Sampling Experience Reverses Preferences for Ambiguity

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Abstract

People often need to choose between alternatives with known probabilities (risk) and alternatives with unknown probabilities (ambiguity). Such decisions are characterized by attitudes towards ambiguity, which are distinct from risk attitudes. Studies of ambiguity attitudes have thus far focused on the static case of single choice, finding ambiguity aversion for medium and high probability events, and ambiguity seeking for low probability events. However, in many situations, decision makers may be able to sample outcomes of an ambiguous alternative, allowing for inferences about its probabilities. The current paper finds that such sampling experience completely reverses ambiguity attitudes. It further shows that this reversal of preferences cannot be explained by participants' updated probabilistic beliefs, suggesting more complex motivational and processing effects.

In many situations we are confronted with choices between alternatives that have well-known risks, and alternatives that have uncertain, or ambiguous, risks. Consumers choose between products of well established brands and those of new brands that offer more uncertain, but potentially higher, benefits (Muthukrishnan, Wathieu, & Xu, 2009). Patients choose between known medications, and uncertain but cheaper generic drugs that contain the same active substances (Curley, Yates, & Abrams, 1986). A large number of decisions in business, insurance, and finance is affected by ambiguity (Einhorn & Hogarth, 1986; Kunreuther, Hogarth, & Meszaros, 1993; Mukerji & Tallon, 2001).

Studies of ambiguity attitudes typically offer participants a one-shot choice between a risky and an ambiguous lottery, where both lotteries are equally valuable under subjective expected utility. The empirically observed pattern of ambiguity attitude can be described by ambiguity aversion (i.e. preference for known risks) for medium and large probabilities of success, and ambiguity seeking (i.e. preference for uncertain risks) for small probabilities (Camerer & Weber, 1992; Einhorn & Hogarth, 1986; Frisch & Baron, 1988; Keren & Gerritsen, 1999).

While studies of ambiguity attitudes have focused on one-shot choices, real life situations often offer the opportunity to gather experience with the unknown risks before reaching a decision. For instance, consumers are encouraged to sample new products at a discounted price, and firms try out product prototypes on limited markets before going into full production. Surprisingly, despite the relevance of such sampling experience in decisions under ambiguity, little is known about its potential effect on ambiguity attitudes. Trautmann and Zeckhauser (2011) find that people shy away from ambiguous alternatives in repeated settings because they do not fully recognize the learning opportunities offered by these alternatives. Rode et al. (1999) show that people sometimes prefer ambiguity if their need is higher than the mean outcome of the known-risk distribution. However, none of these studies speaks to the effect of observing a short sample from the ambiguous alternative before making a choice between ambiguous and risky alternatives.

The idea that ambiguity attitudes might be affected by sampling experience is motivated by the recent literature on decisions from experience. This literature typically studies the case in which decision makers are not told a-priory about the underlying probabilities of the prospects they face, but instead have to learn them from experience. It shows that when people accumulate information on prospects through experience, their risk-taking behavior is different than when they have to react to descriptions of these prospects (Barron & Erev, 2003; Hertwig, Barron, Weber, & Erev, 2004; Newell & Rakow, 2007; Rakow & Newell, 2010). Recent studies show that this difference seems to generalize to tasks in which described options are also experienced (Jessup, Bishara, & Busemeyer, 2008; Lejarrraga & Gonzalez, 2011), and to tasks that involve choice between described sure payoffs and experienced risky options (Hau, Plescak, & Hertwig, 2010).

The current study compares choice between risky and ambiguous options (following the typical studies of preferences for risk and ambiguity), with and without sampling (following the decisions from experience studies that focus on how experience affects risk taking). As such, the current study builds a bridge between the two lines of research. Interestingly, despite the commonalities these literatures share, e.g., people's reactions to different levels of uncertainty, they are studied separately and rarely inform each other. Indeed, to our knowledge the current research is the first attempt to explore the potential relation between experience and ambiguity preferences.

Research on the effect of experience on risk taking has shown that when people sample the outcomes of risky options they behave as if they underweight rare outcomes (Erev, Glozman, & Hertwig, 2008; Hertwig & Erev, 2009; Hertwig et al., 2004; Jessup, Bishara, & Busemeyer, 2008; Ungemach, Chater, & Stewart, 2009). To illustrate, consider a person who samples a prospect that yields a payoff of $1 with probability .1, and 0 otherwise. The rare (in this case desired) outcome of $1 would show only in the minority (10%) of the samples. Thus, sampling such prospect might decrease its attractiveness as it would emphasize that the desired outcome is unlikely. Next consider a gamble that yields $1 with probability .9, and 0 otherwise. The rare outcome in this case is the undesired outcome of getting 0, and the $1 will be present in the majority (90%) of the samples. Thus, sampling this prospect can increase its attractiveness. Applying this finding to our situation we predict that the attractiveness of the sampled ambiguous prospect, relative to a normatively equivalent known-probability risky prospect, increases when the probability of the good outcome is high, and decreases when the probability of the good outcome is low. That is, the experienced-based account of ambiguity attitude predicts the opposite pattern of preference than what is commonly observed in no-sample decisions, where high probability reduces and low probability increases the attractiveness of the ambiguous prospect relative to a normatively equivalent known-probability risky prospect. We test this prediction in Study 1.

Study 1: The Effect of Sampling on Choice between Risk and Ambiguity

We let 2_p0 denote an uncertain prospect that pays a prize of NIS 2 (≈$0.5) with probability p, and zero otherwise. In order to evaluate the effect of sampling on ambiguity attitudes, we study five decision problems with choices between risky prospects 2_p0, with p = .1, .2, .5, .8, and .9, and their equivalent ambiguous prospects. For risky prospects, p is known. For ambiguous prospects, p is unknown.

Method

Fifty six participants were randomly assigned to two experimental conditions. In the "no-sampling" condition, 24 participants made choices between risky and ambiguous prospects based on given descriptions of the two prospects. This replicates the standard procedure used in studies of ambiguity attitude. Table 1 shows the description of the five prospects under risk and ambiguity. Participants were presented with the five decision problems in a random order, indicating for each problem their choice. When they finished marking their choices one problem was selected at random and the selected lottery was played, and paid for real.

In the "sampling" condition, 32 participants also saw the descriptions of the prospects, but could additionally sample the ambiguous prospect before they were asked to make their choice. In particular, participants were told that before making their payoff-relevant choice, there would be a *sampling stage* in which they could sample the ambiguous prospect by clicking on that option as many times they wished (see Figure A1a in the Appendix). Each click generated an independent draw from the relevant distribution (e.g., in problem with p=.9 the sampled outcome was NIS 2 in 90% of the draws and 0 in 10% of the draws). The draws in the sampling stage had no effect on the participant's actual payoff. When they felt they had sampled enough, participants proceeded to the payoff-relevant stage, by clicking a button marked as "real game." In this real-game stage they were asked to make one binding decision between the two prospects for real payoffs (see Figure A1b). This procedure was repeated for all five problems shown in Table 1. The order of the prospects was randomized across participants, and the real game choices were not played out until the end of the experiment when the participants had completed all five problems. Then, one problem was selected at random and the selected lottery in the real game was played, and paid for real. In both conditions, the rewards were added to the participant's show-up fee of NIS20.

Results

The results, presented in Figure 1, show that the choice pattern of participants who sampled the ambiguous prospect was the exact opposite of the choice pattern of participants who could not sample that prospect. The light bars, which show the results of the no-sampling condition, reveal a *negative* relationship between the probability of success and the proportion of choices of the ambiguous prospect ($Z = 5.06$, $p < .01$, random effects probit regression, marginal effect of 1.13% decrease per percentage point of underlying probability). This trend replicates existing findings of ambiguity aversion for moderate and high probabilities, and ambiguity seeking for low probabilities.

Results of the sampling condition, represented by the dark bars in Figure 2, reveal the exact opposite pattern of preferences. This condition reveals a *positive* relationship between the probability of a winning and the proportion of participants preferring the ambiguous prospect (*Z* = 2.69, *p* < .01, random effects probit regression, marginal effect of 0.34% increase per percentage point of underlying probability). Also noteworthy is the elimination of ambiguity aversion under the moderate probability (problem .5) after sampling (p = 0.86, binomial test).

Despite the fact that participants could sample unlimitedly, the median number of samples was only 15, 12.5, 12, 11, and 11 in problems .1, .2, .5, .8, and .9 respectively. Consequently, most participants experienced probabilities that were more extreme than the underlying probabilities. In problems .1 and .2 the observed probability was *lower* than the true underlying probability for most participants (59% and 66%, respectively). In problems .8 and .9, in contrast, the experienced probabilities were *higher* than the true ones for most participants (56% and 59%, respectively).

If participants in the sampling condition chose the ambiguous prospect whenever the experienced probability from sampling is higher than the probability of the matched risky prospect, the observed positive correlation would emerge. To test this proposition, we created a continuous "experienced difference" variable for each participant and each choice problem that is defined as the difference between the observed success probability for the sampled prospect and the known probability of the risky prospect. Adding this variable to the probit regression alongside the underlying probability shows that the larger experienced difference indeed increases the likelihood that the ambiguous prospect is chosen, *Z* = 4.79, *p* < .01, marginal effect 2.28% per percentage point experienced difference. However, the effect of the underlying probability remains significant after including the observed difference, *Z* = 2.41, *p* < .05, .35% per percentage point of underlying probability. Notice that the participants' reliance on the experienced probabilities can also explain the observation that sampling eliminated ambiguity aversion in the moderate (.5) probability condition. As expected, the experienced probability was higher than the objective one for about half (47%) of the participants, and since 75% of the participants' choices corresponded to their experienced difference, no ambiguity aversion was observed at the aggregate level.

If we calculate how often the observed frequency matches the choice behavior in normative terms (i.e., observing a frequency larger (smaller) than the known probability should imply choice of the ambiguous (risky) prospect), we find matching percentages between 53% and 81% for the five prospects. Interestingly, better matching is not clearly correlated with the length of the sampling experience in our data.

Discussion

The results show that sampling the ambiguous prospect completely reverses the traditional pattern of ambiguity attitude. People who make one-shot decisions between descriptions of risky and ambiguous prospects exhibit ambiguity seeking under low probabilities of success, and ambiguity aversion under high probabilities of success. Yet people who sample the ambiguous option, exhibit ambiguity aversion with low probabilities, ambiguity "neutrality" with moderate probabilities, and ambiguity seeking with high probabilities. These results support our hypothesis that ambiguity preferences after sampling are affected by a tendency to underweight low probability events. Indeed, we found evidence that the (biased) sample observed by a person explains a significant part of the variance in the choice behavior.

However, we cannot tell from the results whether the effect of sampling on choice merely reflects probability updating, or whether it might include additional processes. For an example consider people's behavior under the moderate .5 probability in Study 1. Recall that under this probability people exhibit strong ambiguity aversion without sampling, and ambiguity neutrality after sampling. To what extent could this difference be attributed to updates of probability beliefs? If people believe a priory that the probability of the valuable outcome in the ambiguous option is lower than .5 then they might exhibit ambiguity aversion. Then, if during sampling they realize that the valuable outcome occurs in 50% of the time they may update their prior belief and consequently become indifferent between the two options. Such an observation would suggest that the effect of sampling could be fully captured by probability updating. However, if probability beliefs would not match behavior then other process are probably in play as well. That is, if most people assign a prior probability of .5 to the ambiguous option, although they exhibited ambiguity aversion in Study 1, then their behavior could not be explained by mere probability beliefs. Rather, it would possibly reflect other considerations such as the motivational need for justification (e.g., Curley, Yates, & Abrams, 1986). Similarly if they do not assign a probability of .5 after sampling then their "ambiguity neutrality" in this case reflects more than belief updating according to the observed probability. Thus, to better understand the extent to which sampling affects behavior through probabilistic updating in the current context of comparing risky and ambiguous options, we designed a second study where we directly elicit these probabilistic beliefs.

Study 2: Is the effect of sampling driven by changes in beliefs about the underlying event probability?

Study 2 considers the same set of prospects as in Study 1, but instead of analyzing choices between risky and ambiguous prospects, we focused on participants' beliefs about the probability of the ambiguous prospect. Assume that the preference reversal shown in Study 1 is mostly driven by the decision maker's biased probability judgments, due to under-sampling of rare events. If this is the case then after short sampling experience we expect too optimistic beliefs under high probability of success (p=.8 and p=.9), and too pessimistic beliefs for low probability of success (p=.1 and p=.2). Study 2 tests this hypothesis.

Method

Thirty-two new participants were recruited for this study. Each participant was presented with the five decision problems described in Table 1. Because people are usually better in making frequency judgments than in making probability judgments (Hoffrage, Lindsey, Hertwig, & Gigerenzer, 2000), we chose to describe the two prospects as two decks of cards and derived the probability estimations in terms of card frequencies. For example, in problem .9 participants saw two card decks on the screen: a (risky) deck that included 90 green cards and 10 white cards, and another (ambiguous) deck that included 100 green or white cards, with exact numbers of each color unknown. The participants were then asked to estimate the frequency of the green cards in the ambiguous deck twice: once before they sampled the deck, and once after they finished sampling the deck. The elicited estimates before sampling were collected to test if beliefs of the ambiguous deck were (1) influenced by the known probability of the risky deck, and (2) if participants' beliefs of the ambiguous option were generally biased away from 50% in an optimistic or pessimistic way. The estimates elicited after sampling indicate the updated beliefs that would form the basis of a decision after short sampling experience. Participants were paid according to their accuracy in their estimations using the quadratic deviation rule *payment = 4*[1–(true probability–estimated probability)²]*. At the end of the study one of the 10 estimations was randomly selected to determine the final compensation.

Results

The true (objective) probabilities, the observed frequencies, and the estimated probabilities of drawing a green card in each problem are depicted in Figure 2. The average estimated probability before sampling was .52 (Sd =.072), and did not differ between problems, $F(4, 159) = 1.07$, $p = .37$, or deviate from .5, $t(160) = 1.21$, $p = .22$.

After sampling, the estimated probabilities shifted toward the observed frequencies (proportion of green cards observed during sampling). To show this we subtracted the former from the latter creating a "correspondence score." Note that positive scores imply overestimation of the experienced probability and negative score implies underestimation. The correspondence scores were 0.21 in problem 0.1, $t(31) = 3.14$, $p = .0037$; 0.15 in problem 0.2, $t(31) = 2.69$, $p = .0115$; -0.01 in problem 0.5, $t < 1$; -.08 in problem 0.8, $t(31) = -3.13$, $p = .0037$; and -.13 in problem 0.9, $t(31) = -2.65$, $p = .0126$. Those values imply overestimations of the low probabilities, an accurate estimation of the 0.5 probability, and underestimations of the high probabilities. In other words we find that, contrary to our expectations, subjective probabilities were significantly *less* extreme than the observed probabilities (and, as Figure 2 shows, they are also less extreme than the objective probabilities).

Discussion

The results show that, based on the description of ambiguous prospects with two possible outcomes, the average participant gives probability estimates close to 50%. These estimates are not affected by the probability of the matched risky prospect. Note that these subjective beliefs explain the typical pattern of ambiguity seeking for low probability risky prospects and ambiguity aversion for high probability risky prospects, in decision from description. The data thus support Einhorn and Hogarth's (1986) regressive model of ambiguity attitude. Importantly, however, the unbiased belief for the .5 probability suggests a strong motivational component of ambiguity aversion for moderate probabilities that is not driven by probabilistic beliefs. Another indication for such component comes from the observation that, in Study 1, ambiguity aversion under high probabilities is stronger than ambiguity seeking under low probabilities ($t(23) = 2.94$, $p = .007$; for the differences in deviation from neutrality in problems .1 and .2 versus in their reflected problems .8 and .9).

Given these observations the ex-post beliefs provide evidence against a direct probability estimate pathway explaining the preference reversal shown in Study 1. There is clearly no overshooting in the probability estimates for the extreme probabilities. Moreover, assuming that there is a strong motivational component in ambiguity attitude, such overshooting would have to be strong to overcome the negative aspects in the evaluation of ambiguous prospects for medium and small probability prospects. There is no evidence for that in our data. In addition, although for the p=.5 prospect there is a clear sampling effect in Study 1, i.e., shifting preferences from strong ambiguity aversion towards ambiguity neutrality, no biased subjective probabilities in the .5 condition are observed in Study 2. This observation suggests that ambiguity aversion under the .5 probability does not result from a pessimistic belief regarding the proportion of valuable cards in the ambiguous deck.

General Discussion

Allowing decision makers to collect short sampling experience, we found a complete reversal of the well established pattern of ambiguity preference in decisions from description (the classic studies of ambiguity preferences). Eliciting subjective beliefs after sampling, we find that this reversal cannot be explained by mere updating of probability judgments from extreme outcomes after short samples. That is, the choice pattern is not implied by the explicit judgments from sampling. Although surprising, this judgment-choice gap in ambiguity preferences is consistent with recent studies of choice between risky assets, which found that probability judgments of rare events did not correspond to the behavioral patterns of choice (Barron and Yechiam, 2009). These findings suggest that the effect of rare events on experience may reflect other processes, in addition to the explicit updating of event probabilities. We propose two such processes, one based on motivational changes and one based on the effect of biases in the processing of random samples.

Although a sample may reduce the ambiguity of the unknown-probability option to some extent, this option will always remain ambiguous relative to the known-probability risk. The general upward shift for ambiguity preference therefore suggests motivational changes which are caused by sampling experience. This shift could be modeled in a prospect theory framework through changes in the weighting of probabilistic beliefs in the ambiguous event (Wakker, 2004; Wakker, 2010). In particular, while ambiguous prospects are typically associated with *pessimistic* weighting, sampling might induce more *optimistic* weighting and thus an overall upward shift in ambiguity preference. Additionally, while ambiguity is typically associated with likelihood *insensitivity*, sampling might increase likelihood *sensitivity*, and could lead to decision weights that are more extreme than the observed beliefs. Jointly, these two effects can explain the general upward shift of ambiguity preference under sampling, and the reversal in preference between low and high probabilities.

Another potential explanation for the differences in our studies could relate to a processing effect. Asparouhova, Hertzel, and Lemmon (2009) who found that gambler's and hot-hand fallacies often jointly exist in the processing of random processes. In the current study, people made a decision based on a random draw from a process *after* a series of samples. Thus, while their explicit probability estimates in Study 2 may consider the whole sample, choices may reflect their expectations for the *next* draw from the random process. Here hot hand effects may be strong even after larger samples, explaining why longer samples did not lead to stronger correlation between observed frequency and choice behavior. Obviously, longer streaks are more common in the extreme probability events, leading to ambiguity preference for high probability events and ambiguity avoidance for low probability events.

Both the motivational and the processing effects are consistent with recent research in the domain of risky choice that shows that different process models are necessary to explain decisions from description and from sampling (Erev et al., 2010). One of the interesting features of choice between ambiguous and risky alternatives is that it combines aspects from description based choice (some information is available), and from experienced based choice (other information is absent and could be learned). While such a “mixed domain” seems ecologically valid in many decisions we make, and implies an interesting set of theoretical questions, it has not received as much attention yet as the “pure domains” of description or experience. The current study provides the first step: it shows that experience does have a large impact on ambiguity preferences, and provides a first look into the process showing how the observed outcomes during sampling affect people’s choices between risk and ambiguity.

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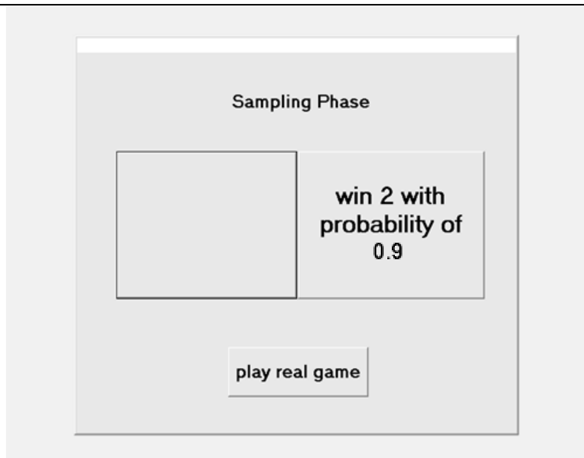
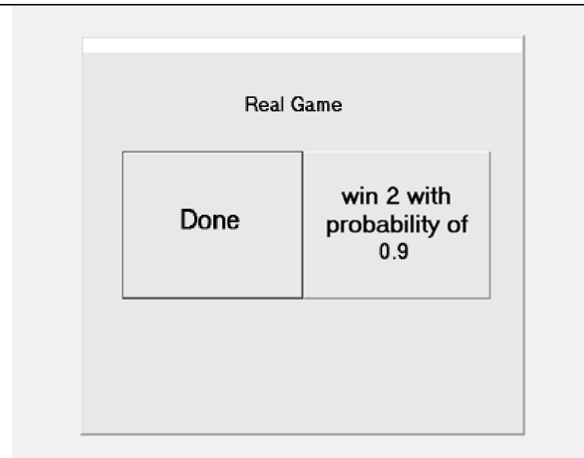
APPENDIX

Figure A1. The experimental screens in Study 1.

<table>
<tr><td>a. “Sampling” stage</td><td>b. “Real game” stage</td></tr>
<tr><td>

The left key represents the ambiguous prospect (identical to the described prospect on the right key), each click on this key initiates an independent draw from its distribution. The bottom key ends the sampling stage, starting the decision (real game) stage.</td><td>

In this example the participant selected the ambiguous (blank) key. The computer marks this choice by writing “Done” on the selected key so the participant knows that her choice was recorded. At the end of the study one problem was selected randomly and paid according to the participant’s choice and its realization.</td></tr>
</table>

Note: The decision problem presented in this example is problem .9.

Table 1. Description of risky and ambiguous prospects in Study 1.

Problem	Description of the risky prospect	Description of the ambiguous prospect
.1	You receive NIS2 with probability .1	You either receive NIS2 or nothing; the probability of winning the NIS2 is unknown.
.2	You receive NIS2 with probability .2	
.5	You receive NIS2 with probability .5	
.8	You receive NIS2 with probability .8	
.9	You receive NIS2 with probability .9	

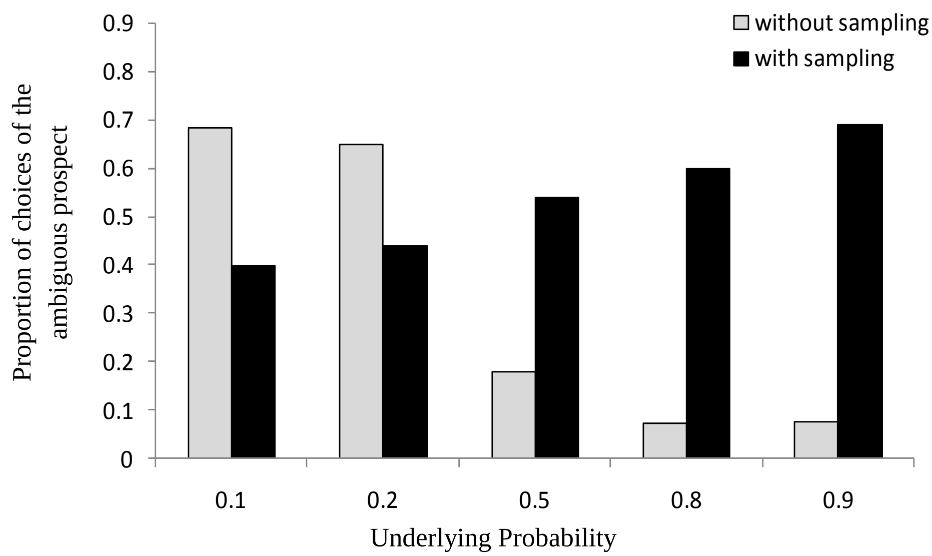


Figure 1. The proportion of choices favoring the ambiguous prospect over the risky prospect in Study 1.

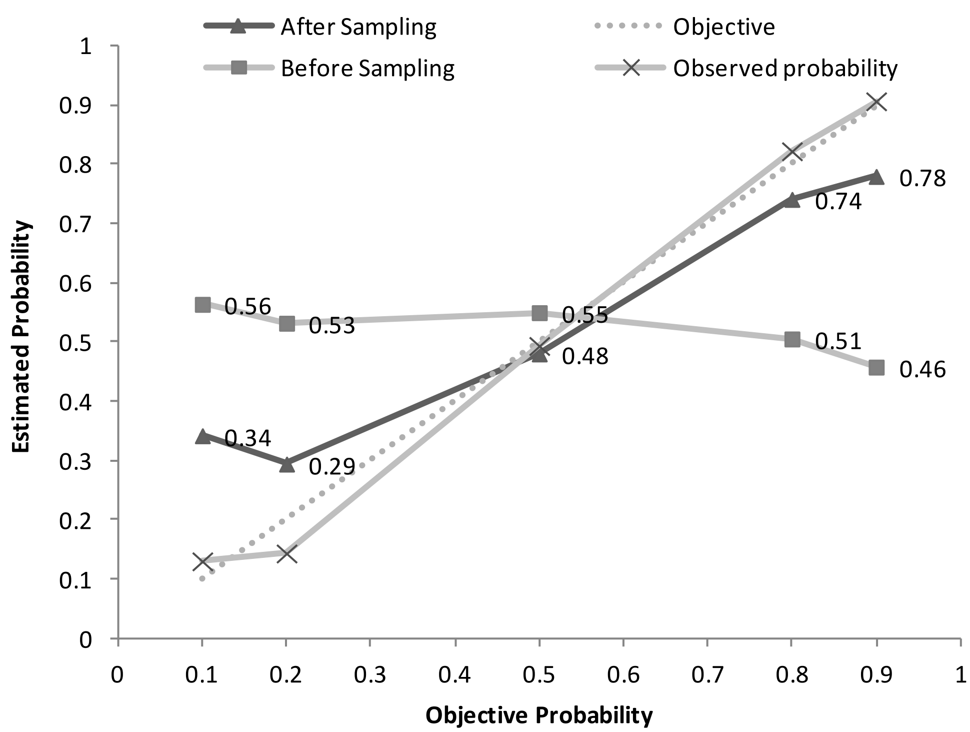


Figure 2. Subjective estimates of the probability of drawing a green card from the ambiguous deck before and after sampling.