

The role of forgone opportunities in decision making under risk

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Abstract We present two experiments designed to study the role of forgone opportunities in decision making under risk. In the first one, we face individuals with a dynamic environment in which their decisions, together with chance, determine their future options. We find that previously faced opportunities influence subsequent choices in predictable ways. Having faced worse options in the past significantly increases individuals' risk aversion and having faced better options reduces it. These patterns are at odds with most existing decision theories, including Expected Utility Theory and standard implementations of Prospect Theory, the dominant models of economic decision making. In our second experiment, we present participants with a similar decision environment, but in which the opportunities they face do not depend on their past choices. The effect of previously faced options on decision behavior in this environment is considerably reduced. This shows that being responsible for forgoing opportunities is an important factor in their influence on behavior, which underscores the relevance of emotions linked to counterfactual thinking, like regret or satisfaction. These results highlight that theories formulated in cognitive terms are not enough to provide an adequate account of the role of forgone opportunities in decision making under risk and uncertainty.

Keywords Decision making under risk · Path-dependence · Reference-dependence · Counterfactual thinking · Emotions

JEL Classifications C91 · D03 · D81

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1 Introduction

It seems intuitively apparent that the opportunities we forgo affect our evaluation of the options currently available to us. A good example of this is that individuals constantly evaluate their outcomes relative to ‘what might have been’. Interesting cases of this kind of behavior can be found in the literature on counterfactual thinking. For instance, Medvec et al. (1995) showed that silver medalists are generally less happy with their results than bronze medalists. Silver medalists seem to feel closer to the opportunity of getting gold and compare their outcome with it. On the other hand, bronze medalists feel closer to the option of finishing without a medal and compare their achievement with that. These counterfactuals do not affect at all the actual outcomes of the athletes, but they determine how they are perceived and evaluated.

Along the same lines, Kahneman and Tversky (1982) faced people with the hypothetical situations of two travelers who missed their flights due to a traffic jam. One of them missed the flight by 30 minutes and the other by only 5 minutes (because his flight had been delayed for 25 minutes). The authors show that people evaluate the second situation significantly more negatively than the first one. Although the actual outcome to be evaluated is the same in both situations (missing the flight), the opportunity of having arrived on time seems closer in the second case and, consequently, it generates a stronger positive counterfactual that affects negatively the evaluation of the actual outcome. Other interesting illustrations of the effects of counterfactual thinking can be found, for example, in Johnson (1986), Kahneman and Miller (1986), Medvec and Savitsky (1997), or Epstein and Roesch (2008) (see Roesch and Olson 1995 for a review).

In a related line of research, on the phenomenon known as ‘inaction inertia’, it has been shown that missing an initial attractive opportunity decreases the likelihood of acting subsequently on a similar, but less attractive, option (see, e.g., Tykocinski et al. 1995; Tykocinski and Pittman 1998; Zeelenberg et al. 2006). Inaction inertia has been linked in the literature to the avoidance of counterfactual regret (see, e.g., Tykocinski and Pittman 1998). Some authors, however, have claimed that the phenomenon occurs for different causes, like a devaluation of the later opportunity produced by facing the initial and more attractive one (see Zeelenberg et al. 2006).

Despite these ideas and the related evidence, almost all existing theories of decision making under risk and uncertainty assume that the evaluation of the options available to the decision maker is independent of previously faced opportunities (unless those opportunities affect the decision maker’s asset position). This is certainly an assumption in Expected Utility Theory, EUT (von Neumann and Morgenstern 1947), and in standard implementations of Prospect Theory, PT (Kahneman and Tversky 1979; Tversky and Kahneman 1992), the dominant models of economic decision making. Other prominent theories that operate under this assumption include, for example, Rank-Dependent Utility Theory (Quiggin 1982), Regret Theory (Bell 1982; Loomes and Sugden 1982), the Transfer of Attention Exchange (TAX) model (see Birnbaum 2008), Decision Field Theory (Busemeyer and Townsend 1993), and most choice heuristics (see, e.g., Brandstatter et al. 2006).

In this paper, we present two experiments designed to study the role of forgone opportunities in decision making under risk. In Experiment 1, we face participants with a dynamic decision environment in which their choices between risky monetary alternatives, together with chance, determine their future options. We use that

environment to show that previously faced opportunities affect subsequent decisions in predictable ways. Namely, having faced worse options in the past significantly increases individuals' degree of risk aversion and having faced better options reduces it.

These patterns are in line with some past evidence on the effects of previously faced risks and choices on subsequent decision behavior (e.g., Cubitt et al. 1998; Busemeyer et al. 2000; Cubitt and Sugden 2001; Post et al. 2008), and they are at odds with most existing decision theories. We discuss two alternative theoretical approaches that could be used to accommodate these findings. The first one involves adopting a reference-dependent approach in which the reference point is determined by expectations influenced by previously faced options. In the second approach, the feeling of regret produced by having missed better opportunities decreases the perceived value of current options. Likewise, the feeling of satisfaction produced by having forgone worse opportunities increases the perceived value of present alternatives.

These two theoretical approaches can be linked to different strands of research found in the literature (which will be reviewed in detail in Section 3). The first one corresponds to a few recent models in decision theory and behavioral economics, in which the influence of previous options is formulated in mostly cognitive terms. In those models, previous circumstances establish a cognitive benchmark or expectation that acts as a reference in the evaluation of subsequent options. The feelings or emotions that past options generate and how they affect decision making are not part of these theories. On the other hand, the second approach comes mostly from psychological research on emotions related to counterfactual thinking, which is usually not taken into account when analyzing decision making under risk and uncertainty.

In Experiment 2, we investigate a crucial element that differentiates between these theoretical accounts, namely the role of emotions linked to being responsible for the missed opportunities, like regret and satisfaction. We present participants with a decision environment analogous to the one used in Experiment 1, but we eliminate subjects' role in missing previous opportunities. Our results show that once subjects' responsibility is eliminated, the effect of previously faced opportunities on decision behavior is considerably diminished. This suggests that emotions like regret and satisfaction, involved in counterfactual thinking and linked to being accountable for missed opportunities, are an important aspect in the influence of forgone options on decision behavior. Consequently, a theory of forgone opportunities set out in purely cognitive terms is unlikely to adequately capture their role in decision making under risk.

Overall, these findings have wide-ranging implications for theories of economic and financial decision making under risk and uncertainty, and also important potential applications.

The rest of the paper is organized as follows. In Section 2, we present Experiment 1. In Section 3, we discuss the proposed theoretical accounts that could accommodate the findings of the experiment and their relationship to the relevant literature. In Section 4, we present Experiment 2. In Section 5, we discuss the general conclusions of the paper.

2 Experiment 1

The main goal of Experiment 1 was to face individuals with a controlled decision environment that was both risky and dynamic, in which the choices they made

(together with chance) determined the options available to them in the future. Behavior in that environment was then used to produce transparent tests of the influence of forgone opportunities on decision making under risk.

2.1 Method

2.1.1 Design and procedure

We designed an individual computerized game, which revolved around two different types of assets; one type pays €100 and the other €0.¹ Five assets of each type were involved in the game (ten overall). The different assets were represented by translucent numbered boxes displayed on the screen in two separate columns, labeled as good boxes, containing €100, and bad boxes, containing €0 (see screenshot in Fig. 1). The game consisted of a series of rounds, in which participants had to choose between a sure amount of money offered to them and progressing to the next round. Each time a subject chose to progress to the next round, one of the remaining assets was automatically lost (i.e., removed from the game by the computer) and the next offer was made. If the participants rejected all the sure amounts of money offered to them throughout the game, they ended up getting the final remaining asset as a payoff. So, the game consisted of a maximum of nine decisions between a sure sum of money and progressing to the next scenario. At the end of the game, subjects were actually paid their corresponding prizes.

The sure amounts offered to the participants followed always a fixed rule, which was 80% of the average value (AV) of the remaining assets. This rule, together with the rest of the game, was thoroughly explained at the beginning of the experimental sessions, and the AV and 80% of the AV of the outstanding assets were always clearly displayed on the screen.² Moreover, the percentages of remaining good and bad boxes were shown at all times on the screen too. After each decision, the participants received additional information on the amounts rejected and the assets lost thus far.

In essence, the game created a dynamic decision environment in which subjects faced opportunities, in the form of sums of money, and those opportunities changed as a function of subjects' choices and chance.

Additionally, to attain a clear picture of the role of forgone opportunities, we needed to generate transparent comparison points in which participants reached exactly the same decisions but having faced different opportunities. To achieve that, we predesigned eight different elimination sequences of good and bad boxes and assigned subjects randomly to them. Each elimination pattern of good and bad boxes was presented under different box-number successions to different subjects. All the sequences were designed to extend over the maximum of nine possible decisions, reaching a standardized final round in which participants faced the same choice between a sure amount of €40 and a 50/50 chance of getting either €100 or €0. The box removed in that last round, and consequently the payoff received by the participants who did not accept any of the offers, was randomly selected by the computer. In

¹ The experiment was programmed using Z-Tree, developed by Fischbacher (2007) at the University of Zürich.

² Written instructions are available from the authors upon request.



Fig. 1 Screenshot from the game

this respect, we simply told subjects that the boxes to be eliminated were randomly determined.

As shown in Table 1, in sequences 1 and 2 (S1 and S2), the elimination of good and bad boxes was alternated, starting with a good box in S1 and with a bad box in S2. In S3 and S4 two eliminations of the same kind were alternated with two of the other, starting with good boxes in S3 and with bad boxes in S4. S5 and S6 consisted of three eliminations of the same type followed by three of the other, plus two alternated boxes at the end. S5 began with good ones and S6 with bad ones. In S7 and S8, four eliminations of the same kind were followed by four of the other, starting with good boxes in S7 and with bad ones in S8.

So, in all the odd-numbered sequences, subjects always faced offers lower or equal to the initial and final €40, which reached lower levels as the number of the sequence increased. In the even-numbered sequences, participants always faced offers higher or equal to €40, which got to higher levels in higher-numbered sequences.

The structure of the sequences provided several transparent comparison points, in which subjects faced exactly the same choices but having forgone different opportunities. It is especially interesting that all the subjects who rejected the previous offers and got to the final round reached the same decision, but following markedly different paths depending on the sequence.

It is interesting to note that our decision environment shared some important similarities with the ‘Deal or No Deal’ TV game show (see Post et al. 2008). However, we created a fully controlled experimental environment that allowed for transparent tests of the influence of previous opportunities on decision making under

Table 1 Structure of the 8 sequences^{a, b}

	Round	1	2	3	4	5	6	7	8	9
S1	Offer	40	35.56	40	34.29	40	32	40	26.67	40
	Box removed	G	B	G	B	G	B	G	B	Random
S2	Offer	40	44.45	40	45.72	40	48	40	53.34	40
	Box removed	B	G	B	G	B	G	B	G	Random
S3	Offer	40	35.56	30	34.29	40	32	20	26.67	40
	Box removed	G	G	B	B	G	G	B	B	Random
S4	Offer	40	44.45	50	45.72	40	48	60	53.34	40
	Box removed	B	B	G	G	B	B	G	G	Random
S5	Offer	40	35.56	30	22.86	26.67	32	40	26.67	40
	Box removed	G	G	G	B	B	B	G	B	Random
S6	Offer	40	44.45	50	57.15	53.34	48	40	53.34	40
	Box removed	B	B	B	G	G	G	B	G	Random
S7	Offer	40	35.56	30	22.86	13.34	16	20	26.67	40
	Box removed	G	G	G	G	B	B	B	B	Random
S8	Offer	40	44.45	50	57.15	66.67	64	60	53.34	40
	Box removed	B	B	B	B	G	G	G	G	Random

^a G=Good box (€100); B=Bad box (€0)

^b In colored versions, red color designates offers under €40; blue color offers above €40

risk. So, our choice environment was defined by some key features not present in the Deal or No Deal game, for instance: transparent and controlled comparison points in which participants face exactly the same choices, a predefined dynamic environment with a fixed rule to generate the choice options, and individual and private decisions.

2.1.2 Participants

A total of 265 university students participated in Experiment 1 (between 30 and 36 per sequence). It was organized in 8 identical sessions that lasted about one hour each.

2.2 Results and discussion

To begin with, Table 2 shows a comprehensive descriptive summary of the results obtained in Experiment 1. The leftmost column contains the number of subjects facing each particular sequence. The rightmost column displays the number of participants remaining in the final round, that is, the number of individuals who rejected the previous offers and got to the final decision between €40 and a 50/50 chance of €100 or €0. The third row for each sequence shows the percentage of remaining subjects accepting the sure offer in each round. The information in Table 2 completely characterizes the behavior displayed by participants in the game. In other words, the original data set can be completely reconstructed from Table 2.

As the table shows, between 11% and 23% of the subjects, depending on the sequence, accepted the initial offer of €40 and stopped playing in the first round;

Table 2 Descriptive summary of results (Experiment 1)

	Round	1	2	3	4	5	6	7	8	9	<i>n</i> last round
S1	Offer	40	35.56	40	34.29	40	32	40	26.67	40	16
<i>n</i> =36	Box rem.	G	B	G	B	G	B	G	B	Random	
	% accept.	11.11	3.13	9.68	7.14	7.69	8.33	22.73	5.88	75	
S2	Offer	40	44.45	40	45.72	40	48	40	53.34	40	13
<i>n</i> =35	Box rem.	B	G	B	G	B	G	B	G	Random	
	% accept.	22.86	14.81	0	8.7	0	14.29	5.56	23.53	30.77	
S3	Offer	40	35.56	30	34.29	40	32	20	26.67	40	13
<i>n</i> =35	Box rem.	G	G	B	B	G	G	B	B	Random	
	% accept.	11.43	3.23	13.33	3.85	24	0	21.05	13.33	61.54	
S4	Offer	40	44.45	50	45.72	40	48	60	53.34	40	13
<i>n</i> =34	Box rem.	B	B	G	G	B	B	G	G	Random	
	% accept.	17.65	0	17.86	0	8.7	19.05	23.53	0	38.46	
S5	Offer	40	35.56	30	22.86	26.67	32	40	26.67	40	8
<i>n</i> =32	Box rem.	G	G	G	B	B	B	G	B	Random	
	% accept.	15.63	3.7	3.85	16	4.76	20	25	33.33	50	
S6	Offer	40	44.45	50	57.15	53.34	48	40	53.34	40	10
<i>n</i> =32	Box rem.	B	B	B	G	G	G	B	G	Random	
	% accept.	15.63	3.7	11.54	13.04	10	0	16.67	33.33	30	
S7	Offer	40	35.56	30	22.86	13.34	16	20	26.67	40	15
<i>n</i> =31	Box rem.	G	G	G	G	B	B	B	B	Random	
	% accept.	22.58	0	4.17	0	4.35	0	13.64	21.05	46.67	
S8	Offer	40	44.45	50	57.15	66.67	64	60	53.34	40	7
<i>n</i> =30	Box rem.	B	B	B	B	G	G	G	G	Random	
	% accept.	20	4.17	30.43	12.5	14.29	33.33	0	12.5	42.86	

between 23% and 48% of the participants got to the final round; and between 30% and 75% of the subjects who faced the final round accepted the last offer. If we assume for instance, just to illustrate, EUT and the widely-used utility function $u(x) = x^{1-r}/(1-r)$, with constant relative risk aversion, the risk aversion coefficient that makes subjects indifferent in the final round between the €40 and the 50/50 chance of €0 or €100 is $r = 0.24$. This means that, under those assumptions, between 30% and 75% of the subjects, with an average of 46.91%, show a risk aversion coefficient greater than 0.24 in the last round. These figures are broadly consistent with previous elicitations of risk attitudes in the literature under the indicated utility function (see, e.g., Holt and Laury 2002).

Let us now focus on the main issue of how the rates of acceptance are affected by the opportunities faced by subjects during the game, making use of the transparent comparison points generated by the design. The small number of participants accepting the sure offer in each particular round makes it difficult to get statistically significant results by comparing only single sequences to each other. However, in some rounds, especially in the final one, it is straightforward to group sequences together in a

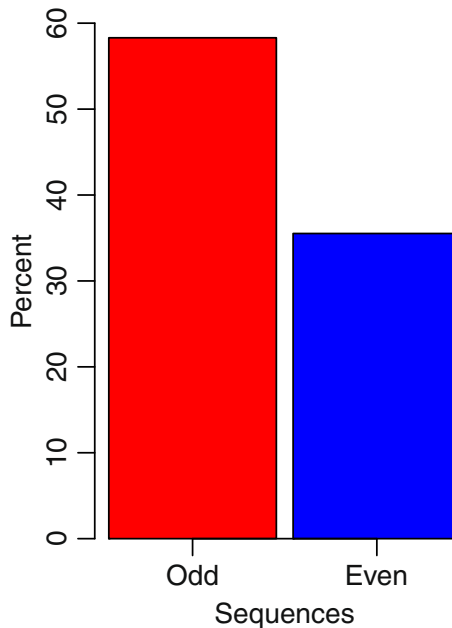
meaningful way to get stronger and clearer results. In what follows, we focus primarily on the final round, where all the sequences get to exactly the same choice but having followed different paths. This provides a common transparent comparison point and it allows for the grouping of sequences.

One clear pattern emerges out of that final stage. Namely, all the sequences in which subjects faced only offers lower than or equal to €40 (the odd-numbered sequences) show higher percentages of acceptance, or in other words higher degrees of risk aversion, than the sequences in which participants faced offers higher than or equal to €40 (the even-numbered sequences). In the odd-numbered sequences, the percentages of acceptance range from 47% to 75%, whereas in the even-numbered sequences they range from 30% to 43%. As Fig. 2 depicts, the difference between the means of the two groups of sequences is 23%.

Note also that this pattern repeats itself in all the transparent comparison points of the game, which include as well round 3 for sequences 1 and 2, round 5 for sequences 1 to 4, and round 7 for sequences 1, 2, 5 and 6. In all those points, the odd-numbered sequences display higher rates of acceptance than the even-numbered ones, with only the exception of sequence 1 in round 5, which shows a percentage slightly below the highest even-numbered one.

The statistical significance of these results is verified by a Fisher's exact test comparing odd-numbered and even-numbered sequences in the final round ($p=0.02$). In other words, the sequences in which subjects faced offers below or equal to €40 show significantly higher acceptance rates (or degrees of risk aversion) in the final round than the ones in which participants faced offers above or equal to €40. A Fisher's exact test comparing the proportions shown by odd-numbered and even-numbered sequences in the first round ($p=0.41$) confirms that the observed differences do not come from differences in the initial samples, but are a consequence of the path followed

Fig. 2 Average percentage of acceptance in the final round in odd-numbered and even-numbered sequences (Experiment 1)



by the subjects in the game. The opportunities that the participants forgo are the only difference between the two groups of sequences at the transparent comparison point provided by the final round.

Table 3 shows a logistic regression analysis that provides further insight into this pattern of results. Two separate regressions are presented. First, the probability of acceptance in the final round is regressed on the group of sequences (odd versus even), the average offer received in each particular sequence, and the interaction between these two variables. Note that the average offer received completely identifies each individual sequence. Within the odd-numbered sequences, offers reach lower levels as the number of the sequence increases; within the even-numbered sequences, offers reach higher levels as the number of the sequence increases. To make the regression results more meaningful once the interaction term is introduced, the two main variables are standardized, subtracting the mean and dividing by the standard deviation. To check for consistency, a second regression is presented without the interaction term and without standardizing the variables.

The results obtained in the logistic regression analysis are clear-cut and in line with what has been presented so far. Namely, the probability of acceptance in the final round is significantly higher among the subjects who have previously faced offers below or at €40 (odd-numbered sequences) than among the ones who have faced offers above or at €40 (even-numbered sequences). The variable representing the specific average size of the offers is not found to be significant, either generally (see main variable) or within any of the subgroups (see interaction).

A potential concern with these results could be that the fact of facing different offers in the odd-numbered and even-numbered sequences produces a self-selection of subjects, so that less risk averse individuals get to the final round in the even-numbered sequences. Such a pattern could undermine the validity of our results, because it would go in the same direction of having lower acceptance rates in the even-numbered sequences. Two different aspects rule out this idea. First, the proportion of people getting to the final round in odd-numbered and even-numbered sequences is not significantly different (Fisher’s exact test, $p = 0.37$). This makes it very difficult to argue that the significant difference observed in the final decisions is a consequence of subjects’ self-selection. Second, Fig. 3 illustrates how, from a theoretical point of view,

Table 3 Logistic regression results for probability of acceptance, final round (Experiment 1)

Variable	Coef.	SD	Z value	P value
odd-even (oe)	-2.271	1.092	-2.080	0.038
average offer (ao) ^a	0.994	0.640	1.552	0.121
oe*ao	-0.568	1.052	-0.539	0.590
Intercept	1.220	0.617	1.980	0.048
odd-even (oe)	-2.459	1.036	-2.373	0.0177
average offer (ao)	0.098	0.063	1.556	0.1198
Intercept	-2.766	2.043	-1.354	0.1757

^a The variable ‘ao’ has been standardized in this specification, subtracting the mean and dividing by the standard deviation

the even-numbered sequences should tend to produce a selection of more (not less) risk averse subjects than the odd-numbered ones, which would result in the opposite pattern to the one observed. A key aspect here is that, when participants face a higher offer, this is always linked to a higher expected value of going on in the game and a lower likelihood of getting €0 if the subject continues. Consequently, it does not follow that rounds with higher offers should make more risk averse subjects accept more. As Fig. 3 shows, the tendency is actually in the opposite direction.

Figure 3 is constructed by taking EUT with a power utility function, $U(x)=x^r$, as a simple structure to capture degrees of risk aversion and plotting the difference between the value of the sure offer and the value of going on in the game for a range of risk aversion parameters r . This is done for each sequence, in 9 separate graphs, and for each round, which results in 9 different curves per graph. Note that $r < 1$ implies risk aversion, $r = 1$ risk neutrality, and $r > 1$ risk seeking. Higher values of r mean always lower degrees of risk aversion. The point where the curves cross the horizontal zero line represents the point of indifference. For the risk aversion parameters to the left of that point, the sure offer is preferred; for the parameters to the right, the option to go on in the game is preferred. The black solid curve in each sequence is the one for the final round, which is identical in all the sequences.

In the odd-numbered sequences, the curves for the first eight rounds cross the zero line further to the right than in the even-numbered sequences. This implies that in the odd-numbered cases there should be subjects with lower degrees of risk aversion who accept offers before the final round. Therefore, the tendency according to this standard theoretical structure would be, if anything, to have less risk averse individuals in the final round in the odd-numbered sequences than in the even-numbered ones. We do not

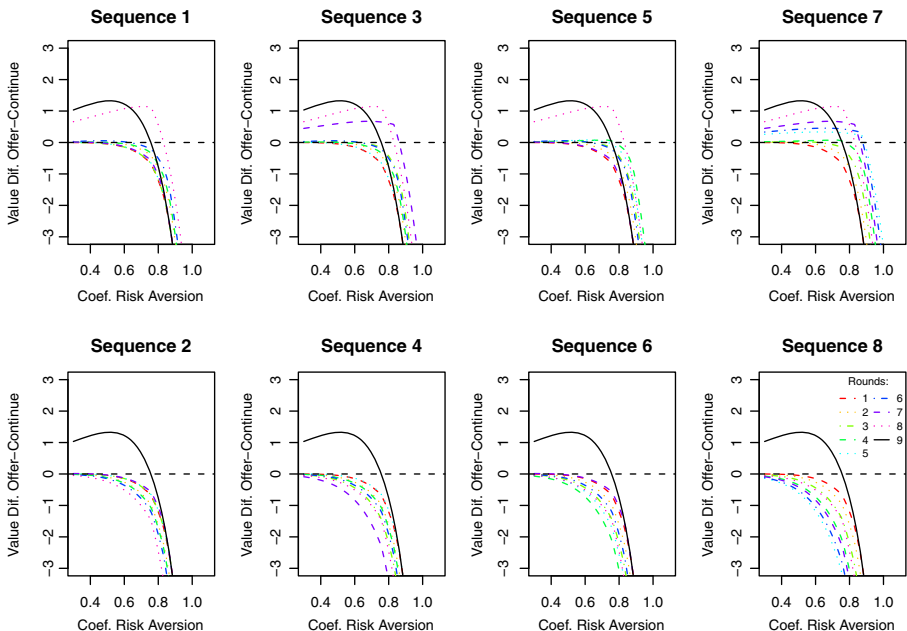


Fig 3 Theoretical illustration of offer acceptance depending on degrees of risk aversion, by sequence and by round

claim at all that subjects' preferences follow such a theory in our set-up. The purpose of Fig. 3 is to show that our design does not imply that odd-numbered sequences should lead to having more risk averse subjects in the final round.

Overall, the results of Experiment 1 show that forgone opportunities play a significant role in decision making under risk. These results are in line with some past findings on the effects of previously faced circumstances on decision behavior. For instance, Cubitt et al. (1998) showed that the principle of 'timing independence' was systematically violated in the context of an experiment about the 'common ratio effect'. Timing independence requires that, if individuals are asked to pre-commit to a choice to be made after a prior act of nature (e.g., playing out a gamble), they should pre-commit to the same option that they would choose if they would make their choice after the act of nature. Similar findings were obtained by Busemeyer et al. (2000). Cubitt and Sugden (2001) used 'accumulator gambles' to show that people violate the standard principles of dynamic choice theory. In Post et al. (2008), the authors analyzed a large dataset from the Deal or No Deal TV game show and concluded that the path followed by participants in the show had a significant influence on their decision behavior.

Our Experiment 1 provides additional evidence on the relevance of previously faced situations in decision making under risk in a new and more complex experimental environment with high payoffs at stake. In the next section, two different theoretical accounts for our findings are discussed, and a crucial distinction between them is then tested in Experiment 2.

3 Theoretical accounts

In this section, we describe two different theoretical approaches that can account for the influence of forgone opportunities on decision making under risk observed in Experiment 1. The first is derived from the reference-dependent approach to individual preferences, and it is mostly cognitive in nature. The second is based on the influence of experienced emotions, like regret and satisfaction, on decision making.

3.1 The reference-dependent approach

Reference-dependent approaches to individual preferences have achieved widespread popularity in decision science, especially since the popularization of Prospect Theory (PT). In general, reference-dependent theories are based on the idea that outcomes are evaluated relative to some relevant reference point. Despite the success of this approach, the crucial issue of how relevant reference points are determined remains understudied and largely unresolved. Most researchers have simply implemented reference-dependent models under the virtually untested assumption that the reference point is the current asset position (or status quo) in the relevant evaluation domain. It should be noted, however, that although Kahneman and Tversky (1979) suggested current asset position as a relevant aspect of reference points and based most of their analyses on it, this assumption is not really a constituent part of PT. Indeed, the authors explicitly state that "there are situations in which gains and losses are coded relative to an expectation or aspiration level that differs from the status quo" (p. 286).

Going back to Experiment 1, it is apparent that standard reference-dependent specifications in which the reference point is just equated with current asset position cannot accommodate the effects of forgone opportunities obtained. Asset position simply does not change at all during our game. There are, however, a number of relatively recent papers in which reference points are explicitly made dependent on expectations based on previous experiences. An important aspect of this approach is that it allows for reference-point effects in contexts in which subjects do not experience actual gains or losses. This provides a well-suited framework to account for the role of forgone opportunities. The most prominent and influential models in this area are probably the ones proposed by Kőszegi and Rabin (2006; 2007). Similar approaches can be found in Lim (1995), Post et al. (2008), or Baucells et al. (2011).

To illustrate how such an approach could explain the results of Experiment 1, we now present a simple reference-dependent model, in which reference points depend on expectations determined by previously faced opportunities. The model can be understood as an adaptation of the theories mentioned in the previous paragraph to our experimental environment.

Let us assume that the reference-dependent value of a specific lottery L_j , designated as $RDV(L_j)$, is determined by the following expression:

$$RDV(L_j) = \sum_{i=1}^n p_i v(x_i), \tag{1}$$

where x_i denotes a specific outcome within the lottery and p_i the probability associated with it. $v(x_i)$ is a reference-dependent value function over outcomes, defined by

$$v(x_i) = \begin{cases} -\lambda(RP-x_i)^\alpha & \text{if } x_i < RP \\ (x_i-RP)^\alpha & \text{if } x_i \geq RP \end{cases}, \tag{2}$$

where RP is the reference point, λ (normally greater than 1) is a loss aversion parameter and α is a parameter determining the curvature of the value function. This specification is essentially the one normally used to implement cumulative PT (Tversky and Kahneman 1992), but without its characteristic probability weighting, which has been removed here for simplicity.

Additionally, instead of associating the reference point with the current asset position, let us assume that RP is determined by the following expectation:

$$RP = O_n + \delta \left(\frac{\sum_{k=1}^{n-1} O_k}{n} - O_n \right), \tag{3}$$

where $\{O_1, \dots, O_n\}$ represent the offers faced during the game, O_n being the current one, and δ is a (non-negative) parameter determining the weight of previous offers in the present reference point. With $\delta=0$, RP simply equals O_n (the current offer) and it is not influenced at all by previously faced opportunities. With $\delta>0$, RP is an expectation determined jointly by the current offer and the average of the previous offers faced

during the game. The higher the average of the offers previously faced, the higher is the expectation that determines the reference point.

It is straightforward that under this specification all the odd-numbered sequences in our experiment, in which subjects face offers below or equal to €40, result in reference points below the current offer in the final period. On the contrary, all the even-numbered sequences, in which subjects face offers above or equal to €40, result in reference points above the current offer in the final period. This establishes a clear difference between these two groups of sequences that leads straightforwardly to the main results obtained in Experiment 1, namely that the odd-numbered sequences show significantly higher acceptance rates than the even-numbered ones. Figure 4 illustrates this point.

The three different plots in Fig. 4 show how changes in the reference point affect the distance in terms of value (or RDV) between the two alternatives in the final choice, for three different sets of parameters. The alternative offering a 50/50 chance of €100 or €0 is labeled L_R (for risky lottery); the sure offer of €40 is labeled L_S (for safe lottery). The vertical axes represent $RDV(L_R) - RDV(L_S)$. The first plot depicts the case of risk aversion ($\alpha < 1$) and no loss aversion ($\lambda = 1$). The second plot shows the case of both risk aversion ($\alpha < 1$) and loss aversion ($\lambda > 1$). Finally, the third plot illustrates the case of no risk aversion ($\alpha = 1$) and loss aversion ($\lambda > 1$). The specific degrees of risk aversion and loss aversion chosen, $\alpha = 0.8$ and $\lambda = 2$, are similar to the ones usually found in implementations of cumulative PT. Virtually any other reasonable parameters result in essentially the same patterns.

The initial plot demonstrates that, under risk aversion, movements of the reference point downwards from the sure offer of 40, such as the ones in the odd-numbered sequences, result in a reduced $RDV(L_R) - RDV(L_S)$ and consequently in higher percentages of acceptance of the sure offer (L_S). This is represented by the lower convex segment of the graph. On the contrary, movements of the reference point upwards from 40, such as the ones in the even-numbered sequences, produce a larger $RDV(L_R) - RDV(L_S)$ and therefore lower rates of acceptance. This corresponds to the higher concave segment of the graph. This is exactly the pattern found in Experiment 1.

The second plot illustrates that, under both risk aversion and loss aversion, the behavior of $RDV(L_R) - RDV(L_S)$ for movements of RP upwards from 40 is essentially the same as in the first plot, but the result of movements below 40 tends to reverse. This reversion, however, results in a much weaker pattern than the one found above 40. Consequently, again under this specification, which is much in line with the ones usually employed for cumulative PT, odd-numbered sequences are predicted to show higher percentages of acceptance than even-numbered ones.

Finally, the third plot depicts the case of loss aversion without risk aversion, which is uncommon in the literature. Under such a specification, movements of the reference point away from the current offer (40 in the final round), in any direction, result in a larger $RDV(L_R) - RDV(L_S)$ and consequently in lower rates of acceptance.³ This pattern together with the one shown in the first plot basically determines the shape of the plot in the middle.

³ Even in this case, assuming a lower δ for movements below the current offer than for movements above it would result in the pattern found in Experiment 1. Such an assumption seems justified by the idea that people adapt easier to good outcomes than to bad ones.

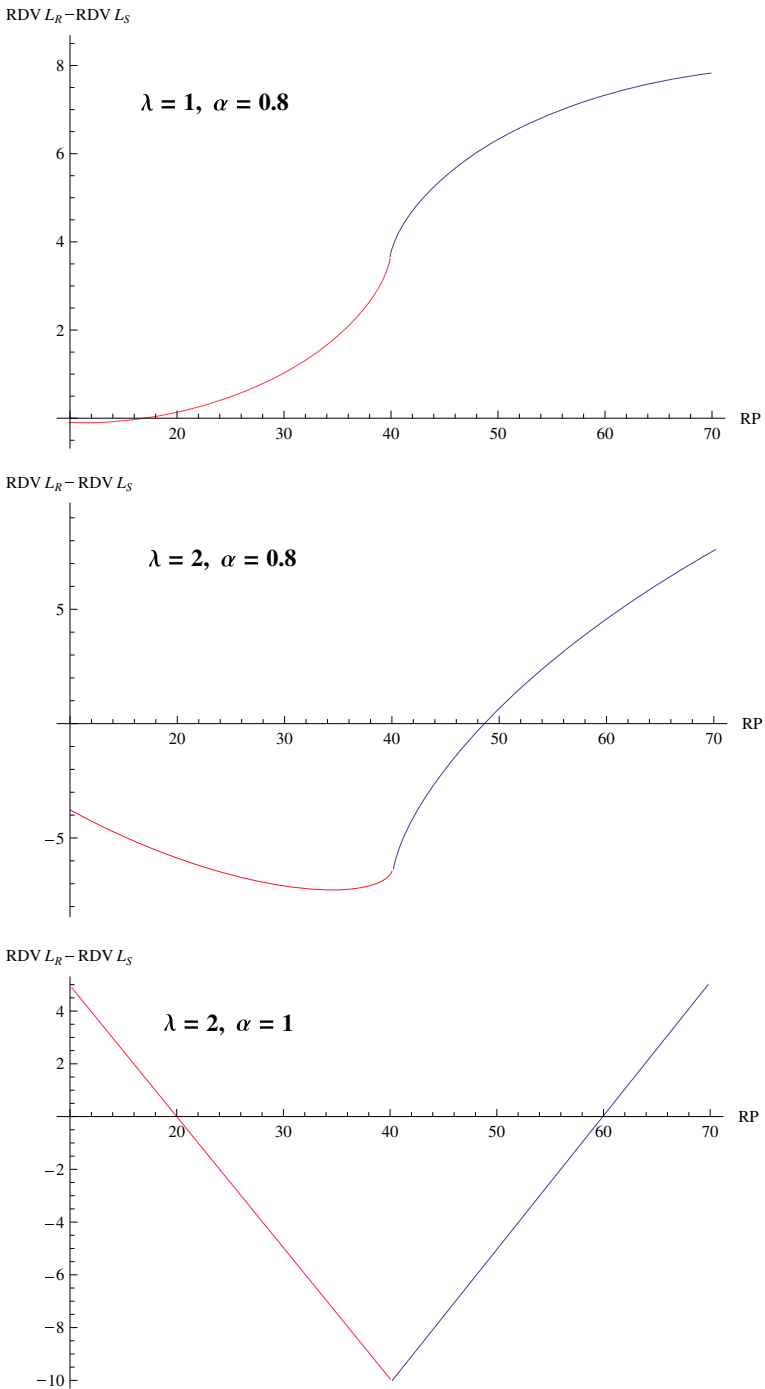


Fig. 4 Effects of changes in the reference point, RP , on the difference between the reference-dependent values of the risky and safe lotteries, $RDV(L_R) - RDV(L_S)$

On the whole, Fig. 4 demonstrates how this simple reference-dependent model can explain the influence of forgone opportunities on decision behavior found in Experiment 1.

3.2 The role of emotions

Our second suggested account for the findings of Experiment 1 focuses on the role of emotions in decision making. This contrasts with the first approach discussed, which is mostly cognitive in nature.

Emotions have often been used to inform decision research (see, e.g., Bechara et al. 2000; Mellers 2000; Slovic et al. 2004; Han et al. 2007). A crucial distinction in this area is between anticipated and experienced emotions. Decision theories, especially in economics, have addressed mostly anticipated emotions (see, e.g., Loomes and Sugden 1982, 1986; Mellers et al. 1997). A prominent example of this is Regret Theory (Bell 1982; Loomes and Sugden 1982), in which choices depend on emotions expected to be experienced once the decision is made. Regret Theory is silent about the effects of emotions experienced in the process of decision making. Some researchers, however, have also investigated the role of experienced emotions in decision making (see, e.g., Loewenstein 1996; Han et al. 2007). A well-known example of this is the ‘Risk as Feelings’ framework (Loewenstein et al. 2001), which revolves around the idea that reactions to risks are based on experienced emotions.

To the best of our knowledge, there are currently no decision theories that take into account the effects of previously faced circumstances on decision making and also incorporate emotional aspects. For example, the expectation-based theories discussed in the previous section can accommodate some effects of previous circumstances on decision behavior, but they are formulated in mostly cognitive terms. They are silent about emotional influences on behavior. On the other hand, theories like Regret Theory or Disappointment Theory (Bell 1985; Loomes and Sugden 1986) incorporate anticipated emotions, but they are totally silent about the influence of previously faced situations on decision making.

In the approach suggested here to accommodate the results of Experiment 1, we focus on experienced emotions. Specifically, the account we propose is based on the idea that, when people are responsible for the opportunities they forgo (which is the case in Experiment 1), they tend to experience a feeling of regret if they miss an opportunity that is better than the next one; likewise, they tend to experience a feeling of satisfaction if they forgo an opportunity that is worse than the subsequent one. Note that a key factor in these emotional reactions is being responsible for the decisions made and the opportunities forgone. In addition, we assume that these feelings affect the evaluation of subsequent opportunities (i.e., subsequent offers in our set-up). More specifically, we propose that regret for having forgone better opportunities diminishes the perceived value of current offers, and satisfaction for having forgone worse options enhances it.

This emotion-based framework leads straightforwardly to the prediction that, in the set-up used in Experiment 1, subjects in the odd-numbered sequences (who forgo worse opportunities) should show higher rates of acceptance in the final round than subjects in the even-numbered sequences (who forgo better opportunities). This is exactly the pattern found in the experiment.

It is of course possible that individuals feel other emotions, like disappointment or elation, in the absence of responsibility, but here we propose (and test in Experiment 2) that being responsible for the opportunities missed (and the associated feeling of regret or satisfaction) plays an important role in the evaluation of subsequent options. Previous evidence that feelings of regret are linked to responsibility can be found, for example, in Zeelenberg et al. (1998). See also Connolly et al. (1997), Ordóñez and Connolly (2000), and Zeelenberg et al. (2000).

This account of our findings provides also a crucial distinction with cognitively-oriented approaches to the role of forgone opportunities in decision making, like the ones discussed in the previous section. Namely, in a cognitive expectation-based approach, being responsible for forgone opportunities is predicted to be largely irrelevant.

The explanation proposed in this section is in line with a number of findings in the psychology and marketing literatures. For example, in research on ‘inaction inertia’, it has been shown that missing an initial desirable opportunity diminishes the likelihood of acting on a subsequent less attractive one (see, e.g., Tykocinski et al. 1995; Tykocinski and Pittman 1998; Zeelenberg et al. 2006). This finding has been linked in the literature to the avoidance of counterfactual regret. It has also been shown that experiencing regret has significant effects on consumers’ repurchasing intentions (Tsiros and Mittal 2000), on the bidding behavior of salespersons (Creyer and Ross 1999), or on different post-consumption behaviors (Zeelenberg and Pieters 2004). A possible way to explain these findings is by using the Theory of Regret Regulation (Zeelenberg and Pieters 2007), which proposes that feeling regret is an aversive state that people will tend to regulate through a number of different behavioral strategies.

Another related line of research revolves around the Functional Theory of Counterfactual Thinking (see Roesse 1994; Epstude and Roesse 2008), according to which counterfactual thoughts have a regulatory role and can help to improve performance. In this framework, ‘downwards’ counterfactual comparisons can be linked to generating positive affective reactions, and ‘upwards’ comparisons can be linked to producing negative comparative evaluations and strengthening intentions to achieve more success (see Markman et al. 1993). In terms of our findings, comparing a good current opportunity to a previous worse one can lead to positive feelings and, as a consequence, to an increased willingness to accept the opportunity. On the contrary, comparing a worse current opportunity to a previous better one can lead to a negative evaluation of the opportunity and a strengthened feeling that it is not good enough.

4 Experiment 2

A key aspect that differentiates between the two theoretical accounts discussed in the previous section is the role of being responsible for the decisions made and the opportunities forgone, and the emotional reactions related to it. Responsibility is largely irrelevant according to the more cognitively-oriented reference-dependent approach, but it is crucial in the emotion-based account of the results of Experiment 1 in terms of counterfactual regret and satisfaction. Experiment 2 is designed to test the relevance of responsibility in the role of forgone opportunities in decision making under risk. To the

best of our knowledge, this is the first test of this kind in the context of decision making under risk and uncertainty.

4.1 Method

4.1.1 Design and procedure

In this experiment, participants were presented with the same individual computerized game as in Experiment 1, but they were told that the game would be played by the computer in front of them up to an unknown round in which they would be told to take control for the remainder of the game. To make the design as similar as possible to Experiment 1, and to make subjects think as much as possible about the offers appearing in the game, in each round in which the participants did not have the control they were told to indicate which option they would have chosen if they were in command. After their response, the computer made a choice and the game went on. The round in which subjects took control of the game was always the final round. At that point, it was clearly indicated to them that they were in charge by using a salient sign on the screen. At the end of the experiment, participants were actually paid according to their decision in the final round. If they chose the sure offer (€40), that was their payoff; if they chose to play until the end, the 50/50 chance of €100 or €0 was implemented by the computer and they were paid according to the result.

This design presented all the subjects with the same decision in the final round, but after having followed the computer along different game paths. Those paths were exactly the same ones experienced by the participants who reached the end of the game in Experiment 1 (see Table 1), but without being responsible for the decisions that led to the final choice. According to the kind of reference-dependent approach outlined above, this should make no difference to the effect of previously faced options on decision behavior. On the contrary, if the patterns observed in Experiment 1 are related to emotions like regret and satisfaction, linked to responsibility, the effect of previous opportunities should be significantly undermined.

4.1.2 Participants

A total of 111 university students participated in this experiment (between 12 and 16 per sequence). It was implemented in two identical sessions that lasted about one hour each.

4.2 Results and discussion

Table 4 shows a descriptive summary of participants' decisions in the final round of the game. In this experiment, subjects only made actual decisions in the final round, in which all of them faced the same choice, but having followed different paths. The eight different elimination sequences were the same as in Experiment 1 (see Table 1). Since participants were only in control in the last round, all of them had to get to the end and face the final decision. In addition, they also gave hypothetical responses in all the previous rounds, stating what they would have done if they were in charge. Those responses are qualitatively different from actual decisions to stay or not in the game,

Table 4 Descriptive statistics (Experiment 2)

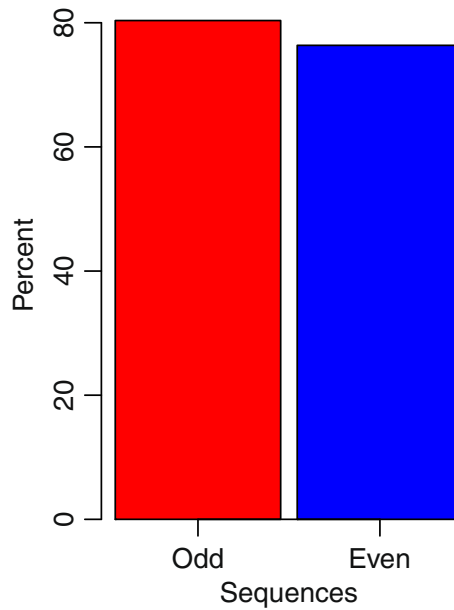
	N	% accept. last round
S1	16	75
S2	15	60
S3	15	87
S4	15	73
S5	13	92
S6	13	92
S7	12	69
S8	12	85

and they do not add much to the main issue investigated here. For these reasons, statistics for them are not reported here (they are available from the authors upon request). The main goal of the hypothetical questions was to make the procedure as similar as possible to Experiment 1, and to make subjects think as much as possible about the options coming up throughout the game.

The main result captured in Table 4 is that there is no systematic pattern differentiating between the odd-numbered and even-numbered sequences. In Experiment 1, all the percentages of acceptance in the odd-numbered sequences were markedly below any of the percentages in the even-numbered ones. Here, the odd-numbered percentages go from 69 to 87% and the even-numbered ones from 60 to 85%. Comparing the percentages pair-wise (S1 with S2, S3 with S4, etc.), on two occasions the odd-numbered ones are greater, but in the other two cases the even-numbered ones are the same or higher. Like in Experiment 1, the small numbers of subjects obtained if the sample is subdivided into the eight different sequences make it difficult to have statistically significant results by comparing single sequences to each other. Again, we put the sequences together into the two distinctive groups defined by odd-numbered and even-numbered ones. As Fig. 5 illustrates, the means of the two groups are 80.36% for the odd-numbered sequences ($N=56$) and 76.36% for the even-numbered ones ($N=55$), resulting in a difference of 4%. This difference is far from being statistically significant (Fisher's exact test, $p=0.65$). In other words, facing the different sequences of opportunities, but without being responsible for forgoing them, had no significant effect on the decisions made by participants in the final round.

An important issue here is that, since all the subjects were forced to get to the end of the game and make the final choice, the exact percentages of acceptance are not directly comparable to the ones obtained in Experiment 1. As the percentages in the final round show (see Table 2 and Table 4), the proportion of people accepting the sure offer is generally higher in Experiment 2 than in Experiment 1. This is because not giving subjects the possibility to opt out of the game until the end results in a sample that contains more risk averse individuals. An important consequence of this is that the size of the effect of previously faced options on the final decisions could be made smaller, which could undermine somewhat the results of Experiment 2. Note, however, that the difference between the results of Experiment 1 and Experiment 2 is not only a matter of effect size. In Experiment 2, the percentages of acceptance in the odd-numbered sequences are not even consistently above the percentages in the even-numbered ones.

Fig. 5 Average percentage of acceptance in the final round in odd-numbered and even-numbered sequences (Experiment 2)



In addition, if we take Experiment 1 and make the implausibly extreme assumption that absolutely all the subjects who did not reach the end of the game would have accepted the offer in the final round, the expected difference in the percentages of acceptance between odd-numbered and even-numbered sequences is reduced to 5.02%. This number is still slightly higher than the 4% obtained in Experiment 2 and the assumption made is implausibly extreme.

Overall, Experiment 2 suggests that an important element determining the impact of forgone opportunities on decision behavior is being responsible for missing those opportunities, which underscores the relevance of emotions like regret or satisfaction involved in counterfactual thinking. This does not mean that cognitive aspects do not play a role in generating reference points based on previously faced options that may affect decisions. Indeed, a few previous studies have documented effects along those lines (see, e.g., Lim 1995; Stewart et al. 2003). Purely cognitive models, however, are unlikely to appropriately capture the underpinnings of behavior in environments in which people's choices affect the options available to them in the future, which is indeed the case in many real-world situations.

5 General discussion

Experiment 1 shows that forgone opportunities play a significant role in decision making under risk, affecting in predictable ways the evaluation of subsequent choice alternatives. Specifically, having faced worse (better) opportunities in the past produces significantly higher (lower) degrees of risk aversion in later decisions. These patterns cannot be accommodated by most existing decision models and they have wide-ranging implications for the understanding of decisions under risk. They demonstrate

that in dynamic risky settings, as most real-world environments are, decision making should be understood as a dynamic process in which the opportunities that individuals forgo determine how later options are evaluated. The findings of Experiment 1 are in line with some previous research, and they provide new evidence on the subject in a more complex experimental environment with high payoffs at stake.

These ideas have also relevant implications for applied and policy settings. Generally, they suggest that making certain opportunities available to decision makers will influence the way they evaluate subsequent risky alternatives in predictable ways. For example, making more attractive opportunities available in a specific domain for some time should make people more willing to take risks to achieve better outcomes in the future. These patterns also provide general guidance on how current alternatives will be evaluated depending on the opportunities encountered before. For instance, a manager who has to make a risky decision on behalf of shareholders should take into account the opportunities that those shareholders have faced in the past. If forgone options have been better than the safer alternatives currently available, shareholders will probably be willing to support more risky actions. On the other hand, if the safer options available are better than previous opportunities, shareholders will probably show more risk-averse inclinations. This offers also some scope for planning the order in which opportunities are made available in order to control reactions to risky courses of action.

We have discussed two theoretical approaches that can accommodate the effects of forgone opportunities observed in Experiment 1. The first one is cognitively-oriented and it involves constructing reference-dependent models in which reference points are determined by expectations influenced by previously faced options. The second approach is based on the idea that experienced emotions involved in counterfactual thinking, like regret and satisfaction, affect the perceived value of currently available alternatives. An important difference between these approaches is the role played by being responsible for forgoing previous opportunities. This is a crucial aspect of emotional reactions like regret and satisfaction, but it is largely irrelevant in the reference-dependent approach described.

Experiment 2 shows that eliminating subjects' role in missing previous opportunities dilutes the effect of those missed opportunities on decision behavior. This suggests that emotions like regret and satisfaction involved in counterfactual thinking are actually important determinants of the influence of forgone options on decisions. It might still be true that more cognitive aspects play a role in creating reference points based on previously faced options that affect behavior. However, purely cognitive models are unlikely to adequately capture the foundations of decision making under risk in settings in which people's choices influence the options available to them in the future.

Such environments seem indeed more similar to many real-world situations. So, the results of Experiment 2 also qualify the implications of our research for more applied and policy settings. In general, making certain opportunities available to decision makers may influence the way they evaluate later risky alternatives, but that influence should be expected to be stronger if they feel somewhat responsible for having forgone previous opportunities.

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