about unknown probabilities. For example, imagine an ambiguous lottery like the ones from the IND and BCR conditions. Suppose that the assistant draws one ball from each bag before the participant makes the keep-or-switch decision. Choice behavior should be unaffected—relative to the current experiment—if both balls are the same color. But how would an R-D SEU maximizer and a Knightian DM react if the assistant drew a blue ball from the Original Bag and a red one from the Alternative Bag? Would this piece of information mitigate inertia? R-D SEU predicts more switching but KDT does not speak directly to this issue, as it does not specify how a DM that entertains multiple priors updates beliefs. The feedback between further theoretical developments and empirical work can shed more light on the effect of information on choice behavior in general, and on inertia in particular.

Another question concerns the correlation between regret aversion and ambiguity-driven indecisiveness (or more generally, ambiguity aversion). Because every participant from the experiment takes part in a single lottery, I cannot assess this correlation. A within-subjects design is needed to address this question. Such a design, for instance, could face every participant with the CONTROL, R, and BCR lotteries. A drawback of a within-subjects design like this one, however, is that experimental effects are more likely to arise than in a between-subjects design.

R-D SEU and KDT can be applied to study choice behavior in several domains in which uncertainty is large and salient, such as technology adoption, financial investment, choice of health care, and choice among alternative insurance programs. (In the Appendix (Section 5.6) I briefly discuss three potential applications.) Yet, the theories might severely fail

to predict behavior in other important situations. The type of uncertainty-averse behavior typically predicted by R-D SEU and KDT appears to be inconsistent with the optimistic beliefs and expectations that people exhibit in many surveys (e.g., Weinstein 1980, 1987). Self-reported beliefs tend to reveal an *optimism bias*—a tendency to overestimate the likelihood of encountering positive events in the future and to underestimate the likelihood of experiencing negative events. There is some evidence that optimism leads to risk-prone behavior.⁴⁰ How could uncertainty-averse behavior and optimistic behavior be reconciled? To nail down the connection between these two opposite types of behavior, we need to better understand (i) how individuals form beliefs in ambiguous environments, and (ii) how these beliefs interact with loss aversion. Much work remains to be done in this area.

⁴⁰For instance, Camerer and Lovallo (1999) show that overconfidence causes excess entry in experimental games that emulate competitive markets. When participants' post-entry payoffs are based on their own skill, individuals tend to overestimate their chances of relative success and enter more frequently (compared to a condition in which payoffs do not depend on skill). Surprisingly, excess entry is even larger in sessions in which participants self-select knowing their success will depend partly on their skill (and that others have self-selected too).

5 Appendix

5.1 Other Theories that Predict a Switch

As I discuss in Section 2.1, SEU predicts that the DM will switch tickets provided that switching is rewarded with a bonus. In this appendix I show that several theories make the same prediction as SEU. These theories are Maxmin Expected Utility (Gilboa and Schmeidler 1989), Smooth Ambiguity Preferences (Klibanoff, Marinacci, and Mukerji 2005, 2012), Variational Preferences (Maccheroni, Marinacci, and Rustichini 2006), Prospect Theory (Kahneman and Tversky 1979), Regret Theory (Bell 1982; Loomes and Sugden 1982), and Disappointment Theory (Bell 1985; Loomes and Sugden 1986).⁴¹

5.1.1 Models of Ambiguity Aversion

Next I discuss the predictions of the major models of ambiguity aversion: Maxmin Expected Utility, Smooth Ambiguity Preferences, and Variational Preferences. In these models, preferences are complete and reference-independent. When the lottery is ambiguous the DM entertains multiple beliefs. The probability weighting function equals the identity function.

Maxmin Expected Utility. The utilities of the tickets are

$$\begin{aligned} U_{MEU}(Original) &= \min_{P(S) \in [1-p, p]} [w + P(S) x] \\ U_{MEU}(Alternative) &= \min_{P(S) \in [1-p, p]} [w + b + (1 - P(S)) x]. \end{aligned}$$

The DM evaluates each ticket in the most pessimistic way, given her set of beliefs $[1-p, p]$. The DM is indifferent between the tickets in the absence of a switching bonus. On the

⁴¹A recent theory of reference-dependent preferences proposed by Krähmer and Stone (2013) allows for both regret and disappointment. This theory also predicts a switch. See Sautua (2015) for a detailed discussion of this and other predictions made by Krähmer and Stone's theory.

other hand, when there is a bonus she strictly prefers the Alternative Ticket and hence will switch tickets.⁴²

Smooth Ambiguity Preferences. The utilities of the lotteries are

$$\begin{aligned}
U_{SP}(Original) &= \int_{P(S) \in [1-p, p]} \phi(w + P(S)x) d\mu(P(S)) \\
U_{SP}(Alternative) &= \int_{P(S) \in [1-p, p]} \phi(w + b + (1 - P(S))x) d\mu(P(S)),
\end{aligned}$$

for some increasing function $\phi(\cdot)$ and subjective probability distribution $\mu(\cdot)$ over $P(S)$. For each $P(S) \in [1 - p, p]$ the expected utilities of the tickets are $w + P(S)x$ and $w + b + (1 - P(S))x$, and the DM is averse to the uncertainty in these expected utility levels that results from her subjective uncertainty about $P(S)$ as represented by $\mu(\cdot)$. Because the DM is clueless about the probability distribution of the likelihood of S over the range $[1 - p, p]$, it is natural to assume that $\mu(\cdot)$ is the uniform distribution with support $[1 - p, p]$.⁴³ Since $\phi(\cdot)$ is increasing, it follows that the DM will switch tickets when the Alternative Ticket pays a bonus.

⁴²Ghirardato et al. (2004) introduce a generalization of the Maxmin Model called the α -Maxmin Model. Given some $\alpha \in [0, 1]$, the utilities of the tickets are

$$\begin{aligned}
U_{\alpha MEU}(Original) &= \alpha \min_{P(S) \in [1-p, p]} [w + P(S)x] + (1 - \alpha) \max_{P(S) \in [1-p, p]} [w + P(S)x] \\
U_{\alpha MEU}(Alternative) &= \alpha \min_{P(S) \in [1-p, p]} [w + b + (1 - P(S))x] \\
&\quad + (1 - \alpha) \max_{P(S) \in [1-p, p]} [w + b + (1 - P(S))x].
\end{aligned}$$

Notice that the Maxmin Model corresponds to $\alpha = 1$. The α -Maxmin Model also implies indifference in the absence of a switching bonus and a strict preference for the Alternative Ticket when there is a bonus.

⁴³That is,

$$\mu(P(S)) = \begin{cases} \frac{1}{2p-1} & \text{if } P(S) \in [1 - p, p] \\ 0 & \text{if } P(S) \notin [1 - p, p] \end{cases}.$$

Variational Preferences. The utilities of the lotteries are

$$\begin{aligned}
U_{VP}(Original) &= \text{Min}_{P(S) \in [1-p, p]} [w + P(S) x + \eta(P(S))] \\
U_{VP}(Alternative) &= \text{Min}_{P(S) \in [1-p, p]} [w + b + (1 - P(S)) x + \eta(1 - P(S))],
\end{aligned}$$

for some nonnegative convex function $\eta(\cdot)$. We can see that the DM will switch tickets when the Alternative Ticket pays a bonus.

5.1.2 Prospect Theory

Preferences are complete and reference-dependent. The DM holds a single belief. The reference point is the same for both tickets and is fixed at initial wealth w : $R_O = R_A = R \equiv (S : w, S^C : w)$. Because final wealth with either ticket is at least as large as initial wealth, both tickets involve potential gains but do not yield any loss. At the moment of the keep-or-switch decision, the DM anticipates any potential gain relative to initial wealth. Simplifying (1) and (2), utilities are given by

$$\begin{aligned}
U_{PT}(Original|R) &= 2 W(0.5) w + W(0.5) x + W(0.5) \mu(x) \\
U_{PT}(Alternative|R) &= 2 W(0.5)(w + b) + W(0.5) x \\
&\quad + [W(0.5) \mu(b) + W(0.5) \mu(b + x)].
\end{aligned}$$

The DM will switch tickets when switching is rewarded with a bonus.⁴⁴

⁴⁴Strictly speaking, Prospect Theory does not feature consumption utility in its original formulation. Thus, to follow the theory closely I should write utilities as $U_{PT}(Original|R) = W(0.5) \mu(x)$ and $U_{PT}(Alternative|R) = W(0.5) [\mu(b) + \mu(b + x)]$. It is clear, however, that the prediction of the theory discussed in the main text remains the same.

5.1.3 Regret Theory

The DM entertains a single belief. The probability weighting function equals the identity function. Preferences are complete and reference-dependent. When the DM evaluates a ticket, the referent is the *other* ticket. That is, we can write the referents as $R_O \equiv (S : w + b, S^C : w + b + x)$ and $R_A \equiv (S : w + x, S^C : w)$.

Consider how a DM feels after playing the lottery. Given the realized state of the world, the DM compares the outcome of the chosen ticket with the outcome of the rejected ticket. If the chosen ticket wins the lottery, the DM feels happy as she knows that she would have failed to win had she made a different choice. That is, winning produces *rejoicing*. On the other hand, if the chosen ticket fails to win, the DM feels sad as she knows that she would have won had she chosen the other ticket. A failure to win induces *regret* about the choice made. At the moment of the keep-or-switch decision, the DM anticipates any rejoicing or regret that could result from her choice. Simplifying (1) and (2), the utilities of the tickets are

$$\begin{aligned} U_{RT}(\textit{Original}|R_O) &= w + 0.5 x + [0.5 \mu(x - b) + 0.5 \mu(-x - b)] \\ U_{RT}(\textit{Alternative}|R_A) &= w + b + 0.5 x + [0.5 \mu(b - x) + 0.5 \mu(x + b)]. \end{aligned}$$

Loss aversion produces *regret aversion*: regret following a failure to win is felt more severely than rejoicing following a win. Regret aversion, however, does not play a role in the choice between tickets. In the absence of a switching bonus, the tickets are ex-ante identical and hence the DM is indifferent between them. A switching bonus, on the other hand, makes the Alternative Ticket more attractive: now the Alternative Ticket yields higher consumption utility, a smaller expected loss, and a larger expected gain. Thus, when $b > 0$ the DM will switch tickets.

5.1.4 Disappointment Theory

The DM holds a single belief. The probability weighting function equals the identity function. Preferences are complete and reference-dependent. The reference point of a ticket is fixed at the certainty equivalent of the ticket, based on its consumption utility. That is, $R_O \equiv (S : w + 0.5 x, S^C : w + 0.5 x)$ and $R_A \equiv (S : w + b + 0.5 x, S^C : w + b + 0.5 x)$.

Consider how the DM feels once the lottery is resolved. Because winning the prize yields a gain relative to the certainty equivalent of the ticket, the DM experiences *elation* if she wins. Conversely, since failing to win yields a loss relative to the certainty equivalent, the DM experiences *disappointment* if she does not win. At the moment of the keep-or-switch decision, the DM anticipates any elation or disappointment that could result from her choice. Simplifying (1) and (2), the utilities of the tickets are

$$\begin{aligned} U_{DT}(Original|R_O) &= w + 0.5 x + [0.5 \mu(0.5 x) + 0.5 \mu(-0.5 x)] \\ U_{DT}(Alternative|R_A) &= w + b + 0.5 x + [0.5 \mu(-0.5 x) + 0.5 \mu(0.5 x)]. \end{aligned}$$

Loss aversion produces *disappointment aversion*: disappointment resulting from a failure to win is felt more severely than elation following a win. Disappointment aversion, however, does not affect the DM's choice behavior. In the absence of a switching bonus, the tickets are ex-ante identical and hence the DM is indifferent. In contrast, when there is a bonus the DM strictly prefers the Alternative Ticket, as it features the same potential for disappointment and elation as the Original Ticket but yields higher consumption utility. Therefore, when $b > 0$ the DM will switch tickets.

5.2 A Hybrid Model

In this appendix I discuss a hybrid model that features a *loss-averse Knightian DM*. On one hand, the DM's beliefs are represented as in KDT. On the other hand, the utilities

of outcomes are modeled as in R-D SEU. When the DM faces a fair lottery, the model is reduced to R-D SEU. As we have seen, the DM will require at least a 2.4% bonus to switch in any fair lottery. To analyze how the interaction between the multiplicity of beliefs and loss aversion affects choice behavior, in the remainder of this appendix I focus entirely on ambiguous lotteries.

Choice Behavior When the Opportunity to Switch Is a Surprise

When the option to switch is a surprise, the referent is the Original Ticket: $R = (S : w+x, S^C : w)$. For each belief $P(S) \in [1-p, p]$, the utilities of the tickets are

$$\begin{aligned} U(\text{Original}|R) &= w + P(S) x \\ U(\text{Alternative}|R) &= w + b + (1 - P(S)) x + [P(S) \mu(b-x) + (1 - P(S)) \mu(b+x)]. \end{aligned}$$

The DM prefers the Original Ticket if and only if $1-p \geq \tilde{P}(b; \mu)$, where $\tilde{P}(b; \mu) \equiv \frac{x+b+\mu(b+x)}{2x+\mu(b+x)-\mu(b-x)}$. Conversely, she prefers the Alternative Ticket if and only if $p \leq \tilde{P}(b; \mu)$. Recall that $p > 0.5$. First suppose that there is no switching bonus. Because $\tilde{P}(0; \mu) < 0.5$, a loss-averse Knightian DM *might* prefer the Original Ticket. By contrast, she will *never* prefer the Alternative Ticket. In sum, when there is no switching bonus the DM will prefer the Original Ticket or will otherwise be indecisive.

Now suppose that the lottery offers a switching bonus. In this case, the DM *might* prefer the Alternative Ticket. To pin down the reservation bonus \tilde{b} , I assume (as in Section 2.2.2) that μ is piecewise-linear and $\eta = 1$. Since the DM prefers the Alternative Ticket if and only if $p \leq \tilde{P}(b; \lambda)$, she will switch if and only if $b/x \geq \tilde{b}$, where $\tilde{b} \equiv \frac{(\lambda+3)p-2}{(\lambda-1)p+2}$. When $p = 0.51$, a loss-averse Knightian DM with $\lambda = 1.1$ will demand a 4.4% bonus to switch. Because \tilde{b} is increasing in both λ and p , we conclude that *any* loss-averse Knightian DM will require *at least* a 4.4% bonus to switch in *any* ambiguous lottery.

Choice Behavior When the Opportunity to Switch Is Anticipated

Consider the case in which the option to switch is anticipated. According to the endowment hypothesis, the DM perceives the Original Ticket as the referent. Therefore, under the endowment hypothesis the Hybrid Model makes the same prediction as when the option to switch is a surprise. This implies that the DM will stick with the Original Ticket when switching is rewarded with less than a 4.4% bonus.

Now I turn to the implications of the plan hypothesis. I have shown that pursuing the plan to stick with the Original Ticket is a personal equilibrium when the bonus is less than 4.4%. Is planning on switching also a personal equilibrium? Next I show that the answer depends on p and the coefficient of loss aversion λ . If the DM plans to switch, the reference point is the Alternative Ticket: $R' = (S : w + b, S^C : w + b + x)$. In this case, for each belief $P(S) \in [1 - p, p]$, the utilities of the tickets are

$$\begin{aligned} U(Original|R') &= w + P(S) x + [P(S) \mu(x - b) + (1 - P(S)) \mu(-(x + b))] \\ U(Alternative|R') &= w + b + (1 - P(S)) x. \end{aligned}$$

Again assume that μ is piecewise-linear and $\eta = 1$. Then, the reservation bonus is $\tilde{b} \equiv \frac{2 p - (1 - p) (1 + \lambda)}{1 + p + (1 - p) \lambda}$. The reservation bonus is decreasing in λ : a DM with high loss-aversion requires little money to switch provided that she has already *planned* to switch. On the other hand, the reservation bonus is increasing in p . Since the effects of λ and p on \tilde{b} run in opposite directions, it is unclear whether a loss-averse Knightian DM who plans to switch will effectively do so for a small bonus. Table A1 shows a calibration of \tilde{b} assuming that λ lies in the range $[1.1, 3.5]$. The calibration exercise indicates that any loss-averse Knightian DM will fail to switch for less than a 2% bonus provided that p lies in the range $[0.7, 1]$. This means that switching is *not* a personal equilibrium if $b/x < 0.02$ and $p \in [0.7, 1]$. In this case, keeping the Original Ticket is the only personal equilibrium, and hence the DM's preferred personal equilibrium.

TABLE A1 --- RESERVATION BONUS IN THE HYBRID MODEL
(Under the Plan Hypothesis when the Opportunity to Switch is Anticipated)

p	λ				
	1.1	1.5	2	3	3.5
0.51	0.00	-0.09	-0.18	-0.32	-0.37
0.55	0.08	-0.01	-0.10	-0.24	-0.30
0.6	0.18	0.09	0.00	-0.14	-0.20
0.7	0.38	0.30	0.22	0.08	0.02
0.8	0.58	0.52	0.45	0.33	0.28
0.9	0.79	0.76	0.71	0.64	0.60
1	1.00	1.00	1.00	1.00	1.00

Notes. For any combination of p and λ , the table shows the minimum value of b/x that would lead the DM to switch. Negative values mean that the DM would be willing to pay a fraction of the prize to switch.

If p is such that switching happens to be a personal equilibrium, which is the preferred personal equilibrium? It turns out that *both* personal equilibria are preferred personal equilibria. For each belief in the relevant range, the *equilibrium* utility of playing the Original Ticket is $w + P(S) x$, whereas the *equilibrium* utility of playing the Alternative Ticket is $w + b + (1 - P(S)) x$. Notice that the comparison between the two consistent plans takes us back to *pure* KDT. Because neither plan dominates the other for *all* beliefs, the plans are incomparable. The Inertia Assumption, however, does not tell us how the DM initially decides between two undominated plans. In this case, the Hybrid Model based on the plan hypothesis makes no sharp prediction about the DM's choice.

In sum, when the option to switch is anticipated but switching is rewarded with less than a 2% bonus, the Hybrid Model predicts that the DM will not switch if p is large. The model, however, does not make a sharp prediction if p is close to 0.5. Under the endowment hypothesis it still predicts that the DM's choice will display inertia, but under the plan

hypothesis it is vague.

5.3 List of Majors

Majors that are Math-intensive or intensive in formal logic: Actuarial Mathematics; Aerospace Engineering; Applied Mathematics; Architecture; Astrophysics; Biochemistry; Bioengineering; Biophysics; Business Economics; Chemical Engineering; Chemistry; Civil Engineering; Computational and Systems Biology; Computer Science; Economics; Earth & Environmental Sciences; Electrical Engineering; Environmental Engineering; Finance; Financial Actuarial Mathematics; Financial Engineering; Geophysics & Space Physics; Masters in Business Administration; Materials Science; Mechanical Engineering; Philosophy; Physics; Statistics.

Majors that are neither Math-intensive nor intensive in formal logic: Afro-American Studies; Anthropology; Applied Linguistics; Art; Art History; Asian American Studies; Asian Humanities; Asian Studies; Atmospheric, Oceanic and Environmental Sciences; Biology; Chicano Studies; Chinese; Classical Civilization; Cognitive Sciences; Communication Studies; Comparative Literature; Culture & Performance; Design Media Arts; Ecology & Evolutionary Biology; Education; English; Environmental Sciences; Epidemiology; Ethnomusicology; French; Gender Studies; Geography; Global Studies; History; Human Biology & Society; International Development Studies; Law; Linguistics; Music Performance; Marine Biology; Masters of Information & Library Sciences; Microbiology, Immunology & Molecular Genetics; Molecular Toxicology; Molecular, Cell & Developmental Biology; Music; Neuroscience; Nursing; Physiological Sciences; Political Science; International Relations; Psychobiology; Psychology; Public Health; Public Policy; Social Welfare; Sociology; Study of Religion; Undecided.

5.4 Preference over Colors in the BASE Condition

The BASE condition fails to fully control for the influence of the intrinsic preferences over colors on choice behavior. Yet, in this appendix I show that excess inertia from the BASE condition cannot be fully explained by the preference over colors. Divide the population of DMs into the following mutually exclusive types based on their preferences: Knightian, R-D SEU maximizers, Hybrid, Color Choosers (those DMs who pick their preferred color when they are indecisive), and Other. Each DM is randomly assigned to one of the experimental conditions. Let $P(\textit{Keep}|\textit{Condition } i)$ denote the proportion of participants from Condition i who keep the Original Ticket. Such proportion defines the amount of inertia from Condition i . By the Law of Total Probability, we have that

$$P(\textit{Keep}|\textit{Condition } i) = \sum_j P(\textit{Keep}|\textit{Condition } i, \textit{Type } j) P(\textit{Type } j|\textit{Condition } i). \quad (6)$$

First notice that random assignment to experimental conditions ensures that the distribution of types remains the same across conditions: $P(\textit{Type } j|\textit{BASE}) = P(\textit{Type } j|\textit{CONTROL})$. The theoretical framework predicts that Knightian DMs, R-D SEU maximizers, and Hybrid DMs will stick with the Original Ticket in the BASE condition but will switch in the CONTROL condition. In addition, a proportion $\mu \in (0, 1)$ of Other DMs are predicted to stick with the Original Ticket in both conditions: $P(\textit{Keep}|\textit{Condition } i, \textit{Other}) = \mu$, $i = \textit{BASE}, \textit{CONTROL}$. These are DMs who are inattentive, or who do not care about the keep-or-switch decision, or who believe in fate, etc. The proportion $1 - \mu$ of Other DMs who do switch are the ones whose preferences I discussed in Section 2.1 (SEU maximizers, Maxmin EU maximizers, etc.).⁴⁵

⁴⁵For expositional convenience, I have abstracted from decision errors. The specification of type-specific choice probabilities, however, can be reinterpreted in a way that accommodates decision errors. First, assume that Knightian DMs, R-D SEU maximizers, and Hybrid DMs do not make mistakes—they always keep the Original Ticket in the BASE condition but switch in the CONTROL condition. Second, think of inertia among Other DMs as a result of both choices based on a genuine preference for the Original Ticket and

Now consider the predictions for choice behavior among the Color Choosers. Because tickets are randomly assigned in the BASE condition, half of the Color Choosers will stick with the Original Ticket. On the other hand, since the Alternative Ticket has a higher expected value than the Original one in the CONTROL condition, all DMs of this type will switch in the CONTROL condition. That is,

$$P(\text{Keep}|\text{Condition } i, \text{Color Choosers}) = \begin{cases} 0 & \text{if } i = \text{CONTROL} \\ 0.5 & \text{if } i = \text{BASE} \end{cases}.$$

Replacing the type-specific choice probabilities for the BASE and CONTROL conditions in (6), we obtain:

$$\begin{aligned} P(\text{Keep}|\text{BASE}) &= P(\text{Knightian}) + P(\text{R-D SEU}) + P(\text{Hybrid}) \\ &\quad + 0.5 P(\text{Color Choosers}) + \mu P(\text{Other}) \\ P(\text{Keep}|\text{CONTROL}) &= \mu P(\text{Other}). \end{aligned}$$

Thus,

$$\begin{aligned} P(\text{Keep}|\text{BASE}) - P(\text{Keep}|\text{CONTROL}) &= P(\text{Knightian}) + P(\text{R-D SEU}) \\ &\quad + P(\text{Hybrid}) + 0.5 P(\text{Color Choosers}). \end{aligned}$$

The problem is to assess whether excess inertia from the BASE condition (i.e., the left-hand side of the above equality) might be entirely driven by Color Choosers. Suppose this is the case—that is, suppose that there are no Knightian DMs, R-D SEU maximizers, or Hybrid DMs. Then, $P(\text{Keep}|\text{BASE}) - P(\text{Keep}|\text{CONTROL}) = 0.5 P(\text{Color Choosers})$. Replacing

decision errors. Some DMs of the Other type have a true preference for the Original Ticket (e.g., those who believe in fate); others would actually prefer to switch but mistakenly end up sticking with the Original Ticket (e.g., some inattentive SEU maximizers).

excess inertia on the left-hand side with its sample value, we can solve for $P(\textit{Color Choosers})$; this yields $P(\textit{Color Choosers}) = 0.78$. In turn, this implies that $P(\textit{Other}) = 0.22$. Finally, using that $\mu = \frac{P(\textit{Keep}|\textit{CONTROL})}{P(\textit{Other})}$ we obtain $\mu = 1.41$, which violates the restriction $\mu < 1$. This shows that excess inertia from the BASE condition is too large to be entirely driven by the preference over colors. Put differently, this exercise provides further support for the claim that regret aversion and indecisiveness are jointly significant determinants of inertia.

5.5 Robustness Checks on the REG Condition

5.5.1 Illusion of Control

There is one subtle difference between the CONTROL and REG conditions that might have biased excess inertia upward. In the CONTROL condition participants rolled the die themselves, while in the REG condition the assistant rolled the die. Some participants might have had the “gut feeling” that rolling the die themselves would increase their winning chance—that is, they might have had an “illusion of control” (Langer 1975). Such illusion of control might have mitigated inertia in the CONTROL condition, but it could not have played any role in the REG condition. To eliminate the potential bias, I ran a variation of REG in which participants rolled the die themselves. Inertia, however, remained almost the same: 49% of participants kept the Original Ticket. Thus, an illusion of control did not affect excess inertia.

5.5.2 Perceived Ambiguity

Removing ambiguity is crucial to separating the effect of regret aversion from that of indecisiveness. Yet, the claim that the REG condition eliminates ambiguity might be challenged. For instance, some participants might have doubted that the die was fair. Next I argue that perceived ambiguity, if anything, seems to have had a negligible effect on choice behavior

in the REG condition. In a Post-Decision Questionnaire, I asked participants to compare the winning chances of both tickets.⁴⁶ Five out of the 28 participants who kept the Original Ticket replied that they could not compare the winning chances based on the information they had. Suppose that these were indecisive individuals who had retained the Original Ticket as a result of perceived ambiguity. If I remove them from the sample, the proportion of participants who kept the Original Ticket falls to 49%, which still yields substantial excess inertia. A one-tailed test of differences in proportions rejects the null hypothesis that this percentage is smaller than or equal to the one from the CONTROL condition ($p = 0.033$).

5.6 Economic Applications

In this appendix I provide three examples to illustrate how economic behavior of a SEU maximizer could differ from that of a R-D SEU maximizer or that of a Knightian DM. As in the main text, I assume that consumption utility is linear and the gain-loss function is piecewise-linear with $\eta = 1$.

5.6.1 Technology Adoption

A farmer has long been using a production technology whose yield is \$10 worth of crops. She learns that a new production technology is available. This technology yields either \$12 or \$9 worth of crops, but the probability distribution of the yield is yet unknown. The farmer considers switching to the new technology. What will she decide?

If the farmer is a SEU maximizer who believes that each possible outcome could occur with equal probability, then she will switch. Now consider a R-D SEU maximizer that maintains the same belief. Because she has been using the current technology for a long time, she perceives its payoff as the reference point. Thus, the utility of sticking with the

⁴⁶I asked them to select one answer out of the following: the chosen ticket had a higher chance, a smaller chance, an equal chance, or they could not tell. Participants answered this question after the keep-or-switch decision but before playing the lottery.

current technology is $w + 10$. On the other hand, the farmer anticipates that switching might result in a gain of \$2 or a loss of \$1. This implies that the expected utility of switching is $w + 10.5 + 0.5 [2 - \lambda]$. She will prefer to stick with the current technology if and only if $\lambda > 3$. Last, consider a Knightian DM who believes that the likelihood of the high yield lies within the range $[0.2, 0.8]$. (Thus, $p = 0.8$.) Keeping the current technology would be strictly preferred if and only if $1 - p > \frac{1}{3}$, while switching would be strictly preferred if and only if $p < \frac{1}{3}$. Because $1 - p < \frac{1}{3}$ and $p > \frac{1}{3}$, the farmer will remain indecisive and hence will stick with the status quo.

5.6.2 Investment

An investor faces a business opportunity that features a fixed cost of \$0.50, and a payoff of \$1 if state S occurs and $-\$0.9$ otherwise. The investor does not know the likelihood of S but believes that it lies within the range $[0.2, 0.8]$. The government offers a subsidy that covers the full fixed cost. Will the investor take up this business opportunity?

A SEU maximizer (whose belief is 0.5) will take advantage of the large government subsidy and will decide to invest. Notice that she would not invest if the fixed cost were not subsidized. Thus, in this case the subsidy has a large effect on the investor's behavior.

Now consider a Knightian DM. If she knew that the actual likelihood of S is close to 0.8, investing would be optimal; on the other hand, if she knew that the likelihood is close to 0.2, she would prefer not to invest. Because the investor believes that the likelihood of S could take any value between 0.2 and 0.8, she will be indecisive and hence will not invest. In this case, the large government subsidy is insufficient to induce the investor to take up the business opportunity. This example suggests that choice behavior in ambiguous environments may be significantly less sensitive to changes in relevant economic variables than standard models (like SEU) would predict.⁴⁷

⁴⁷Two studies document that choices made by many individuals in ambiguous environments are relatively

5.6.3 Health Insurance

This example builds on one provided by Bell (1982, p. 972). If a DM becomes ill, her recovery requires medical expenses that amount to \$1. She believes that the probability that she will become ill is $0 < \pi < 1$. She currently does not have health insurance. The insurance premium is $\$ \pi$. Will the DM purchase insurance?

A SEU maximizer will be indifferent as the insurance contract is fair. Now consider a R-D SEU maximizer whose reference point is determined by expectations. Suppose that her original plan was to remain uninsured. This implies that her reference point is the status quo (i.e., lack of insurance). The expected utility of remaining uninsured is $w - \pi$. On the other hand, the purchase of health insurance yields a gain of $\$(1 - \pi)$ if the DM becomes ill and a loss of $\$ \pi$ if she does not. The potential gain comes from the prospect of saving money in case she gets sick, while the potential loss comes from the feeling that the insurance premium is a waste of money if she does not get sick. Thus, the expected utility of being insured is $w - \pi + [\pi(1 - \pi) - (1 - \pi)\lambda\pi]$. A loss-averse DM ($\lambda > 1$) whose original plan was to remain uninsured will follow through on her plan.

Now suppose that a policy that gets the DM to think carefully about the benefits of health insurance induces her to plan to insure. Given this plan, the DM will come to perceive the purchase of insurance as the reference point. In this case, the expected utility of being insured is $w - p$. On the other hand, being uninsured brings a loss of $\$(1 - \pi)$ if the DM becomes ill and a gain of $\$ \pi$ if she does not. The potential loss comes from the additional medical expenses in case of illness, whereas the potential gain comes from saving the insurance premium in the good health scenario. Therefore, the expected utility

insensitive to changes in economic variables. In a laboratory experiment on asset markets, Bossaerts et al. (2010) find that many participants hold a portfolio that yields identical wealth across ambiguous states of the world for an open set of prices and probabilities. This finding cannot be readily reconciled with SEU and is consistent with preferences that display ambiguity aversion. Using data from a field experiment with Malawian farmers, Bryan (2013) finds that the provision of partial insurance is less likely to induce the adoption of a new crop among farmers measured to be ambiguity-averse.

of remaining uninsured is $w - \pi + [-\lambda\pi(1 - \pi) + (1 - \pi)\pi]$. Now the DM will switch away from the status quo and will purchase insurance.⁴⁸

⁴⁸Research in social psychology has documented a ‘mere-measurement effect’: asking people whether they are likely to engage in a certain behavior can induce them to engage in such behavior (Greenwald et al. 1987; Morwitz and Johnson 1993; Levav and Fitzsimons 2006). One possible explanation for this effect is that measuring people’s intentions may induce people to make a plan, and loss-averse individuals are likely to go through the plan because a deviation might produce a loss. This hypothesis suggests that simply measuring people’s intentions to purchase health insurance might make it more likely that they actually insure.

PROCEDURES, INSTRUCTIONS, AND FORMS

BASE CONDITION

Procedures

- Participants are recruited using the Anderson Lab's online recruitment system.
- Participants enter the lab, are seated at a carrel and are asked to sign the Consent Form to participate in the study.
- Once they have agreed to participate in the study, they are assigned a Participant ID Number.
- Participants are given a handout with General Instructions and Specific Instructions #1. The experimenter reads these instructions aloud.
- Once the experimenter finishes reading Specific Instructions #1, the assistants leave the main room and go to two separate rooms next door. They stay there until the end of the session.
- The experimenter comes by each participant's desk. Each participant picks an envelope containing a ticket. Half of the participants receive a RED ticket and the other half receives a BLUE ticket.
- Participants fill out a questionnaire about personal information and the first portion of a personality questionnaire.
- Participants receive a handout with Specific Instructions #2, which remind them of the lottery that will take place at the end of the session. The experimenter reads these instructions aloud.
- Participants fill out the second portion of the personality questionnaire.
- Participants receive a Decision Form. At this time, they are informed that they have the chance to switch tickets and receive a \$0.10 bonus, if they so desire. They make a keep-or-switch decision.
- Participants play the individual lottery in a room next door.

General Instructions

Welcome to this session. Thanks for coming.

This session will take about 35 minutes. You will receive a \$6 minimum payment if you complete the study. These \$6 are yours. In the session you will have the chance to earn additional money. Whatever you earn from the study today will be added to this minimum payment. All payments will be made with Bruincard deposits in the next two or three weeks.

During this short study, you will be asked to fill out some questionnaires and you will play an individual lottery that involves real money.

Your questionnaire responses as well as the lottery outcome will be kept strictly confidential. At your carrel, you will find a sticker with your Participant ID Number. Please write down this number on the front page of each of the forms that you fill out.

Before we begin, we ask you to respect the following guidelines:

- No talking is allowed. If you have any questions during the study, please raise your hand. I will come to your place and answer your question privately.
- Every participant's task is individual and should be completed in private. Do not look at what other participants are doing.

If you do not comply with these rules, we will be forced to exclude you from the study. Thank you for your cooperation.

Should you have any questions or concerns at this point, please raise your hand. Otherwise, we will move on to the specific instructions.

Specific Instructions #1

Two assistants will help us today. They will do the same things but will proceed independently to help us run the session smoothly. So half of you will interact with one of the assistants, and the other half will interact with the other assistant.

On the front desk you see two identical bags. As of now, they are empty. Each assistant will keep one of the bags in a separate room next door throughout the session.

At the end of the session, each assistant will fill her bag with 10 red and blue balls in total. After setting up the bag, she will call half of the participants, one at a time, and she will randomly draw a ball in front of each participant. Then she will put the ball back into the bag.

In a minute, you will receive a ticket to play an INDIVIDUAL lottery. You will get ONE of two types of tickets:

- (a) The RED ticket pays \$10 if the assistant randomly draws a RED ball from the bag, and nothing if she draws a blue ball.
- (b) The BLUE ticket pays \$10 if the assistant randomly draws a BLUE ball from the bag, and nothing if she draws a red ball.

Please note that the lottery is real. You will actually receive \$10 if you happen to win the prize.

To determine which ticket you get, I will come by your desk and you will pick an envelope from this box I am showing to you. The envelope contains a ticket. Half of you will receive a RED ticket and the other half will get a BLUE ticket. This way, tickets will be randomly assigned.

You can be sure that the bag will have one of the following compositions:

- (i) 8 red balls and 2 blue balls

OR

- (ii) 2 red balls and 8 blue balls.

In other words, the bag will have

- (i) 80% red balls and 20% blue balls

OR

- (ii) 20% red balls and 80% blue balls.

The assistant will set up the bag for each participant AS SHE PLEASES. She is the ONLY person in the lab who will know the actual composition of the bag. She will not reveal this information to anyone at any time, not even after resolving the lottery.

Once the assistant has set up the bag, she will call you INDIVIDUALLY and will randomly draw a ball in front of you.

After drawing a ball, she will check which ticket you are playing and hence will determine whether or not you won the prize.

Please note that, at the moment of setting up the bag in the room next door, the assistant will not know which ticket you are playing. She will only check your ticket after drawing a ball. This way, you can be assured that this is a fair lottery.

Should you have any questions now, please raise your hand, and I will come by your desk. Otherwise, we will proceed with the study.

Next, I will come by your desk and you will pick an envelope with a ticket. Please check which ticket you have and stick your Participant ID Number on the envelope. You will take the envelope with you to the room next door when the assistant calls you.

Then, you will provide some personal information and fill out the first part of a personality questionnaire.

Participant ID Number: _____

Personal Information

All responses will be kept strictly confidential.

(1) Have you participated in other studies conducted in a lab on campus? If yes, please indicate which labs you have been to.

(2) What is your age?

(3) What is your gender? Male _____ Female _____

(4) What is your racial or ethnic background?

White or Caucasian _____ Black or African American _____ Hispanic _____
Asian _____ Native American _____ Multiracial _____ Other _____

(5) What is your major? If you have one, please specify it. If not, indicate “undecided”.

(6) What year are you classified for in the current semester?

Freshman _____ Sophomore _____ Junior _____ Senior _____
Masters student _____ Doctoral student _____

(7) Please indicate the country where you were raised.

(8) What is your native language?

Participant ID Number: _____

Questionnaire: How I am in general (Part I)

Here are a number of characteristics that may or may not apply to you. For each statement in the table, please indicate the extent to which you agree or disagree with that statement, by checking the appropriate column.

All responses will be kept strictly confidential.

I am someone who...	<i>Strongly Disagree</i>	<i>Disagree</i>	<i>Neither Agree Nor Disagree</i>	<i>Agree</i>	<i>Strongly Agree</i>
Is talkative					
Tends to find fault with others					
Does a thorough job					
Is depressed					
Is original, comes up with new ideas					
Is reserved					
Is helpful and unselfish with others					
Can be somewhat careless					
Is relaxed, handles stress well					
Is curious about many different things					
Is full of energy					
Starts quarrels with others					
Is a reliable worker					
Can be tense					
Is ingenious, a deep thinker					
Generates a lot of enthusiasm					
Has a forgiving nature					
Tends to be disorganized					
Worries a lot					
Has an active imagination					
Tends to be quiet					
Is generally trusting					

Once you are done, please raise your hand. I will come by your desk and give you another handout.

Specific Instructions #2

Thank you for completing the previous section. The next section will contain the second part of the personality questionnaire.

Here is a reminder of what will happen at the end of the session:

You have a ticket to play an INDIVIDUAL lottery that offers a \$10 prize. After you are done with all the questionnaires, one of the assistants will call you individually to play the lottery in a room next door.

If you are playing a RED ticket, you will win the prize if the assistant draws a red ball.

If you are playing a BLUE ticket, you will win the prize if the assistant draws a blue ball.

The bag contains either

(i) 80% red balls and 20% blue balls

OR

(ii) 20% red balls and 80% blue balls.

The assistant will set up the bag AS SHE PLEASES, without knowing which ticket you are playing.

She will not reveal the composition of the bag to anyone at any time.

Now you can go ahead and complete the second part of the personality questionnaire.

Participant ID Number: _____

Questionnaire: How I am in General (Part II)

Here are a number of characteristics that may or may not apply to you. For each statement in the table, please indicate the extent to which you agree or disagree with that statement, by checking the appropriate column.

All responses will be kept strictly confidential.

I am someone who...	<i>Strongly Disagree</i>	<i>Disagree</i>	<i>Neither Agree Nor Disagree</i>	<i>Agree</i>	<i>Strongly Agree</i>
Tends to be lazy					
Is emotionally stable, not easily upset					
Is inventive					
Has an assertive personality					
Can be cold and aloof					
Perseveres until the task is finished					
Can be moody					
Values artistic, aesthetic experiences					
Is sometimes shy, inhibited					
Is considerate and kind to almost anyone					
Does things efficiently					
Remains calm in tense situations					
Prefers work that is routine					
Is outgoing, sociable					
Is sometimes rude to others					
Makes plans and follows through with them					
Gets nervous easily					
Likes to reflect, play with ideas					
Has few artistic interests					
Likes to cooperate with others					
Is easily distracted					
Is sophisticated in art, music or literature					

Once you are done, please raise your hand. I will come by your desk and give you further instructions.

Participant ID Number: _____

Decision Form

Thanks for completing the previous questionnaires.

Soon you will play the lottery. Recall that there is a \$10 prize.

You have the chance to switch to the alternative ticket (the one that corresponds to the other color), if you so desire.

If you switch, you will receive \$0.10 in addition to what you get from the lottery.

Please indicate your decision below:

_____ I want to KEEP the original ticket

_____ I want to SWITCH to the alternative ticket

Your decision will be kept strictly confidential.

Should you have any questions before making the decision, please raise your hand and I will come by your desk.

Once you are done, please fold the Decision Form and raise your hand. I will let the assistants know that you are ready to play the lottery.

TRUST CONDITION

Procedures

- Participants are recruited using the lab's online recruitment system.
- Participants enter the lab, are seated at a carrel and are asked to sign the Consent Form to participate in the study.
- Once they have agreed to participate in the study, they are assigned a Participant ID Number. Then, they are read General Instructions.
- Participants are given a handout with Specific Instructions #1. The experimenter reads these instructions aloud. The tickets are randomly assigned.
- Participants are given a handout with Specific Instructions #2. The experimenter reads these instructions aloud.
- Once the experimenter finishes reading Specific Instructions #2, the assistants leave the main room and go to two separate rooms next door. They stay there until the end of the session.
- Participants fill out a questionnaire about personal information and the first portion of a personality questionnaire.
- Participants receive a handout with Specific Instructions #3, which remind them of the lottery that will take place at the end of the session. The experimenter reads these instructions aloud.
- Participants fill out the second portion of the personality questionnaire.
- Participants receive a Decision Form. They are informed that they have the chance to switch to the alternative ticket and receive a \$0.10 bonus, if they so desire. They make a keep-or-switch decision.
- Participants play the individual lottery in a room next door.

[The general section of the instructions (“General Instructions”) was identical for all conditions.]

Specific Instructions #1

There is one red ball and one blue ball inside this small bag I am holding. Please pass the bag along and check it out.

On your carrel you can find an empty envelope, a blank card, and a pencil. Feel free to inspect these materials.

Next, I will come by your desk and you will randomly draw a ball from the bag. You are the only person that should see the color of the ball you drew. After you check the color, please put the ball back into the bag.

Then, once I leave your desk, write down the color you drew on the blank card. Wait for me to leave your desk so that I cannot see what you write on the card. Please make sure your handwriting is clear.

Last, place the card inside the envelope. Please stick your participant ID Number on the envelope.

In a moment, I will explain to you what we will use the cards for.

Specific Instructions #2

Two assistants will help us today. They will do the same things but will proceed independently to help us run the session smoothly. So half of you will interact with one of the assistants, and the other half will interact with the other assistant.

On the front desk you see two identical bags. As of now, they are empty. Each assistant will keep one of the bags in a separate room next door throughout the session.

At the end of the session, each assistant will fill her bag with 10 red and blue balls in total. After setting up the bag, the assistant will call half of the participants, one at a time, and she will randomly draw a ball in front of them. Then she will put the ball back into the bag.

You will use the card that you placed inside the envelope to play an INDIVIDUAL lottery. The card is a ticket to play the lottery.

(c) The RED ticket pays \$10 if the assistant randomly draws a RED ball from the bag, and nothing if she draws a blue ball.

(d) The BLUE ticket pays \$10 if the assistant randomly draws a BLUE ball from the bag, and nothing if she draws a red ball.

Please note that the lottery is real. You will actually receive \$10 if you happen to win the prize.

You can be sure that the bag will have one of the following compositions:

(iii) 8 red balls and 2 blue balls

OR

(iv) 2 red balls and 8 blue balls.

In other words, the bag will have

(iii) 80% red balls and 20% blue balls

OR

(iv) 20% red balls and 80% blue balls.

The assistant will set up the bag AS SHE PLEASES. She is the ONLY person in the lab who will know the actual composition of the bag. She will not reveal this information to anyone at any time, not even after resolving the lottery.

Once the assistant has set up the bag, she will call you INDIVIDUALLY and will randomly draw a ball in front of you.

After drawing a ball, she will check which ticket you are playing and hence will determine whether or not you won the prize.

Please note that, at the moment of setting up the bag in the room next door, the assistant will not know which ticket you are playing. You are the only person who will know your ticket until the lottery is resolved. Also, the assistant will only check your ticket after drawing a ball. This way, you can be assured that this is a fair lottery.

Should you have any questions now, please raise your hand, and I will come by your desk. Otherwise, we will proceed with the study.

Next, you will provide some personal information and fill out the first part of a personality questionnaire.

[Next, participants filled out the forms titled “Personal Information” and “Questionnaire: How I am in General (Part I),” which were identical for all conditions. Then, participants received “Specific Instructions #3,” which were identical to “Specific Instructions #2” from the BASE condition. After the experimenter read these instructions aloud, participants filled out the form titled “Questionnaire: How I am in General (Part II),” which was identical for all conditions. Finally, participants filled out the Decision Form, which was identical to the one from the BASE condition.]

CONTROL CONDITION, version H (Horizontal Stripe is the Status Quo)

[Version V differs from version H only in the status quo die. To reproduce the instructions for version V, take the ones from version H and replace the word HORIZONTAL with the word VERTICAL and the word VERTICAL with the word HORIZONTAL.]

Procedures

- Participants are recruited using the Anderson Lab's online recruitment system.
- Participants enter the lab, are seated at a carrel and are asked to sign the Consent Form to participate in the study.
- Once they have agreed to participate in the study, they are assigned a Participant ID Number.
- Participants are given a handout with General Instructions and Specific Instructions #1. The experimenter reads these instructions aloud.
- Once the experimenter finishes reading Specific Instructions #1, the assistants leave the main room and go to two separate rooms next door. They stay there until the end of the session.
- Participants fill out a questionnaire about personal information and the first portion of a personality questionnaire.
- Participants receive a handout with Specific Instructions #2, which remind them of the lottery that will take place at the end of the session. The experimenter reads these instructions aloud.
- Participants fill out the second portion of the personality questionnaire.
- Participants receive a Decision Form. At this time, they are informed that they have the chance to use the alternative die (instead of the original one) and receive a \$0.10 bonus, if they so desire. They make a keep-or-switch decision.
- Participants play the individual lottery in a room next door.

[The general section of the instructions (“General Instructions”) was identical for all conditions.]

Specific Instructions #1

Two assistants will help us today. They will do the same things but will proceed independently to help us run the session smoothly. So half of you will interact with one of the assistants, and the other half will interact with the other assistant. Each assistant will stay in a separate room next door throughout the session.

On your desk you can see two identical 10-sided dice with numbers 0-9. Feel free to inspect the dice to verify that they are indeed identical.

In addition, you can see two empty plastic cups. One has been labeled with a HORIZONTAL stripe and the other one has been labeled with a VERTICAL stripe. Feel free to inspect the cups to check that they are otherwise identical.

Now, please place one die inside each cup. You will use the die inside the cup labeled with a HORIZONTAL stripe to play an INDIVIDUAL lottery at the end of the session.

The lottery works as follows. At the end of the session, you will grab the cup labeled with a HORIZONTAL stripe and you will line up in the hallway. One of the assistants will call you individually. Then, once you are inside the room, you will roll the die in front of the assistant.

If the die comes up 0, 1, 2, 3 or 4, you will get \$10. If it comes up 5, 6, 7, 8 or 9, you will get nothing.

The assistant will simply record the outcome of the lottery. Please note that the lottery is real. You will actually receive \$10 if you happen to win the prize.

Should you have any questions now, please raise your hand, and I will come by your desk. Otherwise, we will proceed with the study.

Next, you will provide some personal information and fill out the first part of a personality questionnaire.

[Next, participants filled out the forms titled “Personal Information” and “Questionnaire: How I am in General (Part I),” which were identical for all conditions.]

Specific Instructions #2

Thank you for completing the previous section. The next section will contain the second part of the personality questionnaire.

Here is a reminder of what will happen at the end of the session:

You will play an INDIVIDUAL lottery that offers a \$10 prize. After you are done with all the questionnaires, one of the assistants will call you individually to play the lottery in a room next door.

You will take the cup that has a HORIZONTAL stripe with you and you will roll the die in front of the assistant.

If the die comes up 0, 1, 2, 3 or 4, you will get \$10. If it comes up 5, 6, 7, 8 or 9, you will get nothing.

Now you can go ahead and complete the second part of the personality questionnaire.

[Next, participants filled out the form titled “Questionnaire: How I am in General (Part II),” which was identical for all conditions.]

Participant ID Number: _____

Decision Form

Thanks for completing the previous questionnaires.

Soon you will play the lottery. Recall that there is a \$10 prize.

You have the chance to switch to the alternative die (the one inside the cup labeled with a VERTICAL stripe), if you so desire. All you have to do is grab the cup labeled with a VERTICAL stripe instead of the cup labeled with a HORIZONTAL stripe when you line up to play the lottery.

If you switch to the alternative die, you will receive \$0.10 in addition to what you get from the lottery.

Please indicate your decision below:

_____ I want to KEEP the original die

_____ I want to SWITCH to the alternative die

Your decision will be kept strictly confidential.

Should you have any questions before making the decision, please raise your hand and I will come by your desk.

Once you are done, please fold the Decision Form and raise your hand. I will let the assistants know that you are ready to play the lottery.

REG CONDITION

Procedures

- Participants are recruited using the Anderson Lab's online recruitment system.
- Participants enter the lab, are seated at a carrel and are asked to sign the Consent Form to participate in the study.
- Once they have agreed to participate in the study, they are assigned a Participant ID Number.
- Participants are given a handout with General Instructions and Specific Instructions #1. The experimenter reads these instructions aloud.
- Once the experimenter finishes reading Specific Instructions #1, the assistants leave the main room and go to two separate rooms next door. They stay there until the end of the session.
- The experimenter comes by each participant's desk. Each participant picks an envelope containing a ticket. Half of the participants receive an EVEN ticket and the other half receives an ODD ticket.
- Participants fill out a questionnaire about personal information and the first portion of a personality questionnaire.
- Participants receive a handout with Specific Instructions #2, which remind them of the lottery that will take place at the end of the session. The experimenter reads these instructions aloud.
- Participants fill out the second portion of the personality questionnaire.
- Participants receive a Decision Form. At this time, they are informed that they have the chance to switch tickets and receive a \$0.10 bonus, if they so desire. They make a keep-or-switch decision.
- Participants play the individual lottery in a room next door.

[The general section of the instructions (“General Instructions”) was identical for all conditions.]

Specific Instructions #1

Two assistants will help us today. They will do the same things but will proceed independently to help us run the session smoothly. So half of you will interact with one of the assistants, and the other half will interact with the other assistant. Each assistant will stay in a separate room next door throughout the session.

Right now I have an empty plastic cup in my hand. Please pass it along and feel free to inspect it. We will use it in a minute.

On your desk you can see a 10-sided die with numbers 0-9, and a transparent plastic cup. Again, feel free to inspect these objects.

Now, I will collect the dice with the large plastic cup that you passed along.

Next, each assistant will randomly pick a die from the large cup.

Now, the assistants will also pick a transparent plastic cup from this pile. You can see that these transparent plastic cups are like the one you have on your desk. After picking a cup, the assistants will place the die into the cup. Each assistant will keep the die and the cup with her in the room next door until the end of the session.

At the end of the session, you will play an INDIVIDUAL lottery that will be resolved using the die.

The lottery works as follows. At the end of the session, you will line up in the hallway. One of the assistants will call you INDIVIDUALLY. Then, once you are inside the room, she will roll the die in front of you.

In a minute, you will get ONE of two types of tickets:

(e) The ODD ticket pays \$10 if the die comes up 1, 3, 5, 7 or 9, and nothing otherwise.

(f) The EVEN ticket pays \$10 if the die comes up 0, 2, 4, 6 or 8, and nothing otherwise.

To determine which ticket you get, I will come by your desk and you will pick an envelope from this box I am showing to you. The envelope contains a ticket. Half of you will receive an ODD ticket and the other half will get an EVEN ticket. This way, tickets will be randomly assigned.

After rolling the die, the assistant will check which ticket you are playing and will record the outcome of the lottery.

Please note that the lottery is real. You will actually receive \$10 if you happen to win the prize.

Should you have any questions now, please raise your hand, and I will come by your desk. Otherwise, we will proceed with the study.

Next, I will come by your desk and you will pick an envelope with a ticket. Please check which ticket you have and stick your Participant ID Number on the envelope. You will take the envelope with you to the room next door when the assistant calls you.

Then, you will provide some personal information and fill out the first part of a personality questionnaire.

[Next, participants filled out the forms titled “Personal Information” and “Questionnaire: How I am in General (Part I),” which were identical for all conditions.]

Specific Instructions #2

Thank you for completing the previous section. The next section will contain the second part of the personality questionnaire.

Here is a reminder of what will happen at the end of the session:

You will play an INDIVIDUAL lottery that offers a \$10 prize. After you are done with all the questionnaires, one of the assistants will call you individually to play the lottery in a room next door.

Once you are inside the room, the assistant will roll the 10-sided die in front of you.

If you are playing an ODD ticket, you will win the prize if the die comes up 1, 3, 5, 7 or 9.

If you are playing an EVEN ticket, you will win the prize if the die comes up 0, 2, 4, 6 or 8.

After rolling the die, the assistant will check which ticket you are playing and will record the outcome of the lottery.

Now you can go ahead and complete the second part of the personality questionnaire.

[Next, participants filled out the form titled “Questionnaire: How I am in General (Part II),” which was identical for all conditions.]

Participant ID Number: _____

Decision Form

Thanks for completing the previous questionnaires.

Soon you will play the lottery. Recall that there is a \$10 prize.

You have the chance to switch to the alternative ticket, if you so desire.

If you switch, you will receive \$0.10 in addition to what you get from the lottery.

Please indicate your decision below:

_____ I want to KEEP the original ticket

_____ I want to SWITCH to the alternative ticket

Your decision will be kept strictly confidential.

Should you have any questions before making the decision, please raise your hand and I will come by your desk.

Once you are done, please fold the Decision Form and raise your hand. I will let the assistants know that you are ready to play the lottery.

END CONDITION

Procedures

- Participants are recruited using the Anderson Lab's online recruitment system.
- Participants enter the lab, are seated at a carrel and are asked to sign the Consent Form to participate in the study.
- Once they have agreed to participate in the study, they are assigned a Participant ID Number.
- Participants are given a handout with General Instructions and Specific Instructions #1. The experimenter reads these instructions aloud. At this time, participants are informed that they will have the chance to switch tickets and receive a \$0.10 bonus, if they so desire.
- Once the experimenter finishes reading Specific Instructions #1, the assistants leave the main room and go to two separate rooms next door. They stay there until the end of the session.
- The experimenter comes by each participant's desk. Each participant picks an envelope containing a ticket. Half of the participants receive an EVEN ticket and the other half receives an ODD ticket.
- Participants fill out a questionnaire about personal information and the first portion of a personality questionnaire.
- Participants receive a handout with Specific Instructions #2, which remind them of the lottery that will take place at the end of the session. The experimenter reads these instructions aloud.
- Participants fill out the second portion of the personality questionnaire.
- Participants receive a Decision Form. They make a keep-or-switch decision.
- Participants play the individual lottery in a room next door.

[The general section of the instructions (“General Instructions”) was identical for all conditions.]

Specific Instructions #1

Two assistants will help us today. They will do the same things but will proceed independently to help us run the session smoothly. So half of you will interact with one of the assistants, and the other half will interact with the other assistant. Each assistant will stay in a separate room next door throughout the session.

Right now I have an empty plastic cup in my hand. Please pass it along and feel free to inspect it. We will use it in a minute.

On your desk you can see a 10-sided die with numbers 0-9, and a transparent plastic cup. Again, feel free to inspect these objects.

Now, I will collect the dice with the large plastic cup that you passed along.

Next, each assistant will randomly pick a die from the large cup.

Now, the assistants will also pick a transparent plastic cup from this pile. You can see that these transparent plastic cups are like the one you have on your desk. After picking a cup, the assistants will place the die into the cup. Each assistant will keep the die and the cup with her in the room next door until the end of the session.

At the end of the session, you will play an INDIVIDUAL lottery that will be resolved using the die.

The lottery works as follows. At the end of the session, you will line up in the hallway. One of the assistants will call you INDIVIDUALLY. Then, once you are inside the room, she will roll the die in front of you.

In a minute, you will get ONE of two types of tickets:

(g) The ODD ticket pays \$10 if the die comes up 1, 3, 5, 7 or 9, and nothing otherwise.

(h) The EVEN ticket pays \$10 if the die comes up 0, 2, 4, 6 or 8, and nothing otherwise.

To determine which ticket you get, I will come by your desk and you will pick an envelope from this box I am showing to you. The envelope contains a ticket. Half of you will receive an ODD ticket and the other half will get an EVEN ticket. This way, tickets will be randomly assigned.

Before you play the lottery, you will have the chance to switch to the alternative ticket, if you so desire.

If you switch, you will receive \$0.10 in addition to what you get from the lottery.

I will give you a Decision Form, and all you will have to do is indicate whether you want to KEEP your original ticket or SWITCH to the alternative one, by checking the option that you prefer.

After rolling the die, the assistant will check your FINAL ticket and will record the outcome of the lottery.

Please note that the lottery is real. You will actually receive \$10 if you happen to win the prize.

Should you have any questions now, please raise your hand, and I will come by your desk. Otherwise, we will proceed with the study.

Next, I will come by your desk and you will pick an envelope with a ticket. Please check which ticket you have and stick your Participant ID Number on the envelope. You will take the envelope and the Decision Form with you to the room next door when the assistant calls you.

Then, you will provide some personal information and fill out the first part of a personality questionnaire.

[Next, participants filled out the forms titled “Personal Information” and “Questionnaire: How I am in General (Part I),” which were identical for all conditions.]

Specific Instructions #2

Thank you for completing the previous section. The next section will contain the second part of the personality questionnaire.

Here is a reminder of what will happen at the end of the session:

You will play an INDIVIDUAL lottery that offers a \$10 prize. After you are done with all the questionnaires, one of the assistants will call you individually to play the lottery in a room next door.

Once you are inside the room, the assistant will roll the 10-sided die in front of you.

Before you play the lottery, you will have the chance to switch to the alternative ticket, if you so desire.

If you switch, you will receive \$0.10 in addition to what you get from the lottery.

I will give you a Decision Form, and all you will have to do is indicate whether you want to KEEP your original ticket or SWITCH to the alternative one, by checking the option that you prefer.

If you end up playing an ODD ticket, you will win the prize if the die comes up 1, 3, 5, 7 or 9.

If you end up playing an EVEN ticket, you will win the prize if the die comes up 0, 2, 4, 6 or 8.

After rolling the die, the assistant will check which ticket you are playing and will record the outcome of the lottery.

Now you can go ahead and complete the second part of the personality questionnaire.

[Next, participants filled out the form titled “Questionnaire: How I am in General (Part II),” which was identical for all conditions. Then, participants filled out the Decision Form, which was identical to the one from the REG condition.]

IND CONDITION

Procedures

- Participants are recruited using the Anderson Lab's online recruitment system.
- Participants enter the lab, are seated at a carrel and are asked to sign the Consent Form to participate in the study.
- Once they have agreed to participate in the study, they are assigned a Participant ID Number.
- Participants are given a handout with General Instructions and Specific Instructions #1. The experimenter reads these instructions aloud.
- Once the experimenter finishes reading Specific Instructions #1, the assistants leave the main room and go to two separate rooms next door. They stay there until the end of the session.
- The experimenter comes by each participant's desk. Each participant picks an envelope containing a ticket. Half of the participants receive a RED₁ ticket and the other half receives a RED₂ ticket.
- Participants fill out a questionnaire about personal information and the first portion of a personality questionnaire.
- Participants receive a handout with Specific Instructions #2, which remind them of the lottery that will take place at the end of the session. The experimenter reads these instructions aloud.
- Participants fill out the second portion of the personality questionnaire.
- Participants receive a Decision Form. At this time, they are informed that they have the chance to switch tickets and receive a \$0.10 bonus, if they so desire. They make a keep-or-switch decision.
- Participants play the individual lottery in a room next door.

[The general section of the instructions (“General Instructions”) was identical for all conditions.]

Specific Instructions #1

Two assistants will help us today. They will do the same things but will proceed independently to help us run the session smoothly. So half of you will interact with one of the assistants, and the other half will interact with the other assistant.

On the front desk you see two pairs of identical bags. Within each pair, the bags are labeled Bag 1 and Bag 2. As of now, they are empty. Each assistant will keep one pair of bags in a separate room next door throughout the session.

At the end of the session, each assistant will fill each of the two bags with 10 red and blue balls in total. After setting up the bags, she will call half of the participants, one at a time, and she will randomly draw a ball from ONE of the bags in front of each participant. Then she will put the ball back into the bag.

In a minute, you will receive a ticket to play only ONE of two possible INDIVIDUAL lotteries. One lottery involves Bag 1 alone, while the other one involves Bag 2 alone. So you will get ONE of two types of tickets:

- (a) The RED_1 ticket involves Bag 1 only. It pays \$10 if the assistant randomly draws a RED ball from this bag, and nothing if she draws a blue ball.
- (b) The RED_2 ticket involves Bag 2 only. It pays \$10 if the assistant randomly draws a RED ball from this bag, and nothing if she draws a blue ball.

Please note that the lottery is real. You will actually receive \$10 if you happen to win the prize.

To determine which ticket you get, I will come by your desk and you will pick an envelope from this box I am showing to you. The envelope contains a ticket. Half of you will receive a RED_1 ticket and the other half will get a RED_2 ticket. This way, tickets will be randomly assigned.

You can be sure that the compositions of the bags will be given by one of the following combinations:

- (i) Bag 1: 8 RED balls and 2 blue balls
Bag 2: 2 RED balls and 8 blue balls

OR

- (ii) Bag 1: 2 RED balls and 8 blue balls
Bag 2: 8 RED balls and 2 blue balls.

In other words, the compositions will be:

- (i) Bag 1: 80% RED balls
Bag 2: 20% RED balls

OR

- (ii) Bag 1: 20% RED balls
Bag 2: 80% RED balls.

The assistant will set up the bags for each participant AS SHE PLEASES. She is the ONLY person who will know the actual compositions of the bags. She will not reveal this information to anyone at any time, not even after resolving the lottery.

Once the assistant has set up the bags to play your own lottery, she will call you INDIVIDUALLY and will check which lottery you are playing. Then, she will randomly draw a ball from the corresponding bag in front of you, and she will record the outcome of the lottery.

Please note that, at the moment of setting up the bags in the room next door, the assistant will not know which ticket you are playing. She will only check your ticket right before drawing a ball. This way, you can be assured that this is a fair lottery.

Should you have any questions now, please raise your hand, and I will come by your desk. Otherwise, we will proceed with the study.

Next, I will come by your desk and you will pick an envelope with a ticket. Please check which ticket you have and stick your Participant ID Number on the envelope. You will take the envelope with you to the room next door when the assistant calls you.

Then, you will provide some personal information and fill out the first part of a personality questionnaire.

[Next, participants filled out the forms titled “Personal Information” and “Questionnaire: How I am in General (Part I),” which were identical for all conditions.]

Specific Instructions #2

Thank you for completing the previous section. The next section will contain the second part of the personality questionnaire.

Here is a reminder of what will happen at the end of the session:

You have a ticket to play an INDIVIDUAL lottery that offers a \$10 prize. After you are done with all the questionnaires, one of the assistants will call you individually to play the lottery in a room next door.

If you are playing a RED₁ ticket, the assistant will draw a ball from Bag 1, and you will win the prize if she draws a red ball.

If you are playing a RED₂ ticket, the assistant will draw a ball from Bag 2, and you will win the prize if she draws a red ball.

In each bag, there are 10 red and blue balls in total. The compositions of the bags are either

- (i) Bag 1: 80% RED balls
Bag 2: 20% RED balls

OR

- (ii) Bag 1: 20% RED balls
Bag 2: 80% RED balls

The assistant will set up the bags AS SHE PLEASES, without knowing which ticket you are playing.

The assistant will not reveal the compositions of the bags to anyone at any time.

Now you can go ahead and complete the second part of the personality questionnaire.

[Next, participants filled out the form titled "Questionnaire: How I am in General (Part II)," which was identical for all conditions.]

Participant ID Number: _____

Decision Form

Thanks for completing the previous questionnaires.

Soon you will play the lottery. Recall that there is a \$10 prize.

You have the chance to switch to the alternative ticket (the one that corresponds to the other bag), if you so desire.

If you switch, you will receive \$0.10 in addition to what you get from the lottery.

Please indicate your decision below:

_____ I want to KEEP the original ticket

_____ I want to SWITCH to the alternative ticket

Your decision will be kept strictly confidential.

Should you have any questions before making the decision, please raise your hand and I will come by your desk.

Once you are done, please fold the Decision Form and raise your hand. I will let the assistants know that you are ready to play the lottery.

BCR CONDITION

Procedures

- Participants are recruited using the Anderson Lab's online recruitment system.
- Participants enter the lab, are seated at a carrel and are asked to sign the Consent Form to participate in the study.
- Once they have agreed to participate in the study, they are assigned a Participant ID Number.
- Participants are given a handout with General Instructions and Specific Instructions #1. The experimenter reads these instructions aloud.
- Once the experimenter finishes reading Specific Instructions #1, the assistant leaves the main room and goes to a room next door. He stays there until the end of the session.
- The experimenter comes by each participant's desk. Each participant picks an envelope containing a ticket. Half of the participants receive a RED₁ ticket and the other half receives a RED₂ ticket.
- Participants fill out a questionnaire about personal information and the first portion of a personality questionnaire.
- Participants receive a handout with Specific Instructions #2, which remind them of the lottery that will take place at the end of the session. The experimenter reads these instructions aloud.
- Participants fill out the second portion of the personality questionnaire.
- Participants receive a Decision Form. At this time, they are informed that they have the chance to switch tickets and receive a \$0.10 bonus, if they so desire. They make a keep-or-switch decision.
- Participants receive another Decision Form. They make a series of keep-or-switch choices for varying values of the switching bonus. One of all the choices they make (including the one with a \$0.10 bonus) will be randomly selected as the choice-that-counts.
- Participants line up in the hallway. The assistant calls them individually to play the lottery in the room next door. The assistant randomly selects the keep-or-switch choice that counts and then resolves the lottery.

[The general section of the instructions (“General Instructions”) was identical for all conditions.]

Specific Instructions #1

On the front desk you see a pair of identical bags. The bags are labeled Bag 1 and Bag 2. As of now, they are empty. The assistant will keep them in a separate room next door throughout the session.

At the end of the session, the assistant will fill each of the two bags with 10 red and blue balls in total. After setting up the bags, he will call one participant at a time, and he will randomly draw a ball from ONE of the bags in front of the participant. Then he will put the ball back into the bag.

In a minute, you will receive a ticket to play only ONE of two possible INDIVIDUAL lotteries. One lottery involves Bag 1 alone, while the other one involves Bag 2 alone. So you will get ONE of two types of tickets:

- (a) The RED₁ ticket involves Bag 1 only. It pays \$10 if the assistant randomly draws a RED ball from this bag, and nothing if he draws a blue ball.
- (b) The RED₂ ticket involves Bag 2 only. It pays \$10 if the assistant randomly draws a RED ball from this bag, and nothing if he draws a blue ball.

Please note that the lottery is real. You will actually receive \$10 if you happen to win the prize.

To determine which ticket you get, I will come by your desk and you will pick an envelope from this box I am showing to you. The envelope contains a ticket. Half of you will receive a RED₁ ticket and the other half will get a RED₂ ticket. This way, tickets will be randomly assigned.

Now let me tell you how we will determine the compositions of Bag 1 and Bag 2. On the front desk you can see an empty plastic cup. You can also see eleven pieces of paper. Each piece of paper features a different number between 0 (inclusive) and 10 (inclusive). Now I will fold them and put them into the plastic cup. The assistant will randomly draw a number and write it down without showing it to anyone else; then he will fold the piece of paper again and put it back into the cup. Next he will repeat this procedure.

The first number drawn by the assistant will determine the number of RED balls in Bag 1. The second number will determine the number of RED balls in Bag 2. (Recall that each bag will contain 10 red and blue balls in total.)

The assistant is the ONLY person who will know the compositions of Bag 1 and Bag 2. He will not reveal this information to anyone at any time, not even after resolving the lottery.

At the end of the session, you will line up in the hallway. The assistant will call you INDIVIDUALLY and will check which lottery you are playing. Then, he will randomly draw a ball from the corresponding bag in front of you, and he will record the outcome of the lottery.

Should you have any questions now, please raise your hand, and I will come by your desk. Otherwise, we will proceed with the study.

Next, I will come by your desk and you will pick an envelope with a ticket. Please check which ticket you have and stick your Participant ID Number on the envelope. You will take the envelope with you to the room next door when the assistant calls you.

Then, you will provide some personal information and fill out the first part of a personality questionnaire.

[Next, participants filled out the forms titled “Personal Information” and “Questionnaire: How I am in General (Part I),” which were identical for all conditions.]

Specific Instructions #2

Thank you for completing the previous section. The next section will contain the second part of the personality questionnaire.

Here is a reminder of what will happen at the end of the session:

You have a ticket to play an INDIVIDUAL lottery that offers a \$10 prize. After you are done with all the questionnaires, the assistant will call you individually to play the lottery in a room next door.

If you are playing a RED₁ ticket, the assistant will draw a ball from Bag 1, and you will win the prize if he draws a RED ball.

If you are playing a RED₂ ticket, the assistant will draw a ball from Bag 2, and you will win the prize if he draws a RED ball.

The compositions of the bags were randomly determined. The assistant drew two numbers between 0 and 10 independently. The first number determined the number of RED balls (out of 10) in Bag 1. The second number determined the number of RED balls (also out of 10) in Bag 2.

The assistant is the ONLY person who knows the compositions of Bag 1 and Bag 2 and he will not reveal this information to anyone at any time.

Now you can go ahead and complete the second part of the personality questionnaire.

[Next, participants filled out the form titled “Questionnaire: How I am in General (Part II),” which was identical for all conditions. Then, participants filled out the Decision Form, which was identical to the one from the IND condition.]

Decision Form (Part II)

Thanks for completing the first part of the Decision Form. Now you will complete the second part. This one is the last form that you will fill out before playing the lottery. Please look carefully at the following table:

Which option do you prefer?

	OPTION 1			OPTION 2
				SWITCH to the alternative ticket when the bonus is
(1)	KEEP the original ticket	1	2	\$0.20
(2)				\$0.30
(3)				\$0.40
(4)				\$0.50
(5)				\$0.60
(6)				\$0.70
(7)				\$0.80
(8)				\$0.90
(9)				\$1

For each of the nine rows, all you have to do is choose between OPTION 1 and OPTION 2. You have just made a similar decision when the bonus is \$0.10. For each row, indicate your choice by checking the corresponding box.

Your earnings will be determined as follows. Before you play the lottery in the room next door, I will roll a ten-sided die in front of you. The die has numbers 0 through 9 on it. The number that comes out will determine which of the rows will be the row-that-counts. If number 0 comes out, then we will implement the choice you made in the first part of the Decision Form when the bonus was \$0.10. If any other number comes out, we will carry out the choice that corresponds to that row in the table. For example, suppose that 5 comes out. Then we will implement the choice you made in row 5. This means that if your choice in that row was to switch tickets, you will play the lottery with the alternative ticket and you will receive \$0.60 in addition to what you get from the lottery.

Now you can go ahead and make the choices. Please raise your hand once you are done.

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CHAPTER 3

Risk, Ambiguity, and Diversification

1 Introduction

In several choice problems under uncertainty, individuals have the opportunity to *diversify* among choice options. For instance, financial investors pick a portfolio composed of one or more assets; managers allocate a budget among projects; participants from a defined contribution saving plan distribute their contribution among different funds; and farmers decide which crops to plant and how much to invest in each of them. While individuals' attitudes toward risk are a key determinant of the extent of diversification in situations like these, other factors may also play an important role. In particular, in most situations there is not just uncertainty about outcomes—known as *risk*—but also uncertainty about probability distributions over outcomes—known as *ambiguity*.¹ Prior empirical research has widely documented that attitudes toward ambiguity may have an effect on choice behavior beyond the effect of attitudes toward risk.² Yet, the influence of attitudes toward ambiguity on the extent of diversification has remained largely unexplored.³ In this paper, I report the results of a laboratory experiment that investigates how ambiguity affects the decision to diversify among uncertain options.

The experimental design is motivated by the theoretical observation that attitudes toward risk and attitudes toward ambiguity combine to affect choice under ambiguity. For example, someone who is risk-averse may diversify among ambiguous options regardless of

¹The distinction between risk (known probabilities) and ambiguity (unknown probabilities) dates back to Knight (1921) and Ellsberg (1961). Knight used the term uncertainty instead of ambiguity; here I use uncertainty as a generic term that encompasses situations of risk and ambiguity.

²See the recent survey of Machina and Siniscalchi (2014), who also summarize the vast theoretical literature on the topic. For recent applications, see Bossaerts et al. (2010), Bryan (2013), and Sautua (2015).

³An exception is Bossaerts et al. (2010), who conducted a laboratory experiment to study the effect of attitudes toward ambiguity on portfolio choices and asset prices in competitive financial markets.

her attitude toward ambiguity—the mere uncertainty about outcomes might lead her to diversify. Therefore, it is usually hard to infer the *pure* effect of ambiguity on the decision to diversify directly from a situation with ambiguity.

This difficulty becomes evident when we examine the results of previous experimental work on diversification. For example, Bossaerts et al. (2010) find that many participants hold a portfolio that yields identical wealth across ambiguous states of the world for an open set of asset prices and state probabilities. Although this finding is consistent with preferences that display ambiguity aversion (as the authors show carefully), it can also be explained (at least partially) by *loss aversion*. Indeed, in a similar experimental task, Choi et al. (2007) also find that several participants choose nearly safe portfolios for an open set of prices when either of the two states of the world could occur with *known* probability 0.5. As the authors show, disappointment aversion—which is an instance of loss aversion—can produce this behavior. I contribute to this research by presenting a simple design that achieves a clear separation between the effects of risk and ambiguity on diversification.

To separate the effects of risk and ambiguity, I use a between-subjects design with two conditions—one in which the options are risky and another in which they are ambiguous. In the RISK condition, participants have the option to either play one of two independent gambles that pay a \$10 prize with a 50 percent chance, or diversify between the two gambles. If a participant diversifies, she plays both basic gambles, but now each one offers a prize of \$5 instead of \$10. In the AMBIGUITY condition, the only difference is that the two gambles pay the \$10 prize with unknown probabilities. The actual probabilities are independent between gambles and uniformly distributed between 0 and 1. Consequently, the ambiguous gambles are ‘mean-preserving spreads in probabilities’ of their risky counterparts. Thus, while behavior in the RISK condition identifies the effect of risk on the propensity to diversify, the *difference* in behavior between RISK and AMBIGUITY identifies the effect of ambiguity.

The experimental design builds upon the one I used in a recent paper, Sautua (2015).

In that paper, participants chose whether to retain a status quo gamble that had been randomly assigned to them or switch to an alternative gamble for a small bonus. In some conditions, the two gambles were equally risky, whereas in others the gambles were equally ambiguous. In the present experiment, participants face three tasks. In the first task, I replicate the keep-or-switch decision from the previous experiment with a little twist—participants choose the status quo themselves. After participants make the keep-or-switch decision, in the second task they decide whether to retain the chosen gamble or diversify. In the third task, participants make a similar decision—play one of the two basic gambles or the diversified one—in a different situation. In the RISK condition, the winning probabilities differ between the basic gambles. In the AMBIGUITY condition, participants observe one realization of each basic gamble as practice, and then decide which of the three gambles to play for real.

This design enables me to investigate several features of diversification under uncertainty, with a focus on the differential effect of ambiguity relative to risk. Within each condition, the second task establishes the *baseline prevalence* of diversification when both options are equally uncertain. The third task reveals the *sensitivity* of diversification to the arrival of new information about the choice options; in the RISK condition, the new information takes the form of a change in objective probabilities, whereas in the AMBIGUITY condition it is conveyed by past outcomes. The inclusion of the first task is intended to uncover the relationship between the tendency to diversify and the tendency to retain the status quo—which I shall refer to as *inertia*—when diversification is not feasible. The three central questions for this paper are: (i) whether diversification is more prevalent under ambiguity than under risk; (ii) whether ambiguity makes a decision maker more likely to diversify when this is feasible (second task) *and* stick with the status quo when she cannot diversify (first task); and (iii) whether diversification is less sensitive to new information that is supposed to reduce its appeal under ambiguity than under risk.

The data show a clear influence of ambiguity on choice behavior. First, although there is substantial inertia in both conditions when diversification is not feasible, there is *excess* inertia in the AMBIGUITY condition. This result, which is in line with the findings from Sautua (2015), is predicted by Knightian Decision Theory (Bewley 2002). Second, the propensity to diversify in the second task is higher under ambiguity than under risk. Moreover, *excess* diversification from the AMBIGUITY condition is driven by participants whose choices displayed inertia in the first task. Interestingly, as I show below, neither of the major theories of choice under uncertainty (including models of ambiguity aversion) predicts this behavioral pattern. Last, the proportion of participants who continue to diversify in the third task after the arrival of new information is substantially larger in AMBIGUITY than in RISK. Put differently, participants' choice of the diversified gamble displays significantly more inertia under ambiguity than under risk.

The finding that ambiguity increases the prevalence and persistence of diversification may help to explain some behavioral patterns that have been observed with regard to defined contribution saving plans. I briefly elaborate on this point in the concluding section.

2 Experimental Design

2.1 General Aspects of the Design

The experiment took place on the campus of the University of California, Los Angeles, with students drawn from the Anderson Behavioral Lab's subject pool. The experiment features a between-subjects design with two conditions: RISK (51 participants) and AMBIGUITY (49 participants). I carried out each condition through four sessions, with between 9 and 16 participants per session.

I conducted the experiment with paper-and-pencil. In each session, upon arrival at the room, participants were seated at individual desks; then I gave them a series of handouts

containing general and specific instructions (which I also read aloud) and they filled out a few forms. Throughout the session participants made a few incentivized choices; at the end, one of these choices was selected to be played out using the random-lottery method. All payments from a given session (including a \$8 show-up fee) were made by the lab manager through a deposit to participants' university accounts in the next few weeks. The sessions lasted around 45 minutes; I ran them with the help of two assistants, whom I introduced as I read the first portion of instructions.⁴

In Table 1 I summarize some demographic characteristics of the pool of participants.⁵ For each experimental condition, the table shows the percentage of participants who previously participated in other experiments, are women, are Asian, are undergraduate students, pursue a major that is Math-intensive or is intensive in formal logic, and are native English speakers.⁶ For each of these observable characteristics, the last column of the table displays the result of a chi-square test of differences in proportions across conditions. Participants are clearly balanced on observable characteristics. Next, I describe each condition. The Appendix contains full instructions and a sample of the forms that participants filled out.

2.2 The RISK Condition

At the beginning of the session, I asked participants to pick five out of ten possible numbers. They picked five different numbers between 0 (inclusive) and 9 (inclusive) and wrote them down on a blank card. Then they picked a die—Die 1 or Die 2—and wrote it down on another blank card. Participants placed each card into an empty envelope (one was labeled ‘Numbers’ and the other ‘Die’); the envelopes remained closed on their desks until the end

⁴The protocol could have been carried out with only one assistant per session, but I used two to run the sessions faster. I told participants that the two assistants would proceed independently, and that each assistant would interact with roughly half of the participants in the session. (See instructions in the Appendix.) Therefore, in what follows I describe the protocol as if I had used a single assistant.

⁵Participants reported this information on one of the forms that they filled out.

⁶For a classification of majors, see the Appendix (Section 6.1).

TABLE 1 --- DEMOGRAPHIC CHARACTERISTICS OF PARTICIPANTS

Variable	Condition		Chi-Square Test p-value*
	RISK (N = 51)	AMBIGUITY (N = 49)	
Other Experiments	82%	81%	0.887
Female	75%	72%	0.808
Asian	47%	44%	0.741
Undergraduate	94%	94%	0.939
Math-Related Major	37%	35%	0.849
English 1 st Language	80%	83%	0.705

* The p-values are for chi-square tests of differences in proportions. For each variable, the null hypothesis is that the percentage of participants with the relevant characteristic is the same in both experimental conditions.

of the session. Once participants had made their choices, I told them that they would use the cards to play an individual lottery.

In the room next door, the assistant would hold two identical ten-sided dice with numbers 0 through 9.⁷ She would label one of the dice Die 1 and the other Die 2. At the end of the session, each participant would go to the room next door, where the assistant would roll *one* of the dice—the one that the participant had picked and written on the card. If any of the five numbers that the participant had picked came up, she would get \$10; if any of the remaining five numbers came up, she would get nothing. After participants had completed two forms that were unrelated to the lottery, I reminded them about the instructions with regard to the lottery.⁸ Then, participants received Decision Form #1, through which I gave them the

⁷I allowed participants to examine a sample die as I described the lottery.

⁸On one of the forms participants provided demographic information, and on the other they answered the first part of the ‘Big Five’ personality questionnaire (John, Donahue, and Kentle 1991). The personality questionnaire served two purposes. First, it allowed time for participants to adapt to a reference point other than their initial wealth, in case preferences are reference-dependent. (See the discussion in Section 3.) Second, the questionnaire also served as a decoy for the decisions in which I was interested. This was

option to switch dice. Switching dice was rewarded with a \$0.10 bonus—if they switched, participants would receive \$0.10 in addition to what they got from the lottery. Participants indicated whether they wanted to keep the original die or switch to the alternative die by checking the corresponding option. This was the First Stage of the session.

Next, I informed participants that they could either play this lottery (using the chosen die) or play another lottery. If they played the other lottery, the assistant would roll *both* dice. The roll of a given die would pay \$5 if successful (i.e., if any of the five numbers on the participant’s card came up) and nothing otherwise. Thus, the lottery would pay \$10 if both rolls were successful, \$5 if only one roll were successful, and nothing if neither of the rolls were successful. I emphasized that the lottery in which both dice were rolled would not pay the \$0.10 bonus; a participant would receive the bonus if she had previously switched to the alternative die and now decided to use this die alone. On Decision Form #2, participants indicated which lottery they wanted to play by checking the corresponding option. This was the Second Stage of the session.

Finally, I told participants that they would make a similar decision as that from the Second Stage for different probabilities of success of a roll of Die 1 or Die 2. There were four different scenarios for such probabilities: Die 1 30%-Die 2 70%; Die 1 40%-Die 2 60%; Die 1 60%-Die 2 40%; and Die 1 70%-Die 2 30%.⁹ For each scenario, participants had to choose whether to use Die 1, Die 2, or both. As before, using the alternative die alone (i.e., the die that a participant had not written on the card originally) would pay a \$0.10 bonus. I told participants that we would randomly pick one of the scenarios (including the one from the

intended to attenuate experimental effects.

⁹I did not frame the task in terms of probabilities. Rather, I asked participants to write down four sets of numbers on the back side of the card from the envelope labeled ‘Numbers.’ By adding to or subtracting from the five numbers they had picked originally, they came up with one set of three numbers, one of four, one of six, and another of seven. We used these sets of numbers to put the four scenarios into practice. For example, in one scenario a roll of Die 1 would be successful if any of the three final numbers came up, while a roll of Die 2 would be successful if any of the seven final numbers came up. This scenario corresponded to the ‘Die 1 30%-Die 2 70%’ scenario.

Second Stage) after they had made their choices and implement their choice for the selected scenario. On Decision Form #3, participants indicated their choice for each scenario. This was the Third (and final) Stage of the session.

2.3 The AMBIGUITY Condition

At the beginning of the session, participants picked a color—red or blue—and wrote it down on a blank card. Then they picked a bag—Bag 1 or Bag 2—and wrote it down on another blank card. Participants placed each card into an empty envelope (one was labeled ‘Color’ and the other ‘Bag’); the envelopes remained closed on their desks until the end of the session. Once participants had made their choices, I told them that they would use the cards to play an individual lottery.

There were two empty black bags sitting on the front desk, labeled Bag 1 and Bag 2. I informed participants that the assistant would take the bags to the room next door and fill each bag with red and blue balls—each bag would have 10 balls in total. At the end of the session, each participant would go to this room, where the assistant would draw a ball from *one* of the bags—the one that the participant had picked and written on the card. (I told participants that the balls would be drawn with replacement.) If the color of a participant’s ticket matched the color of the ball drawn by the assistant, the participant would get \$10; otherwise, she would get nothing. To determine the composition of each bag, the assistant drew two numbers between 0 and 10 from a cup in front of participants; she drew the numbers with replacement.¹⁰ She was the only person in the lab that knew these two numbers. The first number determined the number of red balls in Bag 1; the second number determined the number of red balls in Bag 2.¹¹

After participants had completed the same two forms that I used in the RISK condition,

¹⁰The cup contained 11 pieces of paper, each one featuring a different number between 0 and 10.

¹¹I told participants that the assistant would never reveal the compositions of the bags, not even after resolving the lottery.

they received Decision Form #1. Through this form I informed participants that they had the option to switch bags. Switching bags was rewarded with a \$0.10 bonus. Participants indicated whether they wanted to keep the original bag or switch to the alternative bag by checking the corresponding option. This was the First Stage of the session.

Next, I informed participants that they could either play this lottery (using the chosen bag) or play another lottery. If they played the other lottery, the assistant would draw a ball from *each* bag. A given draw would pay \$5 if successful (i.e., if the color of a participant's ticket matched the color of the ball) and nothing otherwise. Thus, the lottery would pay \$10 if both draws were successful, \$5 if only one draw were successful, and nothing if neither of the draws were successful. I emphasized that the lottery in which a ball was drawn from each bag would not pay the \$0.10 bonus; a participant would receive the bonus if she had previously switched to the alternative bag and now decided to use this bag alone. On Decision Form #2, participants indicated which lottery they wanted to play by checking the corresponding option. This was the Second Stage of the session.

Finally, I gave participants the opportunity to change their choice of lottery after observing the outcomes of two practice draws. The assistant would draw one ball from each bag in front of the participant and then put the ball back into the bag. For each of the four possible scenarios (red ball from each bag, blue ball from each bag, red ball from Bag 1 and blue ball from Bag 2, and vice versa), participants had to choose whether to use Bag 1, Bag 2, or both. As before, using the alternative bag alone (i.e., the bag that a participant had not written on the card originally) would pay a \$0.10 bonus. On Decision Form #3, participants made a choice for each possible scenario before the assistant performed the practice draws. After the practice draws, the assistant implemented a participant's choice for the actual scenario. This was the Third (and final) Stage of the session.

TABLE 2 --- PREDICTED BEHAVIOR FOR THE RISK CONDITION:
FIRST AND SECOND STAGES

		<i>Second Stage</i>
		Previous Choice
<i>First Stage</i>	Diversified Lottery	
Original Lottery		Reference-Dependent SEU ($\lambda > 1.08$) (Sugden)
Alternative Lottery	Disappointment Theory ($\lambda > 1.08$) Krahmer & Stone's Theory ($\lambda > 1.17$)	Subjective Expected Utility Models of Ambiguity Aversion Prospect Theory (Linear in Probabilities) Reference-Dependent SEU (Kőszegi & Rabin) Knightian Decision Theory

3 Predictions

In this section I discuss the predictions of all major theories of choice under uncertainty for choice behavior in each condition. I focus on the predictions that concern *diversification* in the Second and Third Stages—*when* a participant is expected to choose the lottery in which both dice or bags are used.¹² In Table 2 I summarize the predictions for the First and Second Stages from the RISK condition; in Table 3 I provide a similar summary for the AMBIGUITY condition.

3.1 RISK Condition

In the First Stage from RISK, the decision-maker (henceforth DM) chooses between the Original Lottery—which is resolved by rolling the original die—and the Alternative Lottery—which is resolved by rolling the alternative die. Each lottery is a 50-50 gamble over $x > 0$ dollars and 0 dollars. The Alternative Lottery, however, pays a 1% bonus (i.e., it pays an

¹²For a detailed discussion of *inertia*—and its underlying mechanisms—in the First Stage, I refer the reader to Sautua (2015).

TABLE 3 --- PREDICTED BEHAVIOR FOR THE AMBIGUITY CONDITION:
FIRST AND SECOND STAGES

		<i>Second Stage</i>
		Previous Choice
<i>First Stage</i>	Diversified Lottery	
Original Lottery		Reference-Dependent SEU ($\lambda > 1.08$) (Sugden) Knightian Decision Theory
Alternative Lottery	Disappointment Theory ($\lambda > 1.08$) Krahmer & Stone's Theory ($\lambda > 1.27$)	Subjective Expected Utility Models of Ambiguity Aversion Prospect Theory (Linear in Probabilities) Reference-Dependent SEU (Kőszegi & Rabin)

additional 0.01 x regardless of the outcome of the lottery). Almost all major theories of choice under uncertainty predict that the DM will switch to the Alternative Lottery. By contrast, an extended version of Reference-Dependent Subjective Expected Utility (Sugden 2003; Kőszegi and Rabin 2006, 2007) predicts that the DM will *not* switch, even though switching comes with a bonus. (See the discussion in the Appendix (Section 6.2).)¹³

HYPOTHESIS R1: The choices made by some participants from the RISK condition in the First Stage display inertia.

In the Second Stage, the DM must decide whether to play the lottery she chose in the First Stage or switch to the Diversified Lottery—which is resolved by rolling both dice. The Diversified Lottery pays x with probability 0.25, $0.5x$ with probability 0.5, and 0 with probability 0.25. In the Appendix (Section 6.2) I show that most theories, including Reference-Dependent Subjective Expected Utility, predict that the DM will stick with the lottery chosen in the First Stage.

¹³Inertia follows from an aversion to potential losses that might result from switching. The DM anticipates that she will *regret* a switch that results in a bad outcome, because she might have done better had she not switched. Hence, the DM sticks with the Original Lottery to avoid experiencing regret.

HYPOTHESIS R2: Participants from RISK who did not switch lotteries in the First Stage also stick with the Original Lottery in the Second Stage.

By contrast, two theories predict that the DM is likely to diversify in the Second Stage. These are Disappointment Theory (Bell 1985; Loomes and Sugden 1986) and Krähmer and Stone’s (2013) theory. Consider how the DM evaluates outcomes according to these two theories. A prize y added to initial wealth w yields a *consumption utility* of $m(w + y)$. The function $m(\cdot)$ is continuous and strictly increasing, and $m(0) = 0$. An outcome, however, is not evaluated in isolation—that is, it does not yield *only* consumption utility. The overall utility of an outcome is affected by a comparison to a *reference level*—preferences are reference-dependent. An outcome that is greater than its reference level is encoded by the DM as a *gain*, whereas an outcome that is smaller than its reference level is encoded as a *loss*. Let $u(w + y|w + r)$ be the overall utility of $w + y$ dollars given a reference level of $w + r$ dollars:

$$u(w + y|w + r) = m(w + y) + \mu(m(w + y) - m(w + r)).$$

The function $\mu(\cdot)$ captures the *gain-loss utility* of $w + y$ dollars relative to the referent, $w + r$ dollars. The outcome $w + y$ is encoded as a gain relative to $w + r$ if $y > r$, and it is encoded as a loss if $y < r$. Following Section II of Kőszegi and Rabin (2006), I assume that $\mu(\cdot)$ satisfies the following properties:

A0. $\mu(z)$ is continuous for all z , twice differentiable for $z \neq 0$, and $\mu(0) = 0$.

A1. $\mu(z)$ is strictly increasing.

A2. $\mu'_-(0)/\mu'_+(0) \equiv \lambda > 1$, where $\mu'_+(0) \equiv \lim_{z \rightarrow 0} \mu'(|z|)$ and $\mu'_-(0) \equiv \lim_{z \rightarrow 0} \mu'(-|z|)$.

A2 captures *loss aversion* for small stakes: the DM feels small losses around the reference level more severely than she feels equal-sized gains. The degree of loss aversion is captured by the coefficient λ .

A lottery L is evaluated according to its expected utility:

$$U(L) = \int u(w + y|w + r) dL(y).$$

Because in the experiment prizes are small stakes relative to the DM's initial wealth w , the function $m(\cdot)$ can be taken as approximately linear (Rabin 2000; Kőszegi and Rabin 2006, 2007). Thus, in what follows I assume that $m(w + y) = w + y$. Importantly, the linearity of $m(\cdot)$ for small stakes does not imply risk neutrality when preferences are reference-dependent. The assumption just implies that small-scale risk aversion cannot be attributed to decreasing marginal utility of wealth; rather, it is driven by loss aversion (Rabin 2000).

While both Disappointment Theory and Krähmer and Stone's theory assume that preferences are reference-dependent, they differ with regard to the reference point. Let us first examine the DM's behavior according to Disappointment Theory. The reference level relative to which the DM evaluates an outcome of a lottery is the (ex-ante) certainty equivalent of the lottery, based on its consumption utility.¹⁴ When the outcome exceeds the certainty equivalent, the DM experiences elation; when instead the outcome falls short of the certainty equivalent, the DM experiences *disappointment*.

In the First Stage, the utilities of the Original and Alternative Lotteries are

$$\begin{aligned} U_{DT}(Original) &= w + 0.5 x + [0.5 \mu(x - 0.5 x) + 0.5 \mu(-0.5 x)] \\ U_{DT}(Alternative) &= w + 0.51 x + [0.5 \mu(1.01 x - 0.51 x) + 0.5 \mu(0.01 x - 0.51 x)]. \end{aligned} \tag{1}$$

Loss aversion implies *disappointment aversion*: disappointment resulting from a loss is felt more severely than elation following an equal-sized gain. Disappointment aversion, however, does not affect the DM's choice in the First Stage. We can see from (1) that the

¹⁴Notice that the assumption that $m(w + y) = w + y$ implies that the certainty equivalent of a lottery is equal to its expected payoff.

Alternative Lottery strictly dominates the Original one regardless of the DM's degree of loss aversion—both lotteries feature the same potential for disappointment and elation but the Alternative one yields higher consumption utility. Hence, the DM switches lotteries in the First Stage.

Then, in the Second Stage the DM chooses between the Alternative Lottery and the Diversified Lottery. The utility of the Diversified Lottery is

$$\begin{aligned}
 U_{DT}(Diversified) = & w + 0.5 x \\
 & + [0.25 \mu(x - 0.5 x) + 0.5 \mu(0.5 x - 0.5 x) + 0.25 \mu(-0.5 x)].
 \end{aligned} \tag{2}$$

To predict choice behavior in the Second Stage, we need to make an assumption about the functional form of the gain-loss utility function μ . Following Section IV of Kőszegi and Rabin (2006), μ is piecewise-linear:

$$\mu(z) = \begin{cases} z & \text{if } z \geq 0 \\ \lambda z & \text{if } z < 0 \end{cases}, \tag{3}$$

where $\lambda > 1$ is the coefficient of loss aversion. Combining (1), (2), and (3), we conclude that a disappointment-averse DM prefers the Diversified Lottery if and only if $\lambda > 1.08$. To understand why a disappointment-averse DM is willing to diversify, notice that the Diversified Lottery is a ‘mean-preserving shrink’ of the Alternative Lottery. The Alternative Lottery yields a potential gain of $0.5 x$ with probability 0.5 and an equal-sized potential loss also with probability 0.5. Gains and losses from the Diversified Lottery are of the same size as those from the Alternative Lottery, *but they are half as likely*. The most likely outcome in the Diversified Lottery is a prize of $0.5 x$, which does not create gain-loss utility as it coincides with the reference level. A disappointment-averse DM finds the Diversified Lottery attractive because it features a substantially smaller probability of experiencing disappointment

than the Alternative Lottery.

Now let us examine behavior according to Krähmer and Stone's theory. Imagine the DM facing a choice between two lotteries. To make a decision, she tries to anticipate how she would evaluate each outcome if it happened. Given an outcome, the reference level is the *posterior* expected payoff of the lottery that has the largest expected payoff given the DM's *ex-post* knowledge about the lotteries. It turns out that all lotteries from RISK have an *objective* expected payoff that is known ex-ante. In the First Stage, when the DM chooses between the Original and Alternative Lotteries, the Alternative Lottery has the largest expected payoff. Hence, in the First Stage the expected payoff of the Alternative Lottery is the reference level relative to which all possible outcomes are evaluated. The utilities of the lotteries from the First Stage are

$$\begin{aligned} U_{KS}(Original) &= w + 0.5 x + [0.5 \mu(x - 0.51 x) + 0.5 \mu(-0.51 x)] \\ U_{KS}(Alternative) &= w + 0.51 x + [0.5 \mu(1.01 x - 0.51 x) + 0.5 \mu(0.01 x - 0.51 x)]. \end{aligned} \quad (4)$$

Since the Alternative Lottery strictly dominates the Original Lottery, the DM switches lotteries. Then, in the Second Stage the DM chooses between the Alternative Lottery and the Diversified Lottery. Because the expected payoff of the Alternative Lottery is larger than that of the Diversified Lottery, it is again the reference level for all outcomes. The utility of the Diversified Lottery is

$$\begin{aligned} U_{KS}(Diversified) &= w + 0.5 x \\ &+ [0.25 \mu(x - 0.51 x) + 0.5 \mu(0.5 x - 0.51 x) + 0.25 \mu(-0.51 x)]. \end{aligned} \quad (5)$$

To determine when a Krähmer-Stone DM chooses the Diversified Lottery, combine (4), (5), and (3). The DM diversifies in the Second Stage if and only if her coefficient of loss

aversion λ exceeds 1.17. The rationale for diversification is similar to the one from Disappointment Theory. Compared to the Alternative Lottery, the Diversified Lottery may result in a slightly smaller gain from the best outcome or a slightly larger loss from the worst outcome. Yet, the gain from the best outcome and the loss from the worst outcome are *half as likely* in the Diversified Lottery as in the Alternative Lottery. The significant reduction in the likelihood of a loss makes the Diversified Lottery appealing to a Krähmer-Stone DM.

HYPOTHESIS R3: Some participants from RISK who switched lotteries in the First Stage choose the Diversified Lottery in the Second Stage.

After making a choice in the Second Stage, the DM faces the Third (and final) Stage. In the Third Stage, the probability distributions associated with the Original, Alternative, and Diversified Lotteries change with respect to the ones from the Second Stage. Now, the Original Lottery pays x with known probability p , with $p \in \{0.3, 0.4, 0.6, 0.7\}$. The Alternative Lottery pays the x with probability $1 - p$ and offers a 1% bonus. The Diversified Lottery pays x with probability $p(1 - p)$, $0.5x$ with probability $p^2 + (1 - p)^2$, and 0 with probability $p(1 - p)$. The DM must choose again among the three lotteries. Most theories predict that the DM will not diversify for any value of p . By contrast, Disappointment Theory and Krähmer and Stone's theory imply that the DM may continue to diversify in the Third Stage.

A disappointment-averse DM diversifies in the Third Stage if and only if $\lambda > \lambda_{DT, RISK}$, where

$$\lambda_{DT, RISK} = \begin{cases} 3 & \text{if } p = 0.3 \\ 1.92 & \text{if } p = 0.4 \\ 1.83 & \text{if } p = 0.6 \\ 2.9 & \text{if } p = 0.7 \end{cases}.$$

Notice that the DM is less likely to diversify in the Third Stage than in the Second Stage (i.e., $\lambda_{DT, RISK} > 1.08$). In addition, she is less likely to diversify when $p = 0.3$ or $p = 0.7$

than when $p = 0.4$ or $p = 0.6$.

How does a Krähmer-Stone DM behave in the Third Stage? She does *not* diversify if $p = 0.3$ or $p = 0.7$, but she may diversify if $p = 0.4$ or $p = 0.6$.¹⁵ Specifically, the DM chooses the Diversified Lottery if and only if $\lambda > \lambda_{KS, RISK}$, where

$$\lambda_{KS, RISK} = \begin{cases} 7.04 & \text{if } p = 0.4 \\ 5.55 & \text{if } p = 0.6 \end{cases}.$$

Overall, a Krähmer-Stone DM is also less likely to diversify in the Third Stage than in the Second Stage (i.e., $\lambda_{KS, RISK} > 1.17$).

HYPOTHESIS R4: Participants from RISK are less likely to diversify in the Third Stage than in the Second Stage. In addition, participants are less likely to diversify in the ‘70-30’ or ‘30-70’ scenarios than in the ‘60-40’ or ‘40-60’ scenarios.

I now turn to the predictions for the AMBIGUITY condition, focusing on how they compare to those for the RISK condition.

3.2 AMBIGUITY Condition

In the First Stage from AMBIGUITY, the DM chooses between the Original Lottery—which is resolved by drawing a ball from the original bag—and the Alternative Lottery—which is resolved by drawing a ball from the alternative bag. The Original Lottery pays x with probability q_o and 0 with probability $1 - q_o$. The Alternative Lottery pays x with probability q_a and 0 with probability $1 - q_a$; in addition, it pays a 1% bonus. The winning probabilities q_o and q_a are *unknown* to the DM. All the DM knows is that q_o and q_a are independent and uniformly distributed in $[0, 1]$. Almost all major theories of choice under uncertainty

¹⁵The DM chooses the Alternative Lottery if $p = 0.3$ and the Original Lottery if $p = 0.7$. If the DM does not diversify when $p = 0.4$, then she chooses the Alternative Lottery. Finally, if the DM does not diversify when $p = 0.6$, then she chooses the Original Lottery.

predict that the DM will switch to the Alternative Lottery. By contrast, Knightian Decision Theory (Bewley 2002) and an extended version of Reference-Dependent Subjective Expected Utility predict that the DM will *not* switch, even though switching comes with a bonus. (See the discussion in the Appendix (Section 3).) Recall that Reference-Dependent Subjective Expected Utility makes the same prediction for the RISK condition, but Knightian Decision Theory predicts a switch in RISK.¹⁶

HYPOTHESIS A1: Choices in the First Stage from AMBIGUITY display excess inertia compared to RISK.

In the Second Stage, the DM must decide whether to play the lottery she chose in the First Stage or switch to the Diversified Lottery—which is resolved by drawing a ball from each bag. The Diversified Lottery pays x with probability $q_o q_a$, $0.5x$ with probability $q_o(1 - q_a) + (1 - q_o)q_a$, and 0 with probability $(1 - q_o)(1 - q_a)$. In the Appendix (Section 6.2) I show that most theories, including Reference-Dependent Subjective Expected Utility and Knightian Decision Theory, predict that the DM will stick with the lottery chosen in the First Stage.

HYPOTHESIS A2: Like in RISK, participants from AMBIGUITY who did not switch lotteries in the First Stage also stick with the Original Lottery in the Second Stage.

By contrast, Disappointment Theory and Krähmer and Stone’s theory predict that the DM is likely to diversify in the Second Stage. Consider Disappointment Theory first. A disappointment-averse DM is bayesian. This means that she attaches a *single* subjective probability distribution over prizes to a given lottery—even though the actual probability distribution is unknown. Moreover, given the information about q_o and q_a , the DM proceeds

¹⁶According to Reference-Dependent Subjective Expected Utility, the mechanism that drives inertia is exactly the same as in the RISK condition—that is, the DM seeks to avoid the regret that may follow a switch. Knightian Decision Theory presents a different mechanism—inertia follows from the DM’s *indecisiveness* between the two lotteries. Ambiguity about the winning probabilities of the lotteries is the key factor that triggers such indecisiveness.

as if $q_o = q_a = 0.5$. This has two implications. First, in the Second Stage (as well as in the First Stage) all subjective probability distributions over prizes coincide with their objective counterparts from the RISK condition. Second, reference levels are the same as in RISK, since the (ex-ante) certainty equivalent of an ambiguous lottery is the same as that from its risky counterpart. It follows from these two implications that in the Second Stage a disappointment-averse DM makes the *same* choice in AMBIGUITY as in RISK—that is, she chooses the Diversified Lottery provided that $\lambda > 1.08$.

Krähmer and Stone’s theory also concerns a bayesian DM. Again, this implies that in the first two stages all subjective probability distributions over prizes coincide with their objective counterparts from the RISK condition. Reference levels, however, are not the same as in RISK. To see this, recall that the DM compares an outcome to the posterior expected payoff of the lottery that has the largest expected payoff given the DM’s ex-post knowledge about the lotteries. While the prior knowledge about the lotteries is the same as the ex-post knowledge in the RISK condition, this is not the case in the AMBIGUITY condition. When a Krähmer-Stone DM chooses between two ambiguous lotteries, the outcome of the chosen lottery reveals information about this lottery’s actual probability distribution over prizes. (The outcome, however, does not reveal anything about the probability distribution of the rejected lottery, since the distributions are independent.)

Consider, for instance, how a Krähmer-Stone DM evaluates a choice in the First Stage. If the DM wins the prize, she will infer that the chosen lottery was the best choice and she will update her belief about its winning probability from 0.5 to 0.625.¹⁷ In this case, she will

¹⁷Let $P(\text{win}|\text{good outcome})$ denote the posterior winning probability of the chosen lottery after a good outcome. To compute this probability, first write $P(\text{win}|\text{good outcome}) = P(\text{win}|\text{good outcome}, q \geq 0.5) P(q \geq 0.5|\text{good outcome}) + P(\text{win}|\text{good outcome}, q < 0.5) P(q < 0.5|\text{good outcome})$; here, $q \geq 0.5$ denotes the event in which the *actual* winning probability of the chosen lottery is at least 0.5. Next, notice that $P(\text{win}|\text{good outcome}, q \geq 0.5) = P(\text{win}|q \geq 0.5) = 0.75$ and $P(\text{win}|\text{good outcome}, q < 0.5) = P(\text{win}|q < 0.5) = 0.25$. (This follows from the premise that $q \sim U[0, 1]$.) Then, use Bayes’ rule to obtain $P(q \geq 0.5|\text{good outcome}) = 0.75$; this, in turn, implies that $P(q < 0.5|\text{good outcome}) = 0.25$. Last, replace the probabilities on the right-hand side of the above expression for $P(\text{win}|\text{good outcome})$ to obtain $P(\text{win}|\text{good outcome}) = 0.625$.

compare x to the posterior expected payoff of the *chosen* lottery. On the other hand, if the DM fails to win, she will infer that the rejected lottery—whose winning probability is still 0.5—would have been the best choice.¹⁸ Now, the DM will compare the zero payoff to the posterior expected payoff of the *rejected* lottery. Thus, the utilities of the lotteries from the First Stage are

$$\begin{aligned}
U_{KS}(\textit{Original}|\textit{First Stage}) &= w + 0.5 x + [0.5 \mu(x - 0.625 x) + 0.5 \mu(-0.51 x)](6) \\
U_{KS}(\textit{Alternative}|\textit{First Stage}) &= w + 0.51 x \\
&\quad + [0.5 \mu(1.01 x - 0.625 x - 0.01 x) \\
&\quad + 0.5 \mu(0.01 x - 0.5 x)].
\end{aligned}$$

Because the Alternative Lottery strictly dominates the Original Lottery, the DM switches lotteries. Then, in the Second Stage the DM chooses between the Alternative Lottery and the Diversified Lottery. How would she assess the choice of the Alternative Lottery in the Second Stage? After a win, she would infer that she made the right choice. Hence, she would compare the payoff $(1.01 x)$ to the posterior expected payoff of the Alternative Lottery $(0.625 x + 0.01 x)$. On the other hand, after a failure to win the DM would infer that the Diversified Lottery would have been the best choice. In this case, she would compare the payoff $(0.01 x)$ to the expected payoff of the Diversified Lottery $(0.4375 x)$. Thus, the utility of the Alternative Lottery in the Second Stage is

$$\begin{aligned}
U_{KS}(\textit{Alternative}|\textit{Second Stage}) &= w + 0.51 x \tag{7} \\
&\quad + [0.5 \mu(1.01 x - 0.625 x - 0.01 x) \\
&\quad + 0.5 \mu(0.01 x - 0.4375 x)].
\end{aligned}$$

¹⁸In this case, the subjective winning probability of the chosen lottery is updated downwards to 0.375. To compute this probability, the reader can follow a few steps similar to those discussed in footnote 17.

How would the DM assess the choice of the Diversified Lottery? If both draws had the same outcome, the DM would infer that the Alternative Lottery would have been the best choice. (Its posterior expected payoff would be $0.01 x + 0.625 x$ after two good draws and $0.01 x + 0.375 x$ after two bad draws.) If only the draw from the original bag were good, the DM would infer that diversifying was indeed the best choice. (The expected payoff of the Diversified Lottery continues to be $0.5 x$.) Conversely, if only the draw from the alternative bag were good, the DM would infer that the Alternative Lottery would have been the best choice. (Its posterior expected payoff is $0.01 x + 0.625 x$.) Thus, the utility of the Diversified Lottery is

$$\begin{aligned}
U_{KS}(\textit{Diversified}) = & w + 0.5 x \\
& + [0.25 \mu(x - 0.01 x - 0.625 x) + 0.25 \mu(0.5 x - 0.5 x) \\
& + 0.25 \mu(0.5 x - 0.01 x - 0.625 x) + 0.25 \mu(-0.01 x - 0.375 x)].
\end{aligned} \tag{8}$$

To determine when the DM diversifies, combine (7), (8), and (3). The DM chooses the Diversified Lottery if and only if $\lambda > 1.27$. Notice that a Krähmer-Stone DM is slightly *less* likely to diversify in the Second Stage from AMBIGUITY than in the Second Stage from RISK.

*HYPOTHESIS A3: Like in RISK, some participants from AMBIGUITY who switched lotteries in the First Stage choose the Diversified Lottery in the Second Stage. Yet, the probability that a participant switches lotteries in the First Stage and diversifies in the Second Stage is slightly lower in AMBIGUITY than in RISK.*¹⁹

After the DM makes a choice in the Second Stage, she faces the Third (and final) Stage. In the Third Stage, the DM observes one draw from the original bag and another from the

¹⁹Put differently, Hypothesis A3 states that the proportion of participants from AMBIGUITY who fall into cell (2,1) of Table 3 is slightly lower than the proportion of participants from RISK who fall into cell (2,1) of Table 2.

alternative bag before the lottery she chose in the Second Stage is resolved. She has the opportunity to change her choice after observing the outcomes of these practice draws. So once again, the DM chooses between the Original Lottery, the Alternative Lottery, and the Diversified Lottery. As before, the Alternative Lottery pays a 1% bonus. While most theories predict that the DM will not choose the Diversified Lottery after the practice draws, Disappointment Theory and Krähmer and Stone’s theory imply that the DM may still diversify. Next, I briefly elaborate on this prediction; in the Appendix (Section 6.3) I provide more detail.

The practice draws result in one of four scenarios: (i) a good draw from each bag (‘good draw-good draw’); (ii) a bad draw from each bag (‘bad draw-bad draw’); (iii) a good draw from the original bag and a bad draw from the alternative bag (‘good draw-bad draw’); (iv) a bad draw from the original bag and a good draw from the alternative bag (‘bad draw-good draw’). Given a scenario, the DM updates her beliefs about the probability of a good draw using Bayes’ Rule.²⁰ A disappointment-averse DM diversifies in the Third Stage if and only if $\lambda > \lambda_{DT, AMB}$, where

$$\lambda_{DT, AMB} = \begin{cases} 1.11 & \text{if } scenario = \text{‘good draw – good draw’} \\ 1.11 & \text{if } scenario = \text{‘bad draw – bad draw’} \\ 2.07 & \text{if } scenario = \text{‘good draw – bad draw’} \\ 2.15 & \text{if } scenario = \text{‘bad draw – good draw’} \end{cases}.$$

We see that a disappointment-averse DM is less likely to diversify in the Third Stage

²⁰In practice people may process the information conveyed by the practice draws in a different way. For instance, they may use a heuristic that involves some form of *reinforcement*, where one is more likely to choose options associated with good past outcomes than options associated with bad past outcomes. The reinforcement heuristic is a ‘win stay-lose shift’ heuristic (Charness and Levin 2005). Because bayesian updating and the reinforcement heuristic are aligned in the present setting, I cannot distinguish between them. Charness and Levin (2005) present a laboratory experiment that examines what happens when the two approaches prescribe different courses of action.

than in the Second Stage (i.e., $\lambda_{DT, AMB} > 1.08$).²¹ In addition, she is less likely to diversify when the practice draws yield different outcomes than when they yield the same outcome.

How does a Krähmer-Stone DM behave in the Third Stage? She does *not* diversify if the draws yield different outcomes, but she may diversify if both draws have the same outcome.²² Specifically, she chooses the Diversified Lottery if and only if $\lambda > \lambda_{KS, AMB}$, where

$$\lambda_{KS, AMB} = \begin{cases} 1.34 & \text{if scenario} = \text{'good draw} - \text{good draw'} \\ 1.23 & \text{if scenario} = \text{'bad draw} - \text{bad draw'} \end{cases}.$$

Overall, a Krähmer-Stone DM is less likely to diversify in the Third Stage than in the Second Stage.²³

HYPOTHESIS A4: Participants from AMBIGUITY are less likely to diversify in the Third Stage than in the Second Stage. In addition, participants are less likely to diversify when the practice draws yield different outcomes than when they yield the same outcome.

I next turn to the empirical results from the experiment.

4 Results

In Tables 4 and 5 I summarize participants' behavior in the First and Second Stages; Table 4 corresponds to the RISK condition, while Table 5 corresponds to the AMBIGUITY condition.

²¹If the DM does not diversify when both draws have the same outcome, then she chooses the Alternative Lottery. If she does not diversify in the 'good draw-bad draw' scenario, then she chooses the Original Lottery. Finally, if the DM does not diversify in the 'bad draw-good draw' scenario, then she chooses the Alternative Lottery.

²²The DM chooses the Original Lottery in the 'good draw-bad draw' scenario and the Alternative Lottery in the 'bad draw-good draw' scenario. If she does not diversify when both draws have the same outcome, then she chooses the Alternative Lottery.

²³Strictly speaking, the DM is less likely to diversify in all scenarios from the Third Stage except for the 'bad draw-bad draw' scenario—in which she is marginally more likely to diversify. (In the 'bad draw-bad draw' scenario, $\lambda_{KS, AMB} = 1.23 < 1.27$.) Yet, the difference in the likelihood of diversification between the 'bad draw-bad draw' scenario and the Second Stage is negligible.

In Tables A3 and A4 in the Appendix (Section 6.5) I summarize observed behavior in all three stages.

TABLE 4 --- OBSERVED BEHAVIOR IN THE RISK CONDITION:
FIRST AND SECOND STAGES

<i>Second Stage</i>			
	Diversified Lottery	Previous Choice	Total
<i>First Stage</i>			
Original Lottery	25.5% (13/51)	21.6% (11/51)	47.1% (24/51)
Alternative Lottery	31.4% (16/51)	21.6% (11/51)	53% (27/51)
Total	56.9% (29/51)	43.2% (22/51)	100% (51/51)

TABLE 5 --- OBSERVED BEHAVIOR IN THE AMBIGUITY CONDITION:
FIRST AND SECOND STAGES

<i>Second Stage</i>			
	Diversified Lottery	Previous Choice	Total
<i>First Stage</i>			
Original Lottery	40.8% (20/49)	20.4% (10/49)	61.2% (30/49)
Alternative Lottery	28.6% (14/49)	10.2% (5/49)	38.8% (19/49)
Total	69.4% (34/49)	30.6% (15/49)	100% (49/49)

I begin with an analysis of the extent of inertia in the First Stage. Based on the theoretical analysis from Section 3, we expect inertia in both conditions—but more inertia in AMBIGUITY than in RISK (Hypotheses R1 and A1). The first result supports these predictions.

RESULT 1: In the First Stage of both conditions, a substantial proportion of participants made choices that displayed inertia. In addition, participants' choices from the AMBIGUITY condition displayed excess inertia with respect to the choices made by participants from the RISK condition.

Forty-seven percent of participants from the RISK condition kept the Original Lottery in the First Stage, while 61 percent of participants from the AMBIGUITY condition did so. A one-tailed test of differences in proportions rejects the null hypothesis that the percentage from AMBIGUITY is smaller than or equal to the one from RISK in favor of the alternate hypothesis that the percentage from AMBIGUITY is larger ($p = 0.078$). As I pointed out in Section 3.2, excess inertia from AMBIGUITY is predicted by Knightian Decision Theory. This theory implies that the DM is indecisive between the Original and Alternative Lotteries because the winning chances are ambiguous, and indecisiveness induces inertia. Importantly, ambiguity-driven excess inertia appears to be a consistent finding: the magnitude of excess inertia from this experiment (14 percentage points) is almost the same as the one I found in Sautua (2015) (18 percentage points).

The following result further elaborates on how inertia compares between the two experiments.²⁴

RESULT 2: Letting participants pick the original die or bag increased inertia in the First Stage relative to a situation in which the original die or bag were randomly assigned to participants.

Although excess inertia from the First Stage replicates that from the previous experiment, the *level* of inertia in either condition is higher than that from its counterpart in the previous experiment.²⁵ The proportion of participants from RISK who refuse to switch lotteries is 16 percentage points higher than in the previous experiment (47 percent versus 31 percent). This difference is statistically significant ($p = 0.046$, one-tailed test of differences in proportions). Similarly, the proportion of participants from AMBIGUITY who do not switch lotteries is 12 percentage points higher than in the previous experiment (61 percent

²⁴Because in the previous experiment I focused exclusively on the analysis of inertia in choice under uncertainty, participants faced only the keep-or-switch decision from the First Stage.

²⁵In the Appendix (Section 6.4), I show that participants from both experiments are balanced on several demographic characteristics.

versus 49 percent). The difference is marginally significant ($p = 0.112$, one-tailed test of differences in proportions).

Why are the levels of inertia from this experiment higher than those from the previous experiment? The two experiments differ in how the status quo lottery was determined. In the present experiment participants picked the original die or bag, whereas in the previous experiment these were randomly assigned. The act of choice—as opposed to random assignment—appears to have induced an extra attachment to the Original Lottery, thus producing a ‘choice effect’ in the First Stage.²⁶ An interesting conjecture about this ‘choice effect’ is that choosing the status quo increases the anticipated *intensity* of the regret that might result from a switch. When a bad outcome occurs, the DM may feel more responsible for the ‘mistake’ of having switched if she chose the status quo herself than if the status quo was assigned at random. The ‘choice effect’ is remarkable in this setting, because participants made the initial choice without even knowing that the original die or bag would be a ticket to play a lottery—the lottery was introduced once they had made the initial choice.^{27, 28}

²⁶Roca et al. (2006) also provided evidence of a ‘choice effect’ with regard to gambles. In one condition of their laboratory experiment, participants were given three ambiguous gambles by the experimenter and then had the opportunity to either keep each gamble or exchange it for a risky gamble. In another condition, participants were presented with the three ambiguous gambles, asked to choose one of them, and then offered the option to exchange the chosen gamble for a risky one. The authors found that participants were more likely to retain an ambiguous gamble if they had chosen it than if they had been given the gamble by the experimenter.

²⁷Participants, however, might have *guessed* that they would use the original die or bag to play a lottery based on the information they received when they signed up for the experiment. When they signed up a few days earlier, participants learned that they would fill out some questionnaires and play an individual lottery during the session. Nevertheless, they certainly did not know anything about the characteristics of the lottery.

²⁸Besides being different in how the status quo was determined, the RISK condition and its counterpart from the previous experiment have another subtle difference. In the previous experiment, participants rolled the chosen die themselves, while here the assistant rolled the die. If some people have an ‘illusion of control’ (Langer 1975), they may *feel* that rolling the die themselves increases their winning chances, and this feeling might mitigate inertia. Yet, in Sautua (2015) I showed that an illusion of control did not affect behavior within the previous experiment. Therefore, an illusion of control is unlikely to have contributed to the difference in the levels of inertia across experiments.

Next, I analyze the extent of diversification in the Second Stage. First, I consider those participants who switched lotteries in the First Stage. Based on the theoretical analysis from Section 3, we expect some of these participants to diversify in either condition (Hypotheses R3 and A3). The data are consistent with this prediction.

RESULT 3: In both conditions, a large proportion of those participants who switched lotteries in the First Stage diversified in the Second Stage. In addition, the proportion of participants who switched lotteries in the First Stage and diversified in the Second Stage was not statistically different across conditions.

Of the 27 participants who switched lotteries in the First Stage from RISK, 16 (59 percent) diversified in the Second Stage. Similarly, of the 19 participants who switched in the First Stage from AMBIGUITY, 14 (74 percent) chose the Diversified Lottery in the Second Stage. Thus, the probability of diversifying *conditional* on having switched in the First Stage is significantly different from zero in both conditions. Also, 31 percent of participants from RISK switched lotteries in the First Stage and then diversified, while 29 percent of participants from AMBIGUITY did so. I cannot reject the null hypothesis that the *joint* probability of switching in the First Stage and diversifying in the Second Stage is the same across conditions ($p = 0.76$, two-tailed test of differences in proportions). Result 3 provides support to the premise that loss aversion may induce people to diversify.

Now I analyze Second-Stage diversification among those participants who did not switch lotteries in the First Stage. We expect no diversification among these participants in either condition (Hypotheses R2 and A2). The data, however, are inconsistent with this prediction.

RESULT 4: In both conditions, a substantial proportion of those participants who did not switch lotteries in the First Stage chose to diversify in the Second Stage. The proportion of participants who refused to switch in the First Stage and diversified in the Second Stage was higher in AMBIGUITY than in RISK.

Of the 24 participants who refused to switch lotteries in the First Stage from RISK, 13 (54 percent) chose the Diversified Lottery in the Second Stage. Similarly, of the 30 participants who did not switch lotteries in the First Stage from AMBIGUITY, 20 (67 percent) diversified in the Second Stage. Because the theories that predict that participants will chose the Original Lottery in the First Stage make the same prediction for the Second Stage, Result 4 is inconsistent with any major theory of choice under uncertainty. The data also reveal an interesting relationship between ambiguity, First-Stage inertia, and Second-Stage diversification. In particular, a participant was more likely to refuse to switch lotteries and then diversify in AMBIGUITY than in RISK. While almost 41 percent of participants from AMBIGUITY refused to switch in the First Stage and diversified in the Second Stage, only 25.5 percent of participants from RISK displayed this behavior. The difference across conditions is statistically significant ($p = 0.052$, one-tailed test of differences in proportions).

Put together, Results 3 and 4 indicate that (i) there was *excess diversification* in the Second Stage from AMBIGUITY compared to RISK (69 percent versus 57 percent), and (ii) excess diversification was driven by those participants whose choices displayed inertia in the First Stage. This pattern of behavior cannot be accommodated by current theories of choice under ambiguity.

Now I turn to the analysis of behavior in the Third Stage.²⁹ The next two results document that the extent of diversification responds to changes in the objective distributions over prizes (Result 5) or the outcomes of the practice draws (Result 6). The results are in line with Hypotheses R4 and A4, which state that participants are less likely to diversify in the Third Stage than in the Second Stage.

RESULT 5: In the RISK condition, the propensity to diversify dropped in the Third Stage, when the probability of a successful roll differed between dice.

²⁹Results 5-7 highlight some salient features of participants' behavior in the Third Stage. For more detail, see Tables A3 and A4 in the Appendix (Section 6.5).

In both the ‘40-60’ and ‘60-40’ scenarios, the proportion of participants who chose the Diversified Lottery dropped by 14 percentage points relative to the Second Stage. The proportion of participants who diversified decreased even more in the ‘30-70’ and ‘70-30’ scenarios. In the ‘30-70’ scenario, such proportion dropped by 29 percentage points relative to the Second Stage; and in the ‘70-30’ scenario it dropped by 25 percentage points.³⁰ Thus, we see that the larger the gap in the probabilities of success across dice, the smaller the proportion of participants who diversified.³¹ Nevertheless, a significant proportion of participants from RISK revealed a strong preference for diversification. Of the 51 participants, 10 (almost 20 percent) *always* chose the Diversified Lottery—that is, they diversified in all four scenarios from the Third Stage as well as in the Second Stage.³²

RESULT 6: In the AMBIGUITY condition, the propensity to diversify dropped in the Third Stage when (i) the outcomes of the practice draws were different, or (ii) both practice draws were successful. By contrast, when both draws were unsuccessful, the proportion of participants who diversified remained the same as in the Second Stage.

Participants’ propensity to diversify dropped by almost the same magnitude in the ‘good draw-bad draw’ and ‘bad draw-good draw’ scenarios. In these scenarios, the proportion of participants who chose the Diversified Lottery dropped by 10-12 percentage points compared

³⁰For each scenario, a one-tailed sign test rejects the null hypothesis that the probability of choosing the Diversified Lottery did not decrease compared to the Second Stage ($p = 0.025$ for the ‘40-60’ and ‘60-40’ scenarios; $p < 0.01$ for the ‘30-70’ and ‘70-30’ scenarios).

³¹The proportion of participants who chose the Diversified Lottery is significantly smaller in the ‘30-70’ scenario than in the ‘40-60’ scenario ($p < 0.01$, one-tailed sign test). Similarly, there is less diversification in the ‘70-30’ scenario than in the ‘60-40’ scenario ($p < 0.01$, one-tailed sign test).

In addition, in all four scenarios from the Third Stage, most participants chose the die that gave the largest probability of success. In the ‘60-40’ and ‘70-30’ scenarios, 53 percent and 67 percent, respectively, chose the Original Lottery; in the ‘40-60’ and ‘30-70’ scenarios, 51 percent and 67 percent, respectively, chose the Alternative Lottery.

³²Overall, the results from the Third Stage from RISK are in line with the experimental findings from Loomes (1991). In his experiment, there are three possible states of the world A , B , and C , where $pr(A) > pr(B) > pr(C)$. If state C occurs, the participant wins nothing. The participant can divide £20 between A and B , and she gets the amount assigned to a state if that state occurs. Only a few participants put all the money in A . Rather, most divided the £20 in proportion to $pr(A)/pr(B)$.

to the Second Stage.³³ By contrast, participants' propensity to diversify after two identical draws varied depending on whether the draws were successful or unsuccessful. After two successful draws, diversification decreased by 8 percentage points.³⁴ On the other hand, diversification increased by 2 percentage points after two unsuccessful draws, although a sign test does not reject the null hypothesis of no change ($p = 0.38$, two-tailed test). Thus, participants were 10 percentage points less likely to diversify in the 'good draw-good draw' scenario than in the 'bad-draw-bad draw' scenario. At the same time, participants were 10 percentage points more likely to play the Alternative Lottery in the 'good draw-good draw' scenario than in the 'bad draw-bad draw' scenario.³⁵ Although diversification decreased in three out of four scenarios from the Third Stage, a substantial proportion of participants revealed a strong preference for the Diversified Lottery. Of the 49 participants from AMBIGUITY, 24 (49 percent) diversified in all four scenarios as well as in the Second Stage.

Next, I further investigate the sensitivity of Second-Stage choices to the changes introduced in the Third Stage. I consider all choices—not just the choice of the Diversified Lottery.

RESULT 7. In the Third Stage there was substantial excess inertia in AMBIGUITY compared to RISK. That is, participants were significantly more likely to repeat their Second-Stage choice in AMBIGUITY than in RISK.

To what extent did participants repeat their Second-Stage choice in the Third Stage? To set a meaningful comparison of behavioral persistence across conditions, I restrict the analysis to two scenarios from RISK—'60-40' and '40-60'—and two scenarios from AMBIGUITY—'good draw-bad draw' and 'bad draw-good draw'. The '60-40' scenario is comparable to 'good

³³For each scenario, a one-tailed sign test rejects the null hypothesis that the probability of choosing the Diversified Lottery did not decrease ($p < 0.01$ for the 'good draw-bad draw' scenario and $p = 0.02$ for the 'bad draw-good draw' scenario).

³⁴A one-tailed sign test rejects the null hypothesis that the probability of choosing the Diversified Lottery did not decrease ($p < 0.01$).

³⁵A one-tailed sign test rejects the null hypothesis that a participant was less likely to choose the Alternative Lottery in the 'good draw-good draw' scenario than in the 'bad draw-bad draw' scenario ($p < 0.01$).

draw-bad draw’, while ‘40-60’ is comparable to ‘bad draw-good draw’.³⁶ For each condition, I consider the proportion of participants who repeated their Second-Stage choice in both scenarios. Overall, 35 percent of participants from RISK repeated their choice, whereas 76 percent from AMBIGUITY did so. The percentage from AMBIGUITY is significantly larger ($p < 0.01$, one-tailed test of differences in proportions).

Interestingly, excess inertia from AMBIGUITY in the Third Stage was common to all choice options. If we divide participants into two groups based on their Second-Stage choices—those who chose the Original or Alternative Lotteries and those who diversified, we see stronger behavioral persistence in AMBIGUITY within each group. Of those who chose the Original or Alternative Lotteries in the Second Stage, 67 percent repeated their choice in AMBIGUITY, whereas only 18 percent did so in RISK. Similarly, of those who diversified in the Second Stage, 79 percent repeated their choice in the AMBIGUITY condition, while 48 percent did so in the RISK condition. For both groups, the percentage from AMBIGUITY is significantly larger ($p < 0.01$, one-tailed test of differences in proportions).³⁷

5 Conclusions

In a laboratory experiment, I investigated the effect of ambiguity on the prevalence and persistence of diversification among uncertain options. Overall, I found a significant influence of ambiguity on behavior. I reported three main findings. First, participants’ propensity to diversify was higher when the options were equally ambiguous than when they were equally

³⁶As discussed in Section 3.2, a bayesian DM would update the subjective probability of success from a given bag to 0.625 after a good draw and 0.375 after a bad draw.

³⁷If we further divide those who diversified in the Second Stage based on their First-Stage choices, we still see stronger within-group behavioral persistence in AMBIGUITY. Of those who switched in the First Stage and diversified in the Second Stage, 86 percent diversified again in AMBIGUITY, whereas only 44 percent did so in RISK. The percentage from AMBIGUITY is significantly larger ($p < 0.01$, one-tailed test of differences in proportions). Similarly, of those who did not switch in the First Stage and diversified in the Second Stage, 75 percent diversified again in AMBIGUITY, whereas 54 percent did so in RISK. The percentage from AMBIGUITY is marginally larger ($p = 0.104$, one-tailed test of differences in proportions).

risky. Second, excess diversification under ambiguity was driven by participants who had previously stuck with the status quo gamble when diversification was not feasible. Third, diversification was significantly more persistent after the arrival of new information about the choice options when these options were ambiguous than when they were risky. Interestingly, the major theories of choice under uncertainty cannot accommodate these findings.

These results may help to explain behavior in real economic environments in which ambiguity is large and the option to diversify is available. Consider, for instance, the behavior of participants in TIAA-CREF—the pension plan from the Teachers Insurance and Annuity Association—during the 1980s. For many years, this defined contribution saving plan—the largest in the world—offered two funds: TIAA (a portfolio of bonds, commercial loans, mortgages, and real estate) and CREF (a broadly diversified common stock fund). Besides determining the amount of her annual contribution, a participant’s main decision was to allocate her premium between the two funds. Each year, she could change her allocation at no cost. Participants’ behavior displayed two salient features. First, about half originally split their contributions equally between the two funds (Samuelson and Zeckhauser 1988). Second, the median number of changes in the asset allocation of the lifetime of a participant was zero (Thaler and Sunstein 2009). Thus, the 50-50 allocation was the most common choice and was highly persistent.

The distribution of retirement contributions is a complex decision under ambiguity; many participants may feel overwhelmed and remain *indecisive* among the options. In this context, the 50-50 split might be a *heuristic* to which many participants resort when they are in doubt (Benartzi and Thaler 2001; Thaler and Sunstein 2009); *inertia* in the application of this heuristic might also be the result (at least in part) of ambiguity-driven indecisiveness. Further investigation of the link between ambiguity, diversification, and inertia may help us better predict behavior and inform policy in this and other related domains.

6 Appendix

6.1 List of Majors

Majors that are Math-intensive or intensive in formal logic: Aerospace Engineering; Applied Math; Astrophysics; Biochemistry; Business Economics; Chemical Engineering; Chemistry; Computer Science; Economics; Electrical Engineering; Engineering; Math; Math & Economics; Mechanical Engineering; Physics; Pre-Business Economics; Statistics.

Majors that are neither Math-intensive nor intensive in formal logic: Anthropology; Applied Linguistics; Asian American Studies; Biology; Chinese; Classical Civilization; English; Gender Studies; Geography; Geography & Environmental Sciences; History; Human Biology & Society; International Development Studies; Linguistics & Psychology; Microbiology, Immunology & Molecular Genetics; Molecular, Cell & Developmental Biology; Neuroscience; Nursing; Physiological Sciences; Political Science; Psychobiology; Psychology; Sociology; Theater; UCLA staff; Undecided.

6.2 Theories that Predict No Diversification in the Second Stage

In this appendix I discuss the predictions for behavior in the First and Second Stages made by several theories of choice under uncertainty. These theories are Subjective Expected Utility (Savage 1954), Knightian Decision Theory (Bewley 2002), Maxmin Expected Utility (Gilboa and Schmeidler 1989), Smooth Ambiguity Preferences (Klibanoff, Marinacci, and Mukerji 2005, 2012), Variational Preferences (Maccheroni, Marinacci, and Rustichini 2006), Reference-Dependent Subjective Expected Utility (Sugden 2003; Kőszegi and Rabin 2006, 2007), Prospect Theory (Kahneman and Tversky 1979), and Regret Theory (Bell 1982; Loomes and Sugden 1982). In particular, I show that all these theories predict that the DM will not diversify in the Second Stage from either condition.

6.2.1 Subjective Expected Utility

First, consider the DM's behavior in the RISK condition. The utilities of the lotteries from the First Stage are

$$\begin{aligned}U_{SEU}(Original) &= w + 0.5 x \\U_{SEU}(Alternative) &= w + 0.51 x.\end{aligned}$$

Because the Alternative Lottery strictly dominates the Original Lottery, the DM switches lotteries in the First Stage. Then, in the Second Stage the DM chooses between the Alternative Lottery and the Diversified Lottery. The utility of the Diversified Lottery is

$$U_{SEU}(Diversified) = w + 0.5 x.$$

Since the Alternative Lottery strictly dominates the Diversified Lottery, the DM chooses the Alternative Lottery again.

Now consider the DM's behavior in the AMBIGUITY condition. Because the DM is bayesian and only knows that $q_o, q_a \sim U[0, 1]$, she proceeds as if $q_o = q_a = 0.5$. Hence, the DM's behavior in the First and Second Stages is the same as in the RISK condition.

6.2.2 Knightian Decision Theory

In the RISK condition the DM behaves as a subjective expected utility maximizer, but in the AMBIGUITY condition she behaves differently. Unlike a bayesian DM, a Knightian DM has *multiple beliefs* about actual probabilities (q_o, q_a) . Let B denote such set of beliefs. In particular, because the DM knows that q_o and q_a could take on any values in the $[0, 1]$ interval, $B = [0, 1] \times [0, 1]$. Given a belief $(\tilde{q}_o, \tilde{q}_a) \in B$, the utilities of the lotteries from the

First Stage are

$$\begin{aligned} U_{KDT}(Original) &= w + \tilde{q}_o x \\ U_{KDT}(Alternative) &= w + 0.01 x + \tilde{q}_a x. \end{aligned}$$

The DM prefers the Original Lottery if and only if

$$U_{KDT}(Original) \geq U_{KDT}(Alternative) \quad \text{for all } (\tilde{q}_o, \tilde{q}_a) \in B.$$

Conversely, she prefers the Alternative Lottery if and only if

$$U_{KDT}(Original) \leq U_{KDT}(Alternative) \quad \text{for all } (\tilde{q}_o, \tilde{q}_a) \in B.$$

Clearly, neither of the above inequalities holds for *all* $(\tilde{q}_o, \tilde{q}_a) \in B$; this means that the DM finds the lotteries incomparable. I shall say that the DM is *indecisive*. How does an indecisive DM make a choice? To predict choice behavior in situations like this, Bewley (2002) invoked the *Inertia Assumption*. This assumption states that when there is a status quo option, the DM will switch to an alternative option *only if* the Alternative option is *strictly preferred* to the status quo. This implies that if the DM is indecisive, she will stick with the status quo option. Thus, Knightian Decision Theory predicts that the DM will not switch lotteries in the First Stage.

Then, in the Second Stage the DM chooses between the Original Lottery and the Diversified Lottery. Given a belief $(\tilde{q}_o, \tilde{q}_a) \in B$, the utility of the Diversified Lottery is

$$U_{KDT}(Diversified) = w + \tilde{q}_o \tilde{q}_a x + (\tilde{q}_o(1 - \tilde{q}_a) + (1 - \tilde{q}_o)\tilde{q}_a) 0.5 x.$$

Again, the DM will be indecisive between the lotteries. Hence, she will continue to stick

with the Original Lottery.

6.2.3 Models of Ambiguity Aversion

Next I discuss the predictions of the major models of ambiguity aversion: Maxmin Expected Utility, Smooth Ambiguity Preferences, and Variational Preferences. According to these models, in the RISK condition the DM behaves as a subjective expected utility maximizer. It turns out this also holds for the AMBIGUITY condition. Below I show why this is the case.

Maxmin Expected Utility. Let Π denote the family of all subjective probability distributions over (q_o, q_a) (the likelihood of a good draw from the original and alternative bags). The utilities of the lotteries are

$$\begin{aligned} U_{MEU}(Original) &= \min_{\pi \in \Pi} \int_0^1 \int_0^1 [w + q_o x + q_a 0] \pi(q_o, q_a) dq_a dq_o \\ U_{MEU}(Alternative) &= \min_{\pi \in \Pi} \int_0^1 \int_0^1 [w + 0.01 x + q_o 0 + q_a x] \pi(q_o, q_a) dq_o dq_a \\ U_{MEU}(Diversified) &= \min_{\pi \in \Pi} \int_0^1 \int_0^1 [w + (q_o + q_a) (0.5 x)] \pi(q_o, q_a) dq_a dq_o. \end{aligned}$$

Notice that in the current setting Π is a singleton with $\pi(q_o, q_a) = \pi(q_o)\pi(q_a) \equiv 1$, as the DM knows that $q_o, q_a \sim U[0, 1]$. This implies that $U_{MEU}(Original) = w + 0.5 x$, $U_{MEU}(Alternative) = w + 0.01 x + 0.5 x$, and $U_{MEU}(Diversified) = w + 0.5 x$. Thus, the DM switches lotteries in the First Stage and chooses the Alternative Lottery again in the Second Stage.³⁸

³⁸Ghirardato et al. (2004) introduce a generalization of the Maxmin Model called the α -Maxmin Model.

Smooth Ambiguity Preferences. The utilities of the lotteries are

$$\begin{aligned}
U_{SP}(Original) &= \int_{\pi \in \Pi} \phi \left(\int_0^1 \int_0^1 [w + q_o x + q_a 0] \pi(q_o, q_a) dq_a dq_o \right) d\mu(\pi(.)) \\
U_{SP}(Alternative) &= \int_{\pi \in \Pi} \phi \left(\int_0^1 \int_0^1 [w + 0.01 x + q_o 0 + q_a x] \pi(q_o, q_a) dq_o dq_a \right) d\mu(\pi(.)) \\
U_{SP}(Diversified) &= \int_{\pi \in \Pi} \phi \left(\int_0^1 \int_0^1 [w + (q_o + q_a) (0.5 x)] \pi(q_o, q_a) dq_a dq_o \right) d\mu(\pi(.)),
\end{aligned}$$

for some increasing function $\phi(\cdot)$, the family Π of all subjective probability distributions $\pi(\cdot)$ over (q_o, q_a) , and subjective probability distribution $\mu(\cdot)$ over Π . Using the fact that Π is a singleton with $\pi(q_o, q_a) = \pi(q_o)\pi(q_a) \equiv 1$, we obtain that $U_{SP}(Original) = \phi(w + 0.5 x)$, $U_{SP}(Alternative) = \phi(w + 0.01 x + 0.5 x)$, and $U_{SP}(Diversified) = \phi(w + 0.5 x)$. Since $\phi(\cdot)$ is increasing, the DM switches lotteries in the First Stage and chooses the Alternative Lottery again in the Second Stage.

Given some $\alpha \in [0, 1]$, the utilities of the lotteries are

$$\begin{aligned}
U_{\alpha MEU}(Original) &= \alpha \text{Min}_{\pi \in \Pi} \int_0^1 \int_0^1 [w + q_o x + q_a 0] \pi(q_o, q_a) dq_a dq_o \\
&\quad + (1 - \alpha) \text{Max}_{\pi \in \Pi} \int_0^1 \int_0^1 [w + q_o x + q_a 0] \pi(q_o, q_a) dq_a dq_o \\
U_{\alpha MEU}(Alternative) &= \alpha \text{Min}_{\pi \in \Pi} \int_0^1 \int_0^1 [w + 0.01 x + q_o 0 + q_a x] \pi(q_o, q_a) dq_o dq_a \\
&\quad + (1 - \alpha) \text{Max}_{\pi \in \Pi} \int_0^1 \int_0^1 [w + 0.01 x + q_o 0 + q_a x] \pi(q_o, q_a) dq_o dq_a \\
U_{\alpha MEU}(Diversified) &= \alpha \text{Min}_{\pi \in \Pi} \int_0^1 \int_0^1 [w + (q_o + q_a) (0.5 x)] \pi(q_o, q_a) dq_a dq_o \\
&\quad + (1 - \alpha) \text{Max}_{\pi \in \Pi} \int_0^1 \int_0^1 [w + (q_o + q_a) (0.5 x)] \pi(q_o, q_a) dq_a dq_o.
\end{aligned}$$

Notice that the Maxmin Model corresponds to $\alpha = 1$. The α -Maxmin Model also implies a strict preference for the Alternative Lottery in the First and Second Stages.

Variational Preferences. The utilities of the lotteries are

$$\begin{aligned}
U_{VP}(Original) &= \min_{\pi \in \Pi} \left(\int_0^1 \int_0^1 [w + q_o x + q_a 0] \pi(q_o, q_a) dq_a dq_o + \eta(\pi(.)) \right) \\
U_{VP}(Alternative) &= \min_{\pi \in \Pi} \left(\int_0^1 \int_0^1 [w + 0.01 x + q_o 0 + q_a x] \pi(q_o, q_a) dq_o dq_a + \eta(\pi(.)) \right) \\
U_{VP}(Diversified) &= \min_{\pi \in \Pi} \left(\int_0^1 \int_0^1 [w + (q_o + q_a) (0.5 x)] \pi(q_o, q_a) dq_a dq_o + \eta(\pi(.)) \right),
\end{aligned}$$

for the family Π of all subjective probability distributions $\pi(.)$ over (q_o, q_a) , and non-negative convex function $\eta(.)$ over Π . Using the fact that Π is a singleton with $\pi(q_o, q_a) = \pi(q_o)\pi(q_a) \equiv 1$, we obtain that $U_{SP}(Original) = w + 0.5 x + \eta(\pi(.))$, $U_{SP}(Alternative) = w + 0.01 x + 0.5 x + \eta(\pi(.))$, and $U_{SP}(Diversified) = w + 0.5 x + \eta(\pi(.))$. It follows that the DM switches lotteries in the First Stage and chooses the Alternative Lottery again in the Second Stage.

6.2.4 Reference-Dependent Subjective Expected Utility

This theory encompasses three different models: Sugden's (2003), Kőszegi and Rabin's (2006, 2007), and a model with initial wealth as the reference point—which is a special case of Prospect Theory (Kahneman and Tversky 1979).

Sugden's (2003) Model. In each stage, the reference point is the lottery with which the DM is endowed. Clearly, in the First Stage the reference point is the Original Lottery. When the DM evaluates an outcome from the Original Lottery, the reference level is that same outcome; hence the outcome yields no gain-loss utility. On the other hand, when the DM evaluates an outcome from the Alternative Lottery, its gain-loss utility is the average of how it feels relative to each possible realization of the Original Lottery.³⁹

³⁹Recall that the DM does not get to know the outcome of the Original Lottery when she chooses the Alternative Lottery (because in this case the Original Lottery is not resolved). Then, an outcome from the Alternative Lottery does not have a fixed reference level. This is why the DM compares such outcome to each

Consider the DM's behavior in the RISK condition. The utilities of the lotteries from the First Stage are

$$\begin{aligned}
U_S(\textit{Original}) &= w + 0.5 x \\
U_S(\textit{Alternative}) &= w + 0.51 x + \{0.5 [0.5 \mu(1.01 x) + 0.5 \mu(1.01 x - x)] \\
&\quad + 0.5 [0.5 \mu(0.01 x) + 0.5 \mu(0.01 x - x)]\}.
\end{aligned}$$

Assuming that $\mu(\cdot)$ is piecewise-linear as in (3), we conclude that the DM chooses the Original Lottery in the First Stage if and only if $\lambda > 1.08$. Suppose that the DM chooses the Original Lottery. Then, in the Second Stage the DM chooses between the Original Lottery and the Diversified Lottery. The reference point continues to be the Original Lottery. The utility of the Diversified Lottery is

$$U_S(\textit{Diversified}) = w + 0.5 x + [0.25 \mu(0.5 x) + 0.25 \mu(0.5 x - x)].$$

A payoff of x and a payoff of 0 do not generate gain-loss utility, as in either case the outcome would have been the same had the DM played the Original Lottery. By contrast, a payoff of $0.5 x$ creates either a gain (first term between brackets) or a loss (second term between brackets) relative to the Original Lottery. If the only successful roll is the one from the alternative die, the DM experiences a gain of $0.5 x$ because she would have obtained nothing had she played the Original Lottery. On the other hand, if the only successful roll is the one from the original die, the DM experiences a loss of $0.5 x$ because she would have obtained the full prize x had she played the Original Lottery. Since the DM is loss-averse, the disutility from the loss outweighs the utility from the gain (this means that the sum

possible realization of the Original Lottery. In the original setting of Sugden's (2003) model, the DM does learn the outcomes of all lotteries. In that setting, the gain-loss utility of an outcome from the Alternative Lottery is how it feels relative to the outcome of the Original Lottery.

of the two terms between brackets is negative); hence, loss aversion implies that the DM strictly prefers the Original Lottery to the Diversified Lottery.⁴⁰

Now consider the DM's behavior in the AMBIGUITY condition. Since the DM is bayesian and only knows that $q_o, q_a \sim U[0, 1]$, she proceeds as if $q_o = q_a = 0.5$. This implies that all probability distributions and the reference point remain the same as in the RISK condition. Therefore, the DM's behavior in the First and Second Stages is the same as in RISK.

Kőszegi and Rabin's (2006, 2007) Model. In each stage, the reference point is the lottery that the DM expected to play. The gain-loss utility of an outcome is the average of how it feels relative to each possible realization of the reference lottery.

First, consider the DM's behavior in the RISK condition. Because the option to switch lotteries in the First Stage is a surprise, at the moment of the keep-or-switch decision the DM expected to play the Original Lottery. Thus, the reference point in the First Stage is the Original Lottery. The utilities of the lotteries from the First Stage are

$$\begin{aligned} U_{KR}(Original) &= w + 0.5 x + \{0.5 [0.5 \mu(x)] + 0.5 [0.5 \mu(-x)]\} \\ U_{KR}(Alternative) &= w + 0.51 x + \{0.5 [0.5 \mu(1.01 x) + 0.5 \mu(1.01 x - x)] \\ &\quad + 0.5 [0.5 \mu(0.01 x) + 0.5 \mu(0.01 x - x)]\}. \end{aligned}$$

⁴⁰If the DM were to choose the Alternative Lottery instead of the Original Lottery in the First Stage, she would still not diversify in the Second Stage. The reference point in the Second Stage would be the Alternative Lottery. The utility of the Alternative Lottery would be

$$U_S(Alternative|Second Stage) = w + 0.51 x$$

and the utility of the Diversified Lottery would be

$$\begin{aligned} U_S(Diversified) &= w + 0.5 x \\ &\quad + [0.25 \mu(x - 1.01 x) + 0.25 \mu(0.5 x - 0.01 x) \\ &\quad + 0.25 \mu(0.5 x - 1.01 x) + 0.25 \mu(-0.01 x)]. \end{aligned}$$

It is clear that the Alternative Lottery strictly dominates the Diversified Lottery for any degree of loss aversion.

Since the Alternative Lottery strictly dominates the Original Lottery, the DM switches lotteries. Then, in the Second Stage the DM chooses between the Alternative Lottery and the Diversified Lottery. Because the opportunity to diversify is a surprise to the DM, at the moment of making the Second-Stage choice the DM expects to play the Alternative Lottery. Thus, the reference lottery is the Alternative Lottery. The utilities of the lotteries from the Second Stage are

$$\begin{aligned}
U_{KR}(\textit{Alternative}|\textit{Second Stage}) &= w + 0.51 x + \{0.5 [0.5 \mu(1.01 x - 0.01 x)] \\
&\quad + 0.5 [0.5 \mu(0.01 x - 1.01 x)]\} \\
U_{KR}(\textit{Diversified}) &= w + 0.5 x \\
&\quad + \{0.25 [0.5 \mu(x - 0.01 x) + 0.5 \mu(x - 1.01 x)] \\
&\quad + 0.5 [0.5 \mu(0.5 x - 0.01 x) + 0.5 \mu(0.5 x - 1.01 x)] \\
&\quad + 0.25 [0.5 \mu(-0.01 x) + 0.5 \mu(-1.01 x)]\}.
\end{aligned}$$

To determine whether the DM diversifies in the Second Stage, assume that μ is piecewise-linear as in (3). It turns out that the Alternative Lottery strictly dominates the Diversified Lottery for any degree of loss aversion. As the DM expected to play the Alternative Lottery, she is still willing to bear the risk even after learning that she can diversify.⁴¹

Now consider the DM's behavior in the AMBIGUITY condition. Since the DM is bayesian and only knows that $q_o, q_a \sim U[0, 1]$, she proceeds as if $q_o = q_a = 0.5$. This implies that all the probability distributions and reference points remain the same as in the RISK condition. Hence, the DM's behavior in the First and Second Stages is the same as in RISK.

⁴¹ Compare to a situation in which the DM expected to play the Diversified Lottery and is surprised with the option to switch to the Alternative Lottery. In this case, the reference point is the Diversified Lottery. Now the DM chooses the Alternative Lottery if and only if $\lambda \leq 1.34$. The comparison between the two situations reveals an *endowment effect for risk* (Kőszegi and Rabin 2007, pp. 1053-1054): the DM is more likely to choose the Alternative Lottery (instead of the Diversified Lottery) when she expected to play it than when the option to play it is a surprise.

A Model With Initial Wealth as the Reference Point. The reference level to which any outcome is compared is initial wealth w . First, consider the DM's behavior in the RISK condition. The utilities of the lotteries from the First Stage are

$$\begin{aligned} U_W(Original) &= w + 0.5 x + [0.5 \mu(x)] \\ U_W(Alternative) &= w + 0.51 x + [0.5 \mu(1.01 x) + 0.5 \mu(0.01 x)]. \end{aligned}$$

Since the Alternative Lottery strictly dominates the Original Lottery, the DM switches lotteries. Then, in the Second Stage the DM chooses between the Alternative Lottery and the Diversified Lottery. The utility of the Diversified Lottery is:

$$U_W(Diversified) = w + 0.5 x + [0.25 \mu(x) + 0.5 \mu(0.5 x)].$$

Assuming that $\mu(\cdot)$ is piecewise-linear as in (3), we conclude that the Alternative Lottery strictly dominates the Diversified Lottery for any degree of loss aversion.

Now consider the DM's behavior in the AMBIGUITY condition. Since the DM is bayesian and only knows that $q_o, q_a \sim U[0, 1]$, she proceeds as if $q_o = q_a = 0.5$. This implies that all the probability distributions remain the same as in the RISK condition. Hence, the DM's behavior in the First and Second Stages is the same as in RISK.⁴²

⁴²This model is a special case of Prospect Theory (Kahneman and Tversky 1979), which allows for non-linear probability weighting. While the prediction that the DM will switch in the First Stage from either condition remains the same under Prospect Theory, we no longer have a sharp prediction for the Second Stage; we need to make additional assumptions about the functional form of the probability weighting function in order to predict behavior. Nevertheless, because the DM is Bayesian, the conclusion that her behavior is the same in both conditions still holds.

6.3 Predicted Behavior in the Third Stage from the AMBIGUITY Condition

In this appendix I discuss the predictions of Disappointment Theory and Krähmer and Stone's theory for the Third Stage from the AMBIGUITY condition.

Using Bayes' Rule, the DM updates her beliefs about the probability of a good draw each time a draw is performed. Let \tilde{q}_o and \tilde{q}_a denote the posterior subjective probabilities of a good draw from the original and alternative bags after the practice draws. A disappointment-averse DM evaluates the lotteries as follows:

$$\begin{aligned}
U_{DT}(Original) &= w + \tilde{q}_o x + [\tilde{q}_o \mu(x - \tilde{q}_o x) + (1 - \tilde{q}_o) \mu(-\tilde{q}_o x)] \\
U_{DT}(Alternative) &= w + 0.01 x + \tilde{q}_a x \\
&\quad + [\tilde{q}_a \mu(1.01 x - 0.01 x - \tilde{q}_a x) + (1 - \tilde{q}_a) \mu(0.01 x - 0.01 x - \tilde{q}_a x)] \\
U_{DT}(Diversified) &= w + (\tilde{q}_o + \tilde{q}_a)(0.5 x) + [\tilde{q}_o \tilde{q}_a \mu(x - 0.5 (\tilde{q}_o + \tilde{q}_a) x) \\
&\quad + (\tilde{q}_o(1 - \tilde{q}_a) + (1 - \tilde{q}_o)\tilde{q}_a) \mu(0.5 x - 0.5 (\tilde{q}_o + \tilde{q}_a) x) \\
&\quad + (1 - \tilde{q}_o)(1 - \tilde{q}_a) \mu(-0.5 (\tilde{q}_o + \tilde{q}_a) x)].
\end{aligned}$$

After a good practice draw from bag i ($i = Original, Alternative$), $\tilde{q}_i = 0.625$; and after a bad draw, $\tilde{q}_i = 0.375$. To determine when the DM chooses the Diversified Lottery, assume that μ is piecewise-linear as in (3). This way we obtain the expression for $\tilde{\lambda}_{DT, AMB}$ given in Section 3.2.

Now consider the behavior of a Krähmer-Stone DM. It is important to note that after an *actual* draw, the DM updates her beliefs \tilde{q}_o and \tilde{q}_a once again, and these updated beliefs affect the reference levels. Below I discuss behavior in each scenario separately.

(i) 'good draw-good draw' scenario

After the practice draws but before the actual draws, $\tilde{q}_o = \tilde{q}_a = 0.625$. After a good

actual draw from bag i , \tilde{q}_i is updated to 0.7; after a bad actual draw, \tilde{q}_i is updated to 0.5. Thus, the utilities of the lotteries are

$$\begin{aligned}
U_{KS}(Original) &= w + 0.625 x + [0.625 \mu(x - 0.7 x) + 0.375 \mu(-0.01 x - 0.625 x)] \\
U_{KS}(Alternative) &= w + 0.01 x + 0.625 x \\
&\quad + [0.625 \mu(1.01 x - 0.01 x - 0.7 x) + 0.375 \mu(0.01 x - 0.625 x)] \\
U_{KS}(Diversified) &= w + 0.625 x + [(0.625)^2 \mu(x - 0.01 x - 0.7 x) \\
&\quad + (0.625 * 0.375) \mu(0.5 x - 0.7 x) \\
&\quad + (0.375 * 0.625) \mu(0.5 x - 0.01 x - 0.7 x) \\
&\quad + (0.375)^2 \mu(-0.01 x - 0.5 x)].
\end{aligned}$$

The Alternative Lottery strictly dominates the Original one. Using (3), we obtain that the DM chooses the Diversified Lottery over the Alternative Lottery if and only if $\lambda > 1.34$.

(ii) ‘bad draw-bad draw’ scenario

After the practice draws but before the actual draws, $\tilde{q}_o = \tilde{q}_a = 0.375$. After a good actual draw from bag i , \tilde{q}_i is updated to 0.5; after a bad actual draw, \tilde{q}_i is updated to 0.3. Thus, the utilities of the lotteries are

$$\begin{aligned}
U_{KS}(Original) &= w + 0.375 x + [0.375 \mu(x - 0.5 x) + 0.625 \mu(-0.01 x - 0.375 x)] \\
U_{KS}(Alternative) &= w + 0.01 x + 0.375 x \\
&\quad + [0.375 \mu(1.01 x - 0.01 x - 0.5 x) + 0.625 \mu(0.01 x - 0.375 x)] \\
U_{KS}(Diversified) &= w + 0.375 x + [(0.375)^2 \mu(x - 0.01 x - 0.5 x) \\
&\quad + (0.375 * 0.625) \mu(0.5 x - 0.5 x) \\
&\quad + (0.625 * 0.375) \mu(0.5 x - 0.01 x - 0.5 x) \\
&\quad + (0.625)^2 \mu(-0.01 x - 0.3 x)].
\end{aligned}$$

The Alternative Lottery strictly dominates the Original one. Using (3), we conclude that the DM chooses the Diversified Lottery over the Alternative Lottery if and only if $\lambda > 1.23$.

(iii) ‘good draw-bad draw’ scenario

After the practice draws but before the actual draws, $\tilde{q}_o = 0.625$ and $\tilde{q}_a = 0.375$. After a good actual draw from the original bag, \tilde{q}_o is updated to 0.7; after a bad actual draw, \tilde{q}_o is updated to 0.5. On the other hand, after a good actual draw from the alternative bag, \tilde{q}_a is updated to 0.5; after a bad actual draw, \tilde{q}_a is updated to 0.3. Thus, the utilities of the lotteries are

$$\begin{aligned}
U_{KS}(Original) &= w + 0.625 x + [0.625 \mu(x - 0.7 x) + 0.375 \mu(-0.5 x)] \\
U_{KS}(Alternative) &= w + 0.01 x + 0.375 x \\
&\quad + [0.375 \mu(1.01 x - 0.625 x) + 0.625 \mu(0.01 x - 0.625 x)] \\
U_{KS}(Diversified) &= w + 0.5 x + [(0.625 * 0.375) \mu(x - 0.7 x) \\
&\quad + (0.625)^2 \mu(0.5 x - 0.7 x) + (0.375)^2 \mu(0.5 x - 0.01 x - 0.5 x) \\
&\quad + (0.375 * 0.625) \mu(-0.5 x)].
\end{aligned}$$

Using (3), we obtain that the DM strictly prefers the Original Lottery regardless of her degree of loss aversion.

(iv) ‘bad draw-good draw’ scenario

After the practice draws but before the actual draws, $\tilde{q}_o = 0.375$ and $\tilde{q}_a = 0.625$. After a good actual draw from the original bag, \tilde{q}_o is updated to 0.5; after a bad actual draw, \tilde{q}_o is updated to 0.3. On the other hand, after a good actual draw from the alternative bag, \tilde{q}_a is updated to 0.7; after a bad actual draw, \tilde{q}_a is updated to 0.5. Thus, the utilities of the

lotteries are

$$\begin{aligned}
U_{KS}(Original) &= w + 0.375 x \\
&\quad + [0.375 \mu(x - 0.01 x - 0.625 x) + 0.625 \mu(-0.01 x - 0.625 x)] \\
U_{KS}(Alternative) &= w + 0.01 x + 0.625 x \\
&\quad + [0.625 \mu(1.01 x - 0.01 x - 0.7 x) \\
&\quad + 0.375 \mu(0.01 x - 0.01 x - 0.5 x)] \\
U_{KS}(Diversified) &= w + 0.5 x + [(0.375 * 0.625) \mu(x - 0.01 x - 0.7 x) \\
&\quad + (0.375)^2 \mu(0.5 x - 0.01 x - 0.5 x) \\
&\quad + (0.625)^2 \mu(0.5 x - 0.01 x - 0.7 x) \\
&\quad + (0.625 * 0.375) \mu(-0.01 x - 0.5 x)].
\end{aligned}$$

Using (3) once again, we conclude that the DM strictly prefers the Alternative Lottery regardless of her degree of loss aversion.

6.4 Comparison of Demographics between Experiments: Balancing Tests

In Tables A1 and A2 I compare demographic characteristics of participants between the present experiment and the experiment I reported in Sautua (2015). In Table A1 I compare the RISK condition to its counterpart from the previous experiment; similarly, in Table A2 I compare the AMBIGUITY condition to its counterpart from the previous experiment. For each condition in a given experiment, the tables show the percentage of participants who previously participated in other experiments, are women, are Asian, are undergraduate students, pursue a major that is Math-intensive or intensive in formal logic, and are native English speakers. For each of these observable characteristics, the last column of each table displays

the result of a chi-square test of differences in proportions across experiments. Participants are clearly balanced on observable characteristics. (There is only one statistically significant difference: the proportion of participants from AMBIGUITY who are undergraduates is larger than in the previous experiment.)

TABLE A1 --- DEMOGRAPHIC CHARACTERISTICS OF PARTICIPANTS
FROM CONDITIONS WITH RISKY OUTCOMES

Variable	Experiment		Chi-Square Test p-value*
	Current (N = 51)	Previous (N = 49)	
Other Experiments	82%	84%	0.860
Female	75%	82%	0.390
Asian	47%	61%	0.155
Undergraduate	94%	94%	0.960
Math-Related Major	37%	31%	0.483
English 1st Language	80%	67%	0.137

* The p-values are for chi-square tests of differences in proportions. For each variable, the null hypothesis is that the percentage of participants with the relevant characteristic is the same in both experiments.

TABLE A2 --- DEMOGRAPHIC CHARACTERISTICS OF PARTICIPANTS
FROM CONDITIONS WITH AMBIGUOUS OUTCOMES

Variable	Experiment		Chi-Square Test p-value*
	Current (N = 49)	Previous (N = 49)	
Other Experiments	81%	84%	0.754
Female	72%	73%	0.901
Asian	44%	43%	0.929
Undergraduate	94%	71%	0.004
Math-Related Major	35%	24%	0.240
English 1st Language	83%	82%	0.826

* The p-values are for chi-square tests of differences in proportions. For each variable, the null hypothesis is that the percentage of participants with the relevant characteristic is the same in both experiments.

6.5 Observed Behavior in All Stages

In Tables A3 and A4 I summarize participants' behavior in all stages; Table A3 corresponds to the RISK condition, while Table A4 corresponds to the AMBIGUITY condition.

TABLE A3 --- OBSERVED BEHAVIOR IN THE RISK CONDITION:
ALL STAGES

<i>Panel A: "60-40" Scenario</i>									
	Diversified			Original			Alternative		
		Previous			Previous			Previous	
	Diversified	Choice	Total	Diversified	Choice	Total	Diversified	Choice	Total
Original	0%	0%	0%	9.8%	15.7%	25.5%	0%	0%	0%
Alternative	33.3%	11.1%	44.4%	11.8%	15.7%	27.5%	2%	2%	3.9%
Total	33.3%	11.1%	44.4%	21.6%	31.4%	52.9%	2%	2%	3.9%
<i>Panel B: "40-60" Scenario</i>									
	Diversified			Original			Alternative		
		Previous			Previous			Previous	
	Diversified	Choice	Total	Diversified	Choice	Total	Diversified	Choice	Total
Original	17.6%	5.9%	23.5%	0%	5.9%	5.9%	7.8%	9.8%	17.6%
Alternative	15.7%	3.9%	19.6%	0%	0%	0%	15.7%	17.6%	33.3%
Total	33.3%	9.8%	43.1%	0%	5.9%	5.9%	23.5%	27.5%	51%
<i>Panel C: "70-30" Scenario</i>									
	Diversified			Original			Alternative		
		Previous			Previous			Previous	
	Diversified	Choice	Total	Diversified	Choice	Total	Diversified	Choice	Total
Original	13.7%	3.9%	17.6%	11.8%	17.6%	29.4%	0%	0%	0%
Alternative	11.8%	2%	13.7%	19.6%	17.6%	37.3%	0%	2%	2%
Total	25.5%	5.9%	31.4%	31.4%	35.3%	66.7%	0%	2%	2%
<i>Panel D: "30-70" Scenario</i>									
	Diversified			Original			Alternative		
		Previous			Previous			Previous	
	Diversified	Choice	Total	Diversified	Choice	Total	Diversified	Choice	Total
Original	15.7%	3.9%	19.6%	0%	5.9%	5.9%	9.8%	11.8%	21.6%
Alternative	7.8%	0%	7.8%	0%	0%	0%	23.5%	21.6%	45.1%
Total	23.5%	3.9%	27.5%	0%	5.9%	5.9%	33.3%	33.3%	66.7%

TABLE A4 --- OBSERVED BEHAVIOR IN THE AMBIGUITY CONDITION:
ALL STAGES

<i>Panel A: "Good Draw-Bad Draw" Scenario</i>									
	Diversified			Original			Alternative		
		Previous			Previous			Previous	
	Diversified	Choice	Total	Diversified	Choice	Total	Diversified	Choice	Total
Original	32.7%	0%	32.7%	8.2%	16.3%	24.5%	0%	4.1%	4.1%
Alternative	24.5%	0%	24.5%	4.1%	2%	6.1%	0%	8.2%	8.2%
Total	57.1%	0%	57.1%	12.2%	18.4%	30.6%	0%	12.2%	12.2%
<i>Panel B: "Bad Draw-Good Draw" Scenario</i>									
	Diversified			Original			Alternative		
		Previous			Previous			Previous	
	Diversified	Choice	Total	Diversified	Choice	Total	Diversified	Choice	Total
Original	30.6%	4.1%	34.7%	0%	16.3%	16.3%	10.2%	0%	10.2%
Alternative	24.5%	0%	24.5%	0%	0%	0.0%	4.1%	10.2%	14.3%
Total	55.1%	4.1%	59.2%	0%	16.3%	16.3%	14.3%	10.2%	24.5%
<i>Panel C: "Good Draw-Good Draw" Scenario</i>									
	Diversified			Original			Alternative		
		Previous			Previous			Previous	
	Diversified	Choice	Total	Diversified	Choice	Total	Diversified	Choice	Total
Original	38.8%	0%	38.8%	2%	16.3%	18.4%	0%	4.1%	4.1%
Alternative	22.4%	0%	22.4%	0%	0%	0%	6.1%	10.2%	16.3%
Total	61.2%	0%	61.2%	2%	16.3%	18.4%	6.1%	14.3%	20.4%
<i>Panel D: "Bad Draw-Bad Draw" Scenario</i>									
	Diversified			Original			Alternative		
		Previous			Previous			Previous	
	Diversified	Choice	Total	Diversified	Choice	Total	Diversified	Choice	Total
Original	38.8%	2%	40.8%	2%	16.3%	18.4%	0%	2%	2%
Alternative	26.5%	4.1%	30.6%	0%	0%	0%	2%	6.1%	8.2%
Total	65.3%	6.1%	71.4%	2%	16.3%	18.4%	2%	8.2%	10.2%

INSTRUCTIONS AND FORMS

RISK CONDITION

General Instructions

Welcome to this session. Thanks for coming.

This session will take 40-45 minutes. You will receive an \$8 minimum payment if you complete the study. These \$8 are yours. In the session you will have the chance to earn additional money. Whatever you earn from the study today will be added to this minimum payment. All payments will be made with Bruincard deposits in the next few weeks.

During this short study, you will be asked to fill out some questionnaires and you will play an individual lottery that involves real money.

Your questionnaire responses as well as the lottery outcome will be kept strictly confidential. At your desk, you will find a sticker with your Participant ID Number. Please write down this number on the front page of each of the forms that you fill out.

Before we begin, we ask you to respect the following guidelines:

- No talking is allowed. If you have any questions during the study, please raise your hand. I will come to your place and answer your question privately.
- Every participant's task is individual and should be completed in private. Do not look at what other participants are doing.

If you do not comply with these rules, we will be forced to exclude you from the study. Thank you for your cooperation.

Should you have any questions or concerns at this point, please raise your hand. Otherwise, we will move on to the specific instructions.

Specific Instructions #1

- On your desk you can find two empty envelopes and two blank cards. One of the envelopes is labeled “NUMBERS” and the other is labeled “DIE.” Feel free to inspect the envelopes and the cards.
- Now, please pick five different numbers between 0 (inclusive) and 9 (inclusive).
 - Notice that you have to choose five out of ten possible numbers.
 - Write down the numbers you picked, separated by commas, on one of the cards.
 - Place the card inside the envelope labeled “NUMBERS” and close the envelope.
- Then, please pick a die—DIE 1 or DIE 2.
 - Write down the die you picked on the other card.
 - Place the card inside the envelope labeled “DIE” and close the envelope.

Next, I will explain to you what we will use the cards for.

Specific Instructions #2

- Two assistants will help us today. They will do the same things but will proceed independently to help us run the session smoothly. So roughly half of you will interact with one of the assistants, and the other half will interact with the other assistant.
- These plastic cups contain several 10-sided dice. Each die has numbers 0 through 9. Please pass the cups along and pick one die. Feel free to inspect the die.
- Now, we will collect the dice.
- Each assistant will randomly pick two dice and two transparent plastic cups from the pile you see on the front desk. Each assistant will place one die inside each cup.
- At the end of the session, the assistants will go to a room next door. Each assistant will label one of the dice “DIE 1” and the other die “DIE 2.” (To this end, she will use stickers like the ones that display your Participant ID # on your desk.)
- One of the assistants will call you individually. Once you are inside the room, she will roll one of the two dice in front of you. She will use the transparent plastic cup to roll the die.
- You will use the cards to play an individual lottery. Together, the cards are a ticket to play the lottery.
 - If you picked DIE 1, the assistant will roll DIE 1. If you picked DIE 2, the assistant will roll DIE 2.
 - If any of the five numbers that you picked comes up, you will get \$10.
 - If any of the remaining five numbers comes up, you will get \$0.
- Please note that the lottery is real. You will actually receive \$10 if you happen to win the prize.
- At the end of the session, you will line up in the hallway. One of the assistants will call you individually.
 - First, she will open the envelope labeled “DIE” to find out which die she has to roll.
 - Then, she will roll the corresponding die in front of you.
 - After rolling the die, she will open the envelope labeled “NUMBERS” to check whether you won the prize.

- Because the assistant will find out which numbers you picked only after rolling the die, you can be assured that this is a fair lottery.

Should you have any questions now, please raise your hand, and I will come by your desk. Otherwise, we will proceed with the study.

Next, you will provide some personal information and fill out a personality questionnaire.

Participant ID Number: _____

Personal Information

All responses will be kept strictly confidential.

(1) Have you participated in other studies conducted in a lab on campus? If yes, please indicate which labs you have been to.

(2) What is your age?

(3) What is your gender? Male _____ Female _____

(4) What is your racial or ethnic background?

White or Caucasian _____ Black or African American _____ Hispanic _____
Asian _____ Native American _____ Multiracial _____ Other _____

(5) What is your major? If you have one, please specify it. If not, indicate “undecided”.

(6) What year are you classified for in the current semester?

Freshman _____ Sophomore _____ Junior _____ Senior _____
Masters student _____ Doctoral student _____

(7) Please indicate the country where you were raised.

(8) What is your native language?

Participant ID Number: _____

Questionnaire: How I am in General

Here are a number of characteristics that may or may not apply to you. For each statement in the table, please indicate the extent to which you agree or disagree with that statement, by checking the appropriate column.

All responses will be kept strictly confidential.

I am someone who...	<i>Strongly Disagree</i>	<i>Disagree</i>	<i>Neither Agree Nor Disagree</i>	<i>Agree</i>	<i>Strongly Agree</i>
Is talkative					
Tends to find fault with others					
Does a thorough job					
Is depressed					
Is original, comes up with new ideas					
Is reserved					
Is helpful and unselfish with others					
Can be somewhat careless					
Is relaxed, handles stress well					
Is curious about many different things					
Is full of energy					
Starts quarrels with others					
Is a reliable worker					
Can be tense					
Is ingenious, a deep thinker					
Generates a lot of enthusiasm					
Has a forgiving nature					
Tends to be disorganized					
Worries a lot					
Has an active imagination					
Tends to be quiet					
Is generally trusting					

Once you are done, please raise your hand. I will come by your desk and give you another booklet.

Specific Instructions #3

Thank you for completing the previous questionnaires.

- Recall that you have a ticket to play an individual lottery that offers a \$10 prize.
- The assistant will roll the corresponding die in front of you.
 - You will win the prize if any of the five numbers that you picked comes up.
 - You will get nothing if any of the remaining five numbers comes up.
- After rolling the die, the assistant will check your ticket and will record the outcome of the lottery.

Should you have any questions now, please raise your hand, and I will come by your desk. Otherwise, we will proceed with the study.

Now, you can go ahead and complete the following form.

Participant ID Number: _____

Decision Form #1

You have the opportunity to switch dice, if you so desire.

If you switch dice, you will receive \$0.10 in addition to what you get from the lottery.

Please indicate your decision below (and fill in the blank between brackets next to the corresponding option):

_____ *I want to KEEP the original die [i.e., DIE _____]*

_____ *I want to SWITCH to the alternative die [i.e., DIE _____]*

Your decision will be kept strictly confidential.

Should you have any questions before making the decision, please raise your hand and I will come by your desk.

Please raise your hand once you are done.

Specific Instructions #4

You now have the opportunity to either play this lottery or play another lottery that I will describe next.

- If you decide to play this lottery, everything will happen as described before.
 - The assistant will roll the die you chose on Decision Form #1, and you will get \$10 if any of the five numbers from your ticket comes up.
 - Also, if you chose to switch dice on Decision Form #1, you will get \$0.10 in addition to what you get from the lottery.
- If instead you decide to play the other lottery, the assistant will roll both dice in front of you. The lottery works as follows:
 - First, the assistant will roll DIE 1. If any of the five numbers that you picked comes up, you will get \$5 from this roll. If any of the remaining five numbers comes up, you will get \$0 from this roll.
 - Then, the assistant will roll DIE 2. If any of the five numbers that you picked comes up, you will get \$5 from the second roll. Otherwise, you will get \$0 from the second roll.
- To sum up, if you play the lottery in which both dice are rolled, you will get:
 - \$10 in total if both rolls are successful;
 - \$5 in total if only one roll is successful;
 - \$0 if neither of the rolls is successful.
- Notice that the lottery in which both dice are rolled does not pay the \$0.10 bonus.

Now you can go ahead and complete the following form.

Participant ID Number: _____

Decision Form #2

Please indicate your decision below (and fill in the blank between brackets next to the corresponding option):

_____ *I want to play the lottery in which only the die I chose on Decision Form #1 is rolled. [On Decision Form #1, I chose DIE ____]*

_____ *I want to play the lottery in which both dice are rolled*

Your decision will be kept strictly confidential.

Should you have any questions before making the decision, please raise your hand and I will come by your desk.

Please raise your hand once you are done.

Specific Instructions #5

- Now, please grab the card from the envelope labeled “NUMBERS.”
- You will write four sets of numbers on the back side of the card, each on a separate line.
- First, drop one of the five numbers that you picked originally. Please write down “-1:” and the four final numbers next to it.
- Next, drop one more number. Please write down “-2:” and the three final numbers next to it.
- Now, add one number to the five numbers that you picked originally. Please write down “+1:” and the six final numbers next to it.
- Finally, add one more number. Please write down “+2:” and the seven final numbers next to it.
- Once you are done, please put the card back into the envelope.

Specific Instructions #6

In a moment you will fill out the last form.

- So far, you have faced the following scenario:

Scenario #1:

- A roll of DIE 1 is successful if any of the five numbers that you picked originally comes up.
- A roll of DIE 2 is successful if any of the five numbers that you picked originally comes up.

On Decision Form #2, you chose between (i) a lottery in which only one die is rolled (which pays \$10 if the roll is successful), and (ii) a lottery in which both dice are rolled (which pays \$5 if only one roll is successful and \$10 if both rolls are successful).

- Now, you will make the same choice in four additional scenarios (Scenarios #2 through #5). Like in Scenario #1, the sets of numbers that you wrote on the card will determine whether a roll of a given die is successful. The following table summarizes all scenarios:

Scenario	Roll of DIE 1 successful if ...	Roll of DIE 2 successful if ...
#1	any of <u>five original numbers</u> comes up	any of <u>five original numbers</u> comes up
#2	any of <u>four final numbers</u> comes up	any of <u>six final numbers</u> comes up
#3	any of <u>six final numbers</u> comes up	any of <u>four final numbers</u> comes up
#4	any of <u>three final numbers</u> comes up	any of <u>seven final numbers</u> comes up
#5	any of <u>seven final numbers</u> comes up	any of <u>three final numbers</u> comes up

- In each scenario, you will choose one of three options:
 - play the lottery in which DIE 1 is rolled;
 - play the lottery in which DIE 2 is rolled;
 - play the lottery in which both dice are rolled.
- You will get the \$0.10 bonus if (i) you choose a lottery in which a single die is rolled, and (ii) this die is not the one that you wrote on the card originally.
- You will make a choice for each scenario. (You already made a choice for Scenario #1.) However, only one scenario will count after you have made your choices.
 - To determine the scenario-that-counts, we will come by your desk once you have made your choices, and you will draw a piece of paper from a plastic cup. The cup contains numbers 1 through 5; the number that you draw will determine the scenario-that-counts.
 - We will circle this scenario on the Decision Form that you will fill out. The assistant will then resolve the lottery that you chose for the scenario-that-counts.

Your choices will be kept strictly confidential.

Should you have any questions before making your choices, please raise your hand and I will come by your desk.

Now you can go ahead and complete the last form.

Participant ID Number: _____

Decision Form #3

Please indicate your choice for each scenario by checking the corresponding option.

For Scenario #1, simply repeat the choice you made on Decision Form #2.

Scenario	I want to have DIE 1 rolled	I want to have DIE 2 rolled	I want to have BOTH dice rolled
#1			
#2			
#3			
#4			
#5			

Please raise your hand once you are done.

We will come by your desk to determine the scenario- that-counts and will circle this scenario on the table.

Then you will grab the envelopes and this Decision Form, and you will line up in the hallway to play the lottery. Once your lottery has been resolved, you can leave.

AMBIGUITY CONDITION

[The general section of the instructions (“General Instructions”) was identical to the one from the RISK condition.]

Specific Instructions #1

- On your desk you can find two empty envelopes and two blank cards. One of the envelopes is labeled “COLOR” and the other is labeled “BAG.” Feel free to inspect the envelopes and the cards.
- Now, please pick a color—RED or BLUE.
 - Write down the color on one of the cards.
 - Place the card inside the envelope labeled “COLOR” and close the envelope.
 - Write down your Participant ID # at the bottom.
- Then, please pick a bag—BAG 1 or BAG 2.
 - Write down the bag you picked on the other card.
 - Place the card inside the envelope labeled “BAG” and close the envelope.

Next, I will explain to you what we will use the cards for.

Specific Instructions #2

- Two assistants will help us today. They will do the same things but will proceed independently to help us run the session smoothly. So roughly half of you will interact with one of the assistants, and the other half will interact with the other assistant.
- On the front desk you see two pairs of identical bags. Within each pair, the bags are labeled “BAG 1” and “BAG 2.” As of now, they are empty. At the end of the session, each assistant will take a pair of bags with her to a room next door.
- Each assistant will fill each of the two bags with red and blue balls. Each bag will have 10 balls in total.
- One of the assistants will call you individually. Once you are inside the room, she will randomly draw a ball from one of the bags in front of you. Then she will put the ball back into the bag.
- You will use the cards to play an individual lottery. Together, the cards are a ticket to play the lottery.
 - If you picked BAG 1, the assistant will draw a ball from BAG 1. If you picked BAG 2, the assistant will draw a ball from BAG 2.
 - A RED ticket pays \$10 if the assistant draws a RED ball from the corresponding bag and \$0 if she draws a blue ball.
 - A BLUE ticket pays \$10 if the assistant draws a BLUE ball from the corresponding bag and \$0 if she draws a red ball.
- Please note that the lottery is real. You will actually receive \$10 if you happen to win the prize.

- Now let me tell you how we will determine the compositions of the bags. On the front desk you see an empty plastic cup. You can also see eleven pieces of paper. Each piece of paper features a different number between 0 (inclusive) and 10 (inclusive). Now we will fold them and put them into the plastic cup. The assistant will randomly draw a number and write it down without showing it to anyone else; then she will fold the piece of paper again and put it back into the cup. Next she will repeat this procedure.
 - The first number drawn by the assistant will determine the number of RED balls (out of 10) in BAG 1.
 - The second number will determine the number of RED balls (out of 10) in BAG 2.
 - The assistant is the only person who will know the compositions of the bags. She will not reveal this information to anyone at any time, not even after resolving the lottery.
- At the end of the session, you will line up in the hallway. One of the assistants will call you individually.
 - First, she will open the envelope labeled “BAG” to find out from which bag she has to draw a ball.
 - Then, she will draw a ball from the corresponding bag in front of you.
 - After drawing a ball, she will open the envelope labeled “COLOR” to check whether you won the prize.
- Note that, at the moment of setting up the bags, the assistant will not know which color you are playing. Moreover, she will check your color only after drawing a ball. This way, you can be assured that this is a fair lottery.

Should you have any questions now, please raise your hand, and I will come by your desk. Otherwise, we will proceed with the study.

Next, you will provide some personal information and fill out a personality questionnaire.

[Next, participants filled out the forms “Personal Information” and “Questionnaire: How I am in General,” which were identical to the ones from the RISK condition.]

Specific Instructions #3

Thank you for completing the previous questionnaires.

- Recall that you have a ticket to play an individual lottery that offers a \$10 prize.
- The assistant will draw a ball from the corresponding bag in front of you.
 - You will win the prize if the color of your ticket matches the color of the ball drawn.
- The compositions of the bags were randomly determined. The assistant drew two numbers between 0 and 10 independently.
 - The first number determined the number of RED balls (out of 10) in BAG 1.
 - The second number determined the number of RED balls (out of 10) in BAG 2.
- After drawing a ball, the assistant will check the color of your ticket and will record the outcome of the lottery.

Should you have any questions now, please raise your hand, and I will come by your desk. Otherwise, we will proceed with the study.

Now, you can go ahead and complete the following form.

Participant ID Number: ____

Decision Form #1

You have the opportunity to switch bags, if you so desire. (The color of your ticket will remain the same.)

If you switch bags, you will receive \$0.10 in addition to what you get from the lottery.

Please indicate your decision below (and fill in the blank between brackets next to the corresponding option):

_____ *I want to KEEP the original bag [i.e., BAG ____]*

_____ *I want to SWITCH to the alternative bag [i.e., BAG ____]*

Your decision will be kept strictly confidential.

Should you have any questions before making the decision, please raise your hand and I will come by your desk.

Please raise your hand once you are done.

Specific Instructions #4

You now have the opportunity to either play this lottery or play another lottery that I will describe next.

- If you decide to play this lottery, everything will happen as described before.
 - The assistant will draw a ball from the bag you chose on Decision Form #1, and you will get \$10 if the color of your ticket matches the color of the ball drawn.
 - Also, if you chose to switch bags on Decision Form #1, you will get \$0.10 in addition to what you get from the lottery.
- If instead you decide to play the other lottery, the assistant will draw one ball from each bag. The lottery works as follows:
 - First, the assistant will draw a ball from BAG 1. If the draw is successful, you will get \$5 from this draw. Otherwise, you will get \$0 from this draw.
 - Then, the assistant will draw a ball from BAG 2. If the draw is successful, you will get \$5 from this draw. Otherwise, you will get \$0 from this draw.
- To sum up, if you play the lottery in which the assistant draws one ball from each bag, you will get:
 - \$10 in total if both draws are successful;
 - \$5 in total if only one draw is successful;
 - \$0 if neither of the draws is successful.
- Notice that the lottery in which a ball is drawn from each bag does not pay the \$0.10 bonus.

Now you can go ahead and complete the following form.

Participant ID Number: _____

Decision Form #2

Please indicate your decision below (and fill in the blank between brackets next to the corresponding option):

_____ *I want to play the lottery in which a ball is drawn from the bag I chose on*

Decision Form #1. [On Decision Form #1, I chose BAG ____]

_____ *I want to play the lottery in which a ball is drawn from each bag*

Your decision will be kept strictly confidential.

Should you have any questions before making the decision, please raise your hand and I will come by your desk.

Please raise your hand once you are done.

Specific Instructions #5

In a moment you will fill out the last form.

- Before resolving the lottery, and regardless of the lottery you chose, the assistant will draw one ball from each bag in front of you.
 - These are practice draws, so they do not count towards the lottery.
 - After drawing a ball and showing it to you, the assistant will put the ball back into the bag.
- You can either play the lottery you already chose or change your choice based on the outcomes of the practice draws.
- Notice there are four possible scenarios with regard to the practice draws:
 - The assistant draws a RED ball from each bag.
 - The assistant draws a BLUE ball from each bag.
 - The assistant draws a RED ball from BAG 1 and a BLUE ball from BAG 2.
 - The assistant draws a BLUE ball from BAG 1 and a RED ball from BAG 2.
- In each scenario, you will choose one of three options:
 - play the lottery in which one ball is drawn from BAG 1;
 - play the lottery in which one ball is drawn from BAG 2;
 - play the lottery in which a ball is drawn from each bag.
- You will get the \$0.10 bonus if (i) you choose a lottery in which a single ball is drawn, and (ii) the bag you choose is not the one that you wrote on the card originally.
- You will make a choice for each scenario before the assistant performs the practice draws. Of course, only one scenario will occur once the assistant performs the practice draws. This scenario will be the one-that-counts. The assistant will then resolve the lottery you chose for the scenario-that-counts.

Your choices will be kept strictly confidential.

Should you have any questions before making your choices, please raise your hand and I will come by your desk.

Now you can go ahead and complete the last form.

Decision Form #3

Please indicate your decision for each scenario:

If the assistant draws a RED ball from each bag in the practice draws:

_____ *I want to play the lottery in which one ball is drawn from BAG 1*

_____ *I want to play the lottery in which one ball is drawn from BAG 2*

_____ *I want to play the lottery in which a ball is drawn from each bag*

If the assistant draws a BLUE ball from each bag in the practice draws:

_____ *I want to play the lottery in which one ball is drawn from BAG 1*

_____ *I want to play the lottery in which one ball is drawn from BAG 2*

_____ *I want to play the lottery in which a ball is drawn from each bag*

If the assistant draws a RED ball from BAG 1 and a BLUE ball from BAG 2:

_____ *I want to play the lottery in which one ball is drawn from BAG 1*

_____ *I want to play the lottery in which one ball is drawn from BAG 2*

_____ *I want to play the lottery in which a ball is drawn from each bag*

If the assistant draws a BLUE ball from BAG 1 and a RED ball from BAG 2:

_____ *I want to play the lottery in which one ball is drawn from BAG 1*

_____ *I want to play the lottery in which one ball is drawn from BAG 2*

_____ *I want to play the lottery in which a ball is drawn from each bag*

Please raise your hand once you are done.

You will take the envelopes and this Decision Form with you to play the lottery. Once your lottery has been resolved, you can leave.

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