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# The influence of biased exposure to forgone outcomes

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## Abstract

After making decisions, we often get feedback concerning forgone outcomes (what would have happened had we chosen differently). Yet, many times, our exposure to such feedback is systematically biased. For example, your friends are more likely to tell you about a party you missed if it was fun than if it was boring. Despite its prevalence, the effects of biased exposure to forgone outcomes on future choice have not been directly studied. In three studies (five experiments) using a simplified learning task, we study the basic influence of biased exposure to forgone outcomes in the extreme case in which decision makers can easily infer the missing information such that the biased exposure carries almost no informational value. The results in all studies suggest that nevertheless, the biased exposure to forgone outcomes affected choice. Exposure to forgone outcomes only when they were better than the obtained outcomes (Only-Better-Forgone) increased selections of the forgone option compared with exposure to forgone outcomes only when they were worse than the obtained outcome (Only-Worse-Forgone). Moreover, relative to an unbiased exposure to all forgone outcomes, the effect of exposure to Only-Worse-Forgone was larger than the effect of exposure to Only-Better-Forgone feedback. However, these effects were not universal: In environments that include rare negative events ("disasters"), biased exposure to forgone outcomes had very little effect. We raise potential explanations and further discuss implications for marketing and risk awareness.

KEYWORDS
anticipated regret, decisions from experience, information avoidance, negative recency, rare events, sequential decision making

## 1 | INTRODUCTION

After we make a decision, we normally learn the outcome of that decision. Sometimes, we can also discover the counterfactual: What would have happened had our decision been different. For example, we can both discover the performance of a bond in which we choose to invest and that of a stock we considered but did not end up buying. Thus, we can get accurate feedback regarding both the obtained and the forgone outcomes of our decision. However, whereas feedback concerning obtained outcomes is usually precise, outside of the stock market, our exposure to forgone outcome information is often systematically biased.

In some contexts, we only hear about how good things would have been had we chosen differently. That is, we only get explicit feedback concerning the forgone outcomes when they turn out to be better than what we got. For example, say you contemplate whether to go to a party with some friends and eventually decide to stay home. The next day, your friends are probably much more likely to tell you how the party was if they had a really good time ("you really missed a great one!") than if in retrospect they would have preferred to stay home as well. The *delete* feature on WhatsApp group chats is similarly designed to induce postchoice regret. Unlike many other chat applications, deleted messages on this popular application leave a trace ("Jane deleted this message"). This trace can be thought of as explicit feedback for the decision of whether to open the application and read the messages immediately upon receiving a *new message* notification or postpone opening it for later and risk the feeling of missing out because an unread message was deleted. Naturally, if no messages are deleted, no explicit feedback regarding the forgone outcome (what would have happened had I read the messages immediately) is given.

In other contexts, we only hear about the bad potential consequences of a choice we ended up not making. In these situations, forgone outcome feedback is given only when the forgone outcomes turn out to be worse than what we got. For example, consider the decision to leave home early enough to avoid potential traffic. Later, traffic reports may explicitly provide agents with information that they made the right choice, but only in cases traffic congestion really did occur; traffic reports are normally not provided when traffic is flowing. Similarly, certain parking applications that are used to pay parking fees, such as Pango,[1] provide users with push notifications when their parked vehicle is inspected. That is, users are alerted that had they not paid the fee, they would have been fined. Unsurprisingly, no feedback is given if the car is not inspected; therefore, the feedback is provided in a biased manner.[2]

Despite its relative prevalence, no research specifically investigated the influence of biased exposure to forgone feedback. The current paper makes a step in this direction by investigating the basic influence of such biased exposure in context-free decision-making tasks across different learning environments. Our focus is on situations in which the decision maker can reasonably complement the missing information from its mere absence. We believe any effects of the biased exposure to forgone outcomes observed in such settings are very likely to manifest in situations in which complementing the information is not as easy.[3] Therefore, we focus on investigating the extreme cases in which the feedback is provided only in one set of cases and never in another set of cases and in which participants know that the availability of feedback is biased. Moreover, we only discuss accurate feedback that is provided in a biased manner. False feedback (e.g., lies or "fake news") is not considered.

## 1.1 | Related literature and conflicting hypotheses

How does such systematically biased exposure to forgone outcomes influence choice? Past research did not tackle this question. Rather, it focused on the effects of forgone outcomes information in general or on the effects of selective feedback of obtained outcomes. These lines of research highlight three very different hypotheses concerning the effects of biased exposure to forgone outcomes. First, past research suggests that decision makers are as sensitive (Yechiam & Busemeyer, 2005; Yechiam & Rakow, 2012) and sometimes even more sensitive (Carmon & Ariely, 2000; Grosskopf et al., 2006) to (unbiased) forgone outcome information than to obtained outcome feedback (though an eye-tracking study reports lower vigilance to forgone outcomes than to obtained outcomes (Ashby & Rakow, 2016). We can then reasonably expect that the systematically biased forgone outcomes feedback (provided only when the forgone outcome is better or only when it is worse than the obtained outcome) that enters into the decision process biases decisions. (Fiedler, 2000) The first hypothesis thus states that when forgone outcome feedback is given only when the forgone outcome is better (worse) than the obtained outcome, decision makers will be more (less) likely to choose the forgone alternative.

However, in many cases, systematically biased exposure to forgone outcomes does not objectively bias the available information. Specifically, in the examples provided above, when agents do not get explicit feedback concerning the forgone outcome, they often can (and arguably should) infer from the mere absence of feedback what the forgone outcome was. For example, Pango users who are not notified that their car was inspected can reasonably deduce that it was not inspected. That is, the objective information available in such cases is not truly biased, only the salience of the current state is. In such cases, we may reasonably assume that decision makers are unaffected by the biased exposure to forgone outcomes as they can complement the "missing" information with ease. Therefore, the second hypothesis states that when the missing information from biased exposure to forgone feedback can be complemented with ease, decision makers' choices will not be affected by the biased exposure to forgone outcomes. This hypothesis is further supported by studies on selective feedback in which feedback is provided only when agents make certain choices but not when they make other choices. (Elwin, 2013; Elwin et al., 2007; Griffiths & Newell, 2009; Henriksson et al., 2010; Holzworth et al., 2018; Stewart et al., 2012) In a typical task on selective feedback, participants make multiple job recruitment decisions and only get feedback regarding an applicant's performance when choosing to hire that applicant. The overall finding in these studies is that the selective feedback that results in biased information does not affect performance much, particularly after sufficient experience is gained. (Elwin et al., 2007; Henriksson et al., 2010; Holzworth et al., 2018; Stewart et al., 2012; Tindale, 1989) The common explanation for this result is the "constructivist coding" hypothesis; according to which in the absence of external feedback, people produce internal feedback of what they believe is the most likely outcome. (Elwin et al., 2007)

The third hypothesis regarding the effects of biased exposure to forgone outcomes is less extreme than the first two. It is possible that the effects of the biased exposure to information are qualitatively different in different environmental settings and/or as a function of the direction of the bias (i.e., feedback concerning forgone outcomes only when they are better or only when they are worse than the obtained outcomes). Support for this hypothesis comes from studies on

[1]https://en.pango.co.il/

[2]Note that when the forgone outcome is better than the obtained outcome, like in the party and WhatsApp examples, the agent actually receives "bad news": The feedback informs the agent that the path not taken would have given a better outcome than that which is taken. Congruently, when feedback regarding forgone outcome is provided only when it is worse than the obtained outcome, like in the traffic and Pango examples, the feedback alerts the agent that he or she did the right thing because their realized outcome is better than that they would have gotten had they chosen differently.

[3]We also ran a pilot study, reported in the Supporting Information, in which participants could not know for certain that the feedback is systematically biased (although they could have reasonably inferred it with experience). As expected, the effects of the biased exposure to forgone feedback in that study were larger than those we find in the main studies.

decisions from experience that show differential impact for (unbiased) forgone outcome feedback in different settings. (Rakow et al., 2015) For example, forgone outcome feedback tends to increase risk taking more when the risky option includes rare negative outcomes than when it does not, (Camilleri & Newell, 2011; Yechiam & Busemeyer, 2006; Yechiam et al., 2015) reflecting the elimination of the hot stove effect. (Denrell & March, 2001) This effect is named after Mark Twain's observation that a cat who once touched a hot stove will never again dare to touch it, even when it is cold. Specifically, because an option leading to a poor outcome is more likely to be avoided in future choice, when forgone outcome feedback is not provided, no new information regarding its potential outcomes, good or bad, will be given, leaving its perceived value low; this process is eliminated when forgone outcome feedback is given. Note though that providing feedback concerning forgone outcomes only when the forgone outcome is worse than the obtained outcome should exacerbate the hot stove effect, rather than diminish it: The poor perceived value of an option providing poor outcomes is sometimes reinforced even when not choosing it, yet it cannot be rectified without actively choosing it.

Additional support for the “less extreme” hypothesis comes from studies on anticipated regret. The availability of forgone outcomes feedback allows for a comparison of *what is* and *what would have been*, (Zeelenberg, 1999) which can lead to postdecisional regret (or to reduced satisfaction with the obtained outcome (Teodorescu et al., 2018). If this regret can be anticipated prior to choice, a bias towards the option that minimizes regret can emerge. (Ritov, 1996; Zeelenberg et al., 1996; Zeelenberg & Pieters, 2004) When exposure to forgone outcome feedback is biased such that it is only provided when the forgone outcome is worse than the obtained outcome, the direct comparison between the outcomes never leads to regret. In such cases, we may expect that the forgone outcome will have relatively little influence on choice. Yet, when forgone feedback is only provided when the forgone outcome is better than the obtained outcome, every comparison between the obtained and forgone outcomes leads to regret, and the effects on choice can be large and unexpected. For example, it may lead to effects similar to learned helplessness. (Seligman, 1972; Teodorescu & Erev, 2014a)

An opposite prediction is made by the phenomenon of information avoidance. (Golman et al., 2017; Sweeny et al., 2010) Agents may actively choose to avoid paying attention to and/or avoid internalizing the information concerning the forgone outcome information they are given. Intuitively, this is more likely when the feedback implies that they made a mistake (when the forgone outcome is better than the obtained) than when it implies they did the right thing (when the forgone outcome is worse than the obtained). In line with this intuition, an eye-tracking study (Ashby & Rakow, 2016) found that forgone losses are less attended to (compared with forgone gains). Therefore, we may expect an asymmetry in the influence of biased exposure to forgone outcomes such that the impact of the feedback is smaller when the forgone outcome is better than the obtained outcome than when the forgone outcome is worse than obtained outcomes.

To sum, different lines of research imply very different possible effects of biased exposure to forgone outcomes on choice. This paper explores which effects actually manifest in these situations.

## 2 | GENERAL EXPERIMENTAL DESIGN

We report the results of five experiments that used a similar paradigm and design to investigate the basic effects of biased exposure to forgone outcomes across qualitatively different learning environments. Because we are interested in the fundamental influence of repeated exposure to feedback, we used a simplified learning task (the Clicking Paradigm (Erev & Haruvy, 2016) in which a decision maker repeatedly chooses between two buttons (each associated with a certain payoff distribution) and immediately gets feedback on that choice. Feedback concerning the chosen option (the obtained outcome) was always provided. The availability of feedback concerning the unchosen option (the forgone outcome) was manipulated between subjects.

Specifically, in each study, we compared behavior across three conditions. In Condition All-Forgone, participants received forgone outcome feedback in every trial. This condition served as baseline comparison group. In two other conditions, exposure to forgone outcomes was systematically biased. In Condition Only-Better-Forgone, participants received feedback concerning the forgone outcome if and only if that outcome was attractive, that is, only when it was better (higher) than their obtained outcome in the same trial. In Condition Only-Worse-Forgone, participants received feedback concerning the forgone outcome if and only if that outcome was unattractive, that is, only when it was worse (lower) than their obtained outcome in the same trial.[4]

Importantly, the instructions in the two biased conditions always stated that the provision of forgone feedback is biased. Specifically, participants in Condition Only-Better-Forgone (Only-Worse-Forgone) were told that “in each round, after you make your selection, the outcome you obtain from this selection will appear on the chosen button. In addition, in rounds in which choosing the alternative button would have led to a higher [lower] outcome than the outcome you obtained, the outcome you could have gotten from the unselected button will appear on that button.” The instructions thus implied that participants in those conditions could easily infer the relative sign (or the exact outcome: see Study 2) of the forgone outcome even when it is not provided.

In all studies, choices were incentivized: Participants knew that one of all the decisions they make in the experiment will be randomly selected at the end of the study and that their obtained payoff in that trial will be added to (if positive) or subtracted from (if negative) a fixed preset amount. Hence, no “wealth effects” were possible.

[4]In Study 1a, we also included a condition in which participants never received any forgone feedback. Because the information that can be elicited from the feedback is fundamentally different in this condition, we focus on comparing the groups for which forgone feedback was (at least partially) provided. We report the results for the additional group in the Supporting Information.

In each study, participants faced variants of all four problems presented in Table 1, in random order. These problems are commonly studied in repeated decisions from experience using the same paradigm. (Erev & Haruvy, 2016; Di Guida et al., 2015; Teodorescu et al., 2013; Teodorescu & Erev, 2014b) Each problem in Table 1 contrasts a safer "status quo" option, which provides 0 with certainty, with a risky option, which provides either a loss or a gain. The risky options in Problems 1Eq+ and 2Eq− are both 50/50 gambles (Eq+ represents the positive expected value [EV] for the gamble, and Eq− represents the negative EV of the gamble). Problem 3RT is a "Rare Treasures" problem: Its risky option provides a small loss frequently or a large gain rarely. Problem 4RD is a "Rare Disasters" problem: Its risky option provides a small gain frequently and a large loss rarely. These different environments roughly cover the range of settings discussed above in which forgone outcomes feedback may be biased. Parking inspections are, in many places, relatively rare. Thus, like Problem 4RD, relative to the safer choice of paying the parking fee, the realized outcomes of a decision not to pay are frequently better (free parking) but can sometimes lead to a large loss (a fine). In contrast, parties can turn out to be fun or not and neither necessarily more likely than the other, like Problems 1Eq+ and 2Eq−.

## 2.1 | Data analysis

Because we are interested in the mean response for biased exposure to forgone information, our unit of analysis is a participant's average choice across all trials of each problem. Therefore, before analyzing the data, we first computed for each participant in each problem the choice rate of the risky alternative.

To analyze the data, we implemented using restricted maximum likelihood methods (and packages lme4 (Bates et al., 2014) and lmerTest (Kuznetsova et al., 2017) in R) a linear mixed-effects model, with a random factor for participant, and fixed effects for problem (four levels), for condition (three levels), and for the interaction between them. We use Likelihood Ratio Tests of nested models fitted using maximum likelihood to statistically test for the effects. Our main comparison of interest is the difference between the two biased conditions within each problem. To analyze the interaction where applicable, we use estimated marginal means (using R package emmeans, (Lenth, 2018)), comparing each effect of condition within a problem to its average effect in other problems, as well as pairwise comparisons of condition within problem. In all cases, $p$ values are corrected for multiple comparisons according to Holm method. We use Satterthwaite approximation to compute degrees of freedom and report likelihood profile confidence intervals (CIs).

# 3 | STUDY 1A

Study 1a investigated the effects of biased exposure to feedback in repeated choice of the four problems from Table 1, when no description regarding the payoff distributions is provided. That is, when participants learn only from the provided feedback.

## 3.1 | Method

### 3.1.1 | Participants

To estimate the sample size for this study, we simulated a linear mixed-model that was found to fit pilot data reported in the Supporting Information and performed a power analysis allowing for 95% chance to find a significant interaction based on that model. The analysis suggested that at least 40 participants per condition are required. One hundred and sixty-four Technion students participated in the study, of which 123 (43 female, $M_{age}$ = 24.7) were assigned to three conditions reported in the main text (see Footnote 4 and the Supporting Information). Numbers of participants assigned to each condition are 41, 42, and 40 for conditions All-Forgone, Only- Better-Forgone, and Only-Worse-Forgone, respectively.

### 3.1.2 | Materials and procedure

Participants were set in front of a computer screen in a Technion lab and faced each of the problems from Table 1 for 100 trials with immediate feedback (the order of the problems was random). Buttons associated with each option were unmarked. The show-up fee was 26 Shekels. The average final payment for participants was 26.5 Shekels (approximately 7.5 USD; range in Shekels = [15, 37]). The experiment lasted approximately 15 min, and all participants completed the experiment in full. No participants were excluded from the analysis.

**TABLE 1** Choice problems used in Studies 1 and 2

| | | Status quo option | | Risky option | | | |
|---|---|---|---|---|---|---|---|
| Problem | Type | Outcome | Probability | Loss | $P$ (Loss) | Gain | Higher EV? |
| 1Eq+ | Equal probabilities | 0 | 1 | −9 | .5 | 11 | Risky |
| 2Eq− | Equal probabilities | 0 | 1 | −11 | .5 | 9 | Safe |
| 3RT | Rare treasures | 0 | 1 | −1 | .9 | 10 | Risky |
| 4RD | Rare disasters | 0 | 1 | −10 | .1 | 1 | Safe |

## 3.2 | Results

Figure 1 displays the mean aggregate risky choice rates in each problem and each condition. It shows an interesting pattern. In three of the four problems (Problems 1Eq+, 2Eq−, and 3RT), the biased exposure to forgone feedback seems to have large effects on choice, as is evident by the large differences between the choice rates of the two biased conditions. However, in the rare disasters problem (Problem 4RD), the choice rates in these two conditions are nearly identical. Comparison of the biased conditions to the benchmark condition (All-Forgone) suggests that, generally, exposure to only better forgone outcomes increases and exposure to only worse forgone outcomes decreases the risky rates, but surprisingly, this did not occur in Problem 4RD.

A linear mixed-effects model (see Table S1) suggests that condition has a significant impact on the risky choice rates, $\chi^2(2) = 18.41$, $p < .001$. Of main interest, the mean choice rate of the risky options in Only-Better-Forgone ($M = 0.526$) significantly differs from the mean choice rate of the risky options in Only-Worse-Forgone ($M = 0.373$), $t(120) = 4.37$, $p < .001$. The mean risky choice rate in the baseline Condition All-Forgone was intermediate between these two ($M = 0.434$), significantly lower than in Only-Better-Forgone, $t(120) = 2.64$, $p = .019$, and marginally significantly higher than in Only-Worse-Forgone, $t(120) = -1.73$, $p = .086$.

Yet the effect of condition on choice was not the same in every problem, as indicated by a significant interaction of condition and problem, $\chi^2(6) = 14.82$, $p = .022$. Analysis of this interaction suggests that it stems from a different impact in the rare disasters problem. For example, the effect of condition is significant in Problem 1Eq+, $F(2,426) = 7.425$, $p < .001$; Problem 2Eq−, $F(2,426) = 4.976$, $p = .007$; and Problem 3RT, $F(2,426) = 8.874$, $p < .001$; but not in Problem 4RD, $F(2,426) = 0.242$, $p = .785$. Indeed, the effect of Only-Better-Forgone in Problem 4RD significantly differs from its effect in the other problems, $t(360) = -3.411$, $p = .009$, whereas none of the other effects of condition within each problem differ from the effect of the same condition in other problems ($ps > .36$).

More specifically, whereas in the first three problems, the choice rates in Only-Better-Forgone are significantly higher than those in the Only-Worse-Forgone, $t(426.06) = 3.65$, $p < .001$; $t(426.06) = 2.94$, $p = .010$; and $t(426.06) = 4.20$, $p < .001$, for Problems 1Eq+, 2Eq−, and 3RT, respectively; in Problem 4RD, there is virtually no difference between the rates, $t(426.06) = 0.30$. Turning to comparisons with the baseline condition within each of the problems, we find the differences between Only-Worse-Forgone and All-Forgone are $b = -0.044$, 95% CI [−0.154, 0.064] in Problem 1Eq+; $b = -0.029$, 95% CI [−0.138, 0.081] in Problem 2Eq−; $b = -0.133$, 95% CI [−0.243, −0.024] in Problem 3RT; and $b = -0.039$, 95% CI [−0.148, 0.071] in Problem 4RD. The differences between Only-Better-Forgone and All-Forgone are $b = 0.157$, 95% CI [0.049, 0.265] in Problem 1Eq+; $b = 0.134$, 95% CI [0.026, 0.242] in Problem 2Eq−; $b = 0.099$, 95% CI [−0.009, 0.207] in Problem 3RT; and $b = -0.022$, 95% CI [−0.13, 0.086] in Problem 4RD. Note that the direction of the effect of the positively biased exposure to information is negative in the rare disasters problem.

The model further suggests that problem has a large main effect on the choice rates, as is expected, and as was found in many previous studies of these problems using this paradigm, $\chi^2(3) = 125.9$, $p < .001$. Indeed, the estimated marginal mean choice rate across forgone conditions in Problem 1Eq+ ($M = 45.6\%$) is significantly higher than the estimated mean choice rate in Problem 2Eq− ($M = 38.8\%$): $t(360) =$

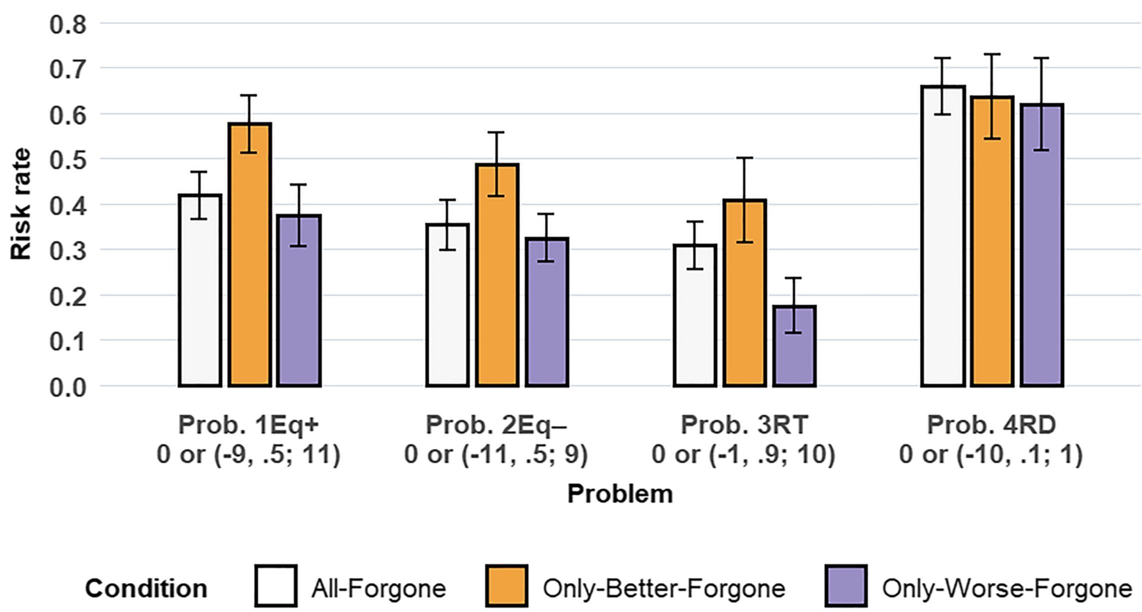


**FIGURE 1** Mean aggregate rates of Risky choice in Study 1a (lab study). The notation (*x*, *p*; *y*) refers to an option that provides *x* with probability *p*, and *y* otherwise. In problems 1Eq+ and 3RT, the risky option has a higher expected value; in problems 2Eq− and 4RD, the safe option has a higher expected value. Error bars indicate 95% CI for the mean accounting for the within-subject design as in Morey (2008) and Cousineau (2005)

2.39, $p$ = .018, as can be expected because the gamble's EV is positive in Problem 1Eq+ and negative in Problem 2Eq−. In contrast, the estimated mean choice rate of the positive-EV gamble in Problem 3RT ($M$ = 29.6%) is significantly lower than that of the negative-EV gamble in Problem 4RD ($M$ = 63.7%): $t(360) = -11.96$, $p < .001$. This pattern reflects underweighting of rare events, a phenomenon according to which, in decisions from experience, agents tend to behave as if the likelihood of the rare event is lower than it really is (e.g.,(Barron & Erev, 2003; Erev et al., 2017; Hertwig & Erev, 2009)).

#### 3.2.1 | Within-task learning

Although the instructions imply that in the biased exposure conditions, participants can infer with certainty the sign of the missing forgone outcomes, it is possible that they do not fully understand it before they have the chance to experience the task themselves. Moreover, with experience in the task, participants likely realize they are facing binary lotteries and can therefore infer with high confidence the missing outcome (and not just its sign). Therefore, it is interesting to know if the effects described above replicate even after participants gain experience with the same choice task, or if they diminish.

We therefore repeated the analyses above for the first 50 trials of the task and the last 50 trials of the task separately. The results show that the main findings hold in both cases. Specifically, the main effect of condition is significant both in the first half of the task, $\chi^2(2) = 16.46$, $p < .001$, and in the second half of the task, $\chi^2(2) = 16.98$, $p < .001$. In both halves, participants in Condition Only-Worse-Forgone chose the risky option least ($M$ = 0.399 in the first half; $M$ = 0.346 in the second half), participants in Condition Only-Better-Forgone chose the risky option most ($M$ = 0.534 in the first half; $M$ = 0.518 in the second half), and participants in the baseline condition chose it intermediately ($M$ = 0.457 in the first half; $M$ = 0.411 in the second half).

Moreover, in both halves, the impact of condition in the rare disasters problem seems different than in the other problems. In the first half, we find a significant interaction, $\chi^2(6) = 14.13$, $p$ = .028, and post hoc analysis shows it is triggered by a different effect of Condition Only-Better-Forgone in Problem 4RD than in the other problems, $t(360) = 3.31$, $p$ = .012. The interaction in the second half of the task is only marginally significant, $\chi^2(6) = 12.22$, $p$ = .057, but we analyze it nonetheless and again see that it stems from a different effect of Condition Only-Better-Forgone in Problem 4RD than in the other problems, $t(360) = 2.98$, $p$ = .037.

Interestingly, the (unstandardized) effect sizes of condition tend to be larger in the second half of the task than in the first half. For example, the paired differences between the two biased conditions (i.e., the differences between Conditions Only-Better-Forgone and Only-Worse-Forgone) are larger in the last 50 trials than in the first 50 trials, in all four problems. In the first half of the task, these differences are $b$ = 0.174 ($p$ = .005) in Problem 1Eq+, $b$ = 0.130 ($p$ = .053) in Problem 2Eq−, $b$ = 0.226 ($p < .001$) in Problem 3RT, and $b$ = 0.012 in Problem 4RD (nonsignificant), and in the second half of the task, they are $b$ = 0.230 ($p$ = .001) in Problem 1Eq+, $b$ = 0.195 ($p$ = .008) in Problem 2Eq−, $b$ = 0.239 ($p < .001$) in Problem 3RT, and $b$ = 0.021 (nonsignificant) in Problem 4RD. These results suggest that participants did not learn to overcome the biased exposure to feedback. If anything, with experience, their behavior reflected an increased sensitivity to the biased exposure to feedback.

## 4 | STUDY 1B

Study 1b is an online replication of lab Study 1a, with a different pool of participants and a larger sample. The only other differences between the studies is that all payoffs in Study 1b were multiplied by 10, so each “point” was worth £0.01 (rather than 1 Israeli Shekel), and the inclusion of a simple attention check in the instructions screen to make sure participants were reading it (those who failed the check never made a single choice).

### 4.1 | Participants

The sample included 286 persons who were recruited online using Prolific (www.prolific.com). Of these, 82 were excluded before making any choices, either because they accessed the task using a mobile device (which was not allowed) or because they failed the attention check. Eighteen additional participants left the experiment before finishing it. The final sample included 186 participants (123 female, $M_{age}$ = 40.4): 60, 62, and 66 for Conditions All-Forgone, Only- Better-Forgone, and Only-Worse-Forgone, respectively. On average, they completed the experiment in 22 min and were paid £2.99 (range = [1.85, 4.05]).

### 4.2 | Results

Figure 2 shows a similar general pattern to that found in Study 1a. Indeed, using a mixed-effects model (Table S2), we again find a significant main effect of condition, $\chi^2(2) = 40.12$, $p < .001$. Participants in this study also chose the risky option least in Condition Only-Worse-Forgone ($M$ = 0.388), more in Condition All-Forgone ($M$ = 0.509), and most in Condition Only-Better-Forgone ($M$ = 0.548). The former of these is significantly lower than each of the other two: $t(183) = -4.76$, $p < .001$, and $t(183) = -6.36$, $p < .001$ respectively, but the difference between the two latter conditions did not reach conventional significance levels: $t(183) = 1.53$, $p$ = .128.

The results also replicate the significant interaction between problem and condition, $\chi^2(6) = 22.67$, $p < .001$, and, again, the source of the interaction is in the different effect of condition in the rare disasters problem. The effect of condition is significant in Problem 1Eq+, $F(2, 653.7) = 15.11$, $p < .001$; Problem 2Eq−, $F(2, 653.7) = 16.29$, $p < .001$; and Problem 3RT $F(2, 653.7) = 12.71$, $p < .001$; but not in Problem 4RD, $F(2, 653.7) = 0.235$, $p$ = .791. The effect of Only-

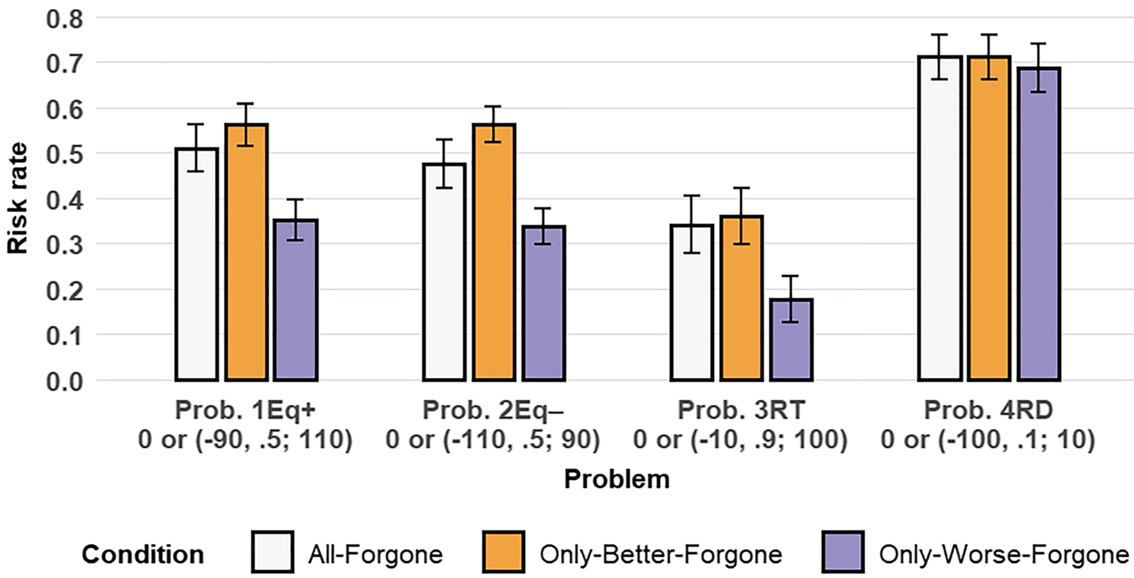


**FIGURE 2** Mean aggregate rates of Risky choice in Study 1b (online study). The notation *(x, p; y)* refers to an option that provides *x* with probability *p*, and *y* otherwise. In problems 1Eq+ and 3RT, the risky option has a higher expected value; in problems 2Eq– and 4RD, the safe option has a higher expected value. Error bars indicate 95% CI for the mean accounting for the within-subject design as in Morey (2008) and Cousineau (2005)

Better-Forgone in Problem 4RD significantly differs from its effect in the other problems, $t(549) = -3.28$, $p = .012$. Here, we also find that the effect of Only-Worse-Forgone in Problem 4RD significantly differs from its effect in the other problems: $t(549) = 4.38$, $p < .001$. The effects within each of the other problems do not differ from the effect in the rest of the problems ($ps > .35$).

We again find that in the first three problems, the choice rates in Only-Better-Forgone are significantly higher than those in the Only-Worse-Forgone, $t(653.72) = 5.27$, $p < .001$; $t(653.72) = 5.66$, $p < .001$; and $t(653.72) = 4.58$, $p < .001$, for Problems 1Eq+, 2Eq–, and 3RT respectively, but do not differ in Problem 4RD, $t(653.72) = 0.59$. The differences between Only-Worse-Forgone and All-Forgone are $b = -0.159$, 95% CI [−0.238, −0.08] in Problem 1Eq+; $b = -0.138$, 95% CI [−0.217, −0.059] in Problem 2Eq–; $b = -0.164$, 95% CI [−0.243, −0.085] in Problem 3RT; and $b = -0.024$, 95% CI [−0.103, 0.055] in Problem 4RD. The (considerably smaller) differences between Only-Better-Forgone and All-Forgone are $b = 0.051$, 95% CI [−0.028, 0.131] in Problem 1Eq+; $b = 0.088$, 95% CI [0.008, 0.168] in Problem 2Eq–; $b = 0.018$, 95% CI [−0.061, 0.098] in Problem 3RT; and $b = -0.001$, 95% CI [−0.08, 0.079] in Problem 4RD.

Finally, again, we find that problem has a large effect on choice behavior, $\chi^2(3) = 294.9$, $p < .001$. The estimated marginal means of the risky choice rate in the four problems are 0.474 in Problem 1Eq+, 0.458 in Problem 2Eq–, 0.292 in Problem 3RT, and 0.703 in Problem 4RD. All pairwise comparisons between these means, except for the difference between Problems 1Eq+ and 2Eq–, are highly significant ($ps < .001$). Despite the clear difference between the merits of choosing the risky option in Problems 1Eq+ and 2Eq–, participants did not exhibit a clear difference in behavior: $t(549) = 0.79$, $p = .429$.

### 4.2.1 | Within-task learning

We also again investigated participants' sensitivity to the biased exposure in the two halves of the task and again found very little differences between the two halves. The main effect of condition is significant in both halves, $\chi^2(2) = 42.05$, $p < .001$, and $\chi^2(2) = 32.86$, $p < .001$, respectively, and the choice rates are in the expected directions: smallest in Only-Worse-Forgone ($M_1 = 0.404$, $M_2 = 0.371$), intermediate in All-Forgone ($M_1 = 0.516$, $M_2 = 0.502$), and largest in Only-Better-Forgone ($M_1 = 0.558$, $M_2 = 0.539$). The interaction is also significant in both halves, $\chi^2(6) = 15.85$, $p = .015$, and $\chi^2(6) = 23.72$, $p < .001$, respectively, and triggered by different effects in Problem 4RD than in the other problems. Finally, again, the effect sizes of condition tend to be slightly larger later in the task. The differences between conditions Only-Better-Forgone and Only-Worse-Forgone in the first half of the task are $b = 0.196$ in Problem 1Eq+, $b = 0.217$ in Problem 2Eq–, $b = 0.166$ in Problem 3RT (all $ps < .001$), and $b = 0.035$ in Problem 4RD (nonsignificant), and in the second half of the task, they are $b = 0.225$ in Problem 1Eq+, $b = 0.234$ in Problem 2Eq–, $b = 0.199$ in Problem 3RT (all $ps < .001$), and $b = 0.012$ in Problem 4RD (nonsignificant).

## 4.3 | Discussion

The results of replication Study 1b are similar to those of Study 1a in many respects. For example, in both studies, we find that biased exposure to forgone outcome impacts the choice rate similarly in most settings, but much less so in rare disaster settings and that these effects are robust to experience. However, considering the minor changes in design between the two studies, it is also interesting to consider the discrepancies in results of these studies. The clearest discrepancies are that in Study 1b, we get much smaller differences between Condition Only-Better-Forgone and Condition All-Forgone, as well as larger differences between Condition Only-Worse-Forgone and Condition All-Forgone. These differences are most evident in Problem 1Eq+ and Problem 2Eq− (problems with equal probabilities). Because the mean choice rates in the biased conditions are very similar in both studies, these differences seem to stem from a higher choice rate of the risky option in the All-Forgone condition in Study 1b than in Study 1a. That is, had this rate in Study 1a been higher (or that in Study 1b been lower), we would have likely gotten even more similar results. Notably, behavior in the baseline condition is of less interest for the current paper. Nevertheless, we were able to get the data from three experiments (reported in (Erev & Haruvy, 2016; Di Guida et al., 2015)) that used the same paradigm to run the same 50/50 problems as we did. We analyzed the first 100 choices made in these experiments in each problem and found that in all three experiments, the rates of risky choice were considerably higher than those found in Study 1a and similar to those found in Study 1b.[5] Thus, it seems that the discrepancies between Study 1a and Study 1b are most likely to be the result of the somewhat lower than expected risk rates observed in Study 1a for the baseline condition rather than a systematic difference in the effect of biased exposure to forgone outcomes.

## 5 | STUDY 2

In our experiments, we explicitly tell participants that the exposure to forgone feedback is biased so they can complement the relative sign of the undisclosed forgone outcome with complete certainty. For example, a participant in Condition Only-Worse-Forgone who in some trial does not get feedback concerning the forgone outcome can know for sure that this outcome would have been better than the obtained outcome in that trial. However, because participants in Study 1 were not told what the possible outcomes from each option are, they could not complement the magnitude of the undisclosed forgone outcome with certainty. We believe this information structure reflects many real-world examples. For example, if your friends do not tell you about the great party you missed, you may reason that the party was bad, but you do not really know how bad it was. Moreover, in our simplified settings, participants received abundant experience with each of the simple problems and, arguably, could have reasonably assumed (at least later in the task) that there are very few possible outcomes in each option and therefore could also complement the outcome itself and not just its relative sign.

Nevertheless, it is interesting to check whether the effects from Study 1 hold even when participants can complement all missing information with complete certainty. Furthermore, even participants' ability to complement the relative sign in Study 1 depends on them reading, understanding, and remembering the explicit instructions regarding the biased nature of the information (an assumption that may not hold; Cohen, Plonsky, & Erev, 2019). To make sure that the effect of biased exposure to forgone outcomes is robust to participants' knowledge and ability to complement it, we ran Study 2. This study replicates Study 1 while providing participants with a complete description of the payoff structure of each option, clearly marked for the whole duration of the experiment. Specifically, participants faced the four problems from Table 1 for 50 trials with immediate feedback. We decreased the number of trials because we assumed the addition of a description of the payoff structure would turn the task to be too boring.

Study 2 included two experiments. After running the first experiment, we looked at the data and found what we believed to be an extremely unlikely result. Specifically, the choice rate in the Only-Better-Forgone condition in Problem 3RT was 11 percentage points lower than the choice rate in All-Forgone condition, and this difference was significant ($p = .032$). We could not think of any theoretical justification for this result and suspected it was a Type I error. We thus decided to run an exact replication of that experiment and combine the two datasets to check if this unlikely result holds. It did not. Moreover, the only statistically significant difference in choice rates between the two parts of the study corresponded to the suspicious result. Hence, there is no evidence that other results from the first experiment did not replicate in the second one. In the following, we report the analysis of the combined data. In the Supporting Information, we report the results of each experiment separately. Note that relative to a decision not to run the exact replication after seeing the significant result, running the replication and pooling the data cannot inflate the Type I error rate, because this rate refers to the likelihood of incorrectly detecting a significant result (which the first half of the sample already included). Moreover, the statistical power of the test using the pooled data is higher than the power of the test using just the original sample, because the sample size has increased. Yet, relative to a decision not to collect additional data (after seeing the effect is significant), our decision may have inflated the Type II error rate, although presumably by a very small degree due to the substantially increased power.[6]

### 5.1 | Participants

The sample included 488 people who were recruited online using Prolific (www.prolific.co). Of these, 121 were excluded before making any choices, either because they accessed the task using a mobile device or because they failed an attention check. Seven additional

[5]For the experiment reported by Erev and Haruvy,(Erev & Haruvy, 2016) the risky rates were 56% in Problem 1Eq+ and 48% for Problem 2Eq−. For the Israeli sample reported in Di Guida et al.,(Di Guida et al., 2015) the risky rates were 48% in Problem 1Eq+ and 46% in Problem 2Eq−. For the Taiwanese sample reported in the same paper, the risky rates were 51% in Problem 1Eq+ and 46% in Problem 2Eq−. We were not able to get the data for the Denmark sample in that paper.

[6]In other words, our protocol is similar to an optional stopping protocol, except it biases our conclusions against finding a statistically significant effect.

participants left the experiment before finishing it. The final sample included 360 participants (240 female, $M_{age}$ = 38): 119, 122, and 119 for Conditions All-Forgone, Only-Better-Forgone, and Only-Worse-Forgone, respectively. On average, they completed the experiment in 14 min and were paid £2.25 (range = [1.1, 3.3]).

## 5.2 | Results

Figure 3 shows the mean choice rates of the risky option within problems and conditions. Here, the choice rates are generally higher, and the effects are generally smaller than in Study 1, but again, there seems to be a clear impact of the forgone condition on choice. The results (Table S3) show a main effect of condition: $\chi^2(2) = 27.14$, $p < .001$, with significantly lower risk rates in Condition Only-Worse-Forgone ($M = 0.527$) than in Condition All-Forgone ($M = 0.642$), $t(357) = -4.43$, $p < .001$, and in Condition Only-Better-Forgone ($M = 0.649$), $t(357) = -4.72$, $p < .001$. The difference between the two latter conditions is insignificant.

The interaction of condition and problem is only marginally significant $\chi^2(6) = 12.53$, $p = .051$, but again, the effect of condition is highly significant within each of the first three problems, but not in Problem 4RD: $F(2, 1179.66) = 6.48$, $p = .002$; $F(2, 1179.66) = 13.65$, $p < .001$; $F(2, 1179.66) = 8.30$, $p < .001$; and $F(2, 1179.66) = 1.25$, $p = .287$, respectively. Post hoc tests show that the only effect of condition within a problem that is nearing conventional significance levels for difference from the effect in other problems is that of Condition Only-Worse-Forgone within Problem 4RD: $t(1071) = 2.67$, $p = .092$ (corrected for multiple comparisons using Holm method).

In the first three problems, the choice rates in Only-Better-Forgone are significantly higher than those in Only-Worse-Forgone, $t(1179.66) = 3.12$, $p = .006$; $t(1179.66) = 5.07$, $p < .001$; and $t(1179.66) = 2.97$, $p = .006$, respectively. Again, this difference in the rare disasters problem is statistically insignificant $t(1179.66) = 1.50$. The differences between Only-Worse-Forgone and All-Forgone are very similar to those found in Study 1b. They are $b = -0.121$, 95% CI [−0.196, −0.045] in Problem 1Eq+; $b = -0.142$, 95% CI [−0.218, −0.066] in Problem 2Eq−; $b = -0.152$, 95% CI [−0.228, −0.075] in Problem 3RT; and $b = -0.046$, 95% CI [−0.122, 0.030] in Problem 4RD. The differences between Only-Better-Forgone and All-Forgone are $b = -0.001$, 95% CI [−0.077, 0.075] in Problem 1Eq+; $b = 0.054$, 95% CI [−0.022, 0.129] in Problem 2Eq−; $b = -0.037$, 95% CI [−0.113, 0.038] in Problem 3RT; and $b = 0.011$, 95% CI [−0.064, 0.087] in Problem 4RD. Notice that the direction of the effect here is negative in Problems 1Eq+ and 3RT but positive in Problems 2Eq− and 4RD. This mixture likely suggests that the two conditions (Only-Better-Forgone and All-Forgone) elicit roughly the same behavior.

As expected, problem has a significant main effect $\chi^2(3) = 155.62$, $p < .001$. The estimated marginal means of the risky choice rate in the four problems are 0.682 in Problem 1Eq+, 0.552 in Problem 2Eq−, 0.491 in Problem 3RT, and 0.700 in Problem 4RD. All pairwise comparisons between these means, except for the difference between Problems 1Eq+ and 4RD, are highly significant ($ps < .003$).

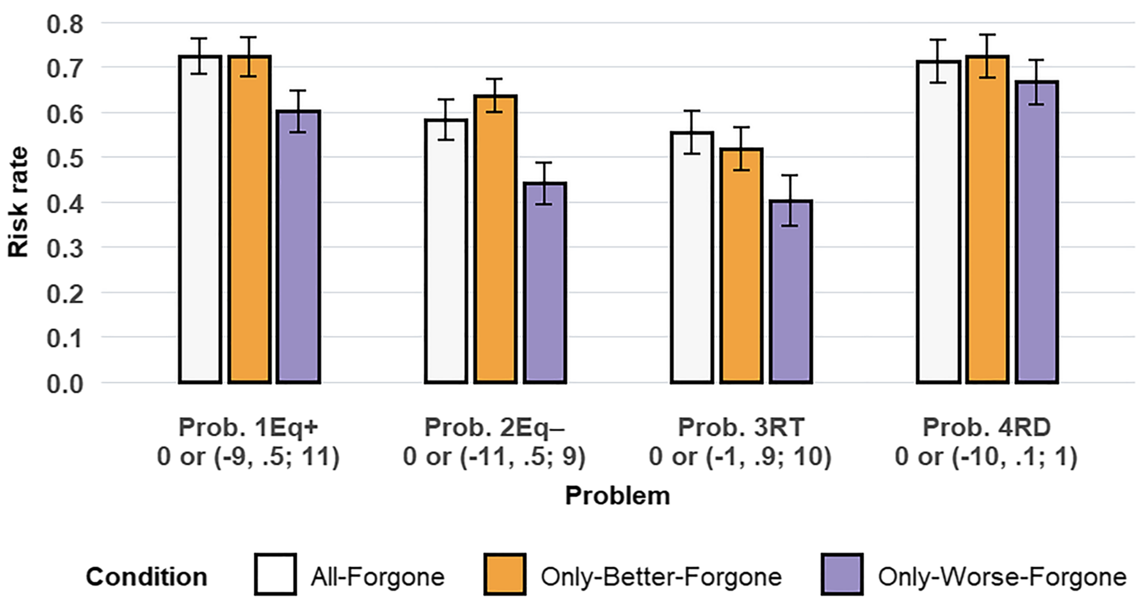


**FIGURE 3** Mean aggregate rates of Risky choice in Study 2 that included both feedback and a description of payoff distributions. The notation *(x, p; y)* refers to an option that provides *x* with probability *p*, and *y* otherwise. In problems 1Eq+ and 3RT, the risky option has a higher expected value; in problems 2Eq− and 4RD, the safe option has a higher expected value. Error bars indicate 95% CI for the mean accounting for the within-subject design as in Morey (2008) and Cousineau (2005)

### 5.3 | Discussion

The results of this study suggest that even when participants have complete information that allows them to complement any missing information regarding forgone outcomes, the biased exposure to such outcomes impacts choice. Moreover, the results again suggest that this impact is far less pronounced in rare disaster settings, just like in Study 1 that included no description of the payoff structure. These findings echo previous research suggesting that the addition of exact distributional information has only minor impact on behavior in repeated decisions from experience. (Erev et al., 2017; Jessup et al., 2008; Lejarraga & Gonzalez, 2011; Teodorescu et al., 2013)

Interestingly, the nature of the effect of the biased exposure to feedback is asymmetric (even in Problems 1Eq+, 2Eq−, and 3RT). Whereas getting feedback concerning only forgone outcomes that are worse than the obtained outcomes has a relatively large effect in comparison with the full information baseline, the difference between getting complete feedback and getting feedback only concerning forgone outcomes that are better than the obtained has is virtually zero. That is, in this study, as long as feedback concerning forgone outcomes that are better than the obtained outcomes is provided, there is very little difference between getting or not getting feedback concerning forgone outcomes that are worse than the obtained outcomes. Under one interpretation of this result, participants are more likely to produce internal feedback that complements the missing forgone outcome information when this information is likely to reinforce their behavior than when this information implies they made a mistake, in line with an information avoidance account. (Golman et al., 2017; Sweeny et al., 2010)

Another clear difference between the results of this study from those of Study 1 is that here, the choice rates of the risky gambles were considerably higher. For example, averaging over conditions, participants here chose the bad (negative EV) gamble in Problem 2Eq − in more than 55% of the trials, whereas in Study 1, participants chose that gamble in 39% (Study 1a) and 46% (Study 1b) of the trials. In Problem 3RT, this difference is even greater with participants in both Studies 1a and 1b choosing the gamble in just 29% of the trials and those in Study 2 choosing it in 49% of the trials on average. This surprising result is in line with previous findings in decisions from experience showing more risk seeking when prior description of the payoff structure is added. (Teodorescu et al., 2013)

## 6 | STUDY 3

So far, we focused on tasks in which a risky action that can provide either a gain or a loss is contrasted with the status quo, which we manifest as a payoff of 0 with certainty. This design choice implies that when choosing the risky option, information regarding the forgone outcome is of very little use. This is particularly true in Study 2 in which participants choosing the risky option know with complete certainty that the forgone outcome is 0 regardless of the condition they are in and the outcome they obtain. That is, there is an inherent asymmetry between the usefulness of feedback concerning forgone outcomes when participants choose the risky option and when they choose the status quo. In Study 3, we diminish this asymmetry by adding noise to the safer of the two options thus increasing the value of getting forgone outcome feedback when choosing the risky option as well. Specifically, the design of this study was identical to that used in Study 1b except that the safe (status quo) option provided +5 or −5 with equal probability in each trial (instead of 0 with certainty).

### 6.1 | Participants

The sample included 285 people who were recruited online using Prolific (www.prolific.co). Of these, 99 were excluded before making any choices, either because they accessed the task using a mobile device or because they failed an attention check. Six additional participants left the experiment before finishing it. The final sample included 180 participants (106 female, four nonbinary gender, $M_{age}$ = 37.2): 60 in each condition. On average, they completed the experiment in 23 min and were paid £2.95 (range = [1.85, 4.05]).

### 6.2 | Results

Figure 4 presents the main results. Analysis using a mixed-effects model (Table S4) shows that the addition of noise to the status quo option did not change the main pattern reported above. Condition has a main effect on choice $\chi^2(2) = 53.73$, $p < .001$, with least choice for the risky option in Condition Only-Worse-Forgone ($M$ = 0.355), significantly lower than in both Condition Only-Better-Forgone ($M$ = 0.522), $t(177) = -6.89$, $p < .001$, and Condition All-Forgone ($M$ = 0.517), $t(177) = -6.69$, $p < .001$. Again, there was no significant difference between the two latter conditions.

The model also suggests that the effect of condition is different for different problems $\chi^2(6) = 14.06$, $p = .029$, an interaction originating mainly from the different effect in the rare disasters problem. The effect of condition is significant in Problem 1Eq+, $F(2, 648.51) = 19.73$, $p < .001$; in Problem 2Eq−, $F(2, 648.51) = 11.85$, $p < .001$; and in Problem 3RT, $F(2, 648.51) = 18.13$, $p < .001$. In Problem 4RD, the effect is marginally significant: $F(2, 648.51) = 2.99$, $p = .051$. Yet the effect of Only-Worse-Forgone in Problem 4RD significantly differs from its effect in the other problems: $t(531) = 3.17$, $p = .020$. Other effects did not differ in different problems ($p$s > .15, corrected using Holm method).

Choice rates of the risky option in Only-Better-Forgone are significantly higher than those in the Only-Worse-Forgone in Problem 1Eq+, $t(648.51) = 5.16$, $p < .001$; Problem 2Eq−, $t(648.51) = 4.52$, $p < .001$; and Problem 3RT, $t(648.51) = 5.64$, $p < .001$; but not in Problem 4RD, $t(648.51) = 1.7$. The differences between Only-Worse-Forgone and All-Forgone are $b_1 = -0.223$, 95% CI [−0.3, −0.146]; $b_2 = -0.150$, 95% CI [−0.227, −0.073]; $b_3 = -0.183$, 95% CI [−0.260, −0.106]; and $b_4 = -0.093$, 95% CI [−0.17, −0.016]. The differences between Only-Better-Forgone and All-Forgone are $b_1 = -0.02$, 95% CI [−0.097,

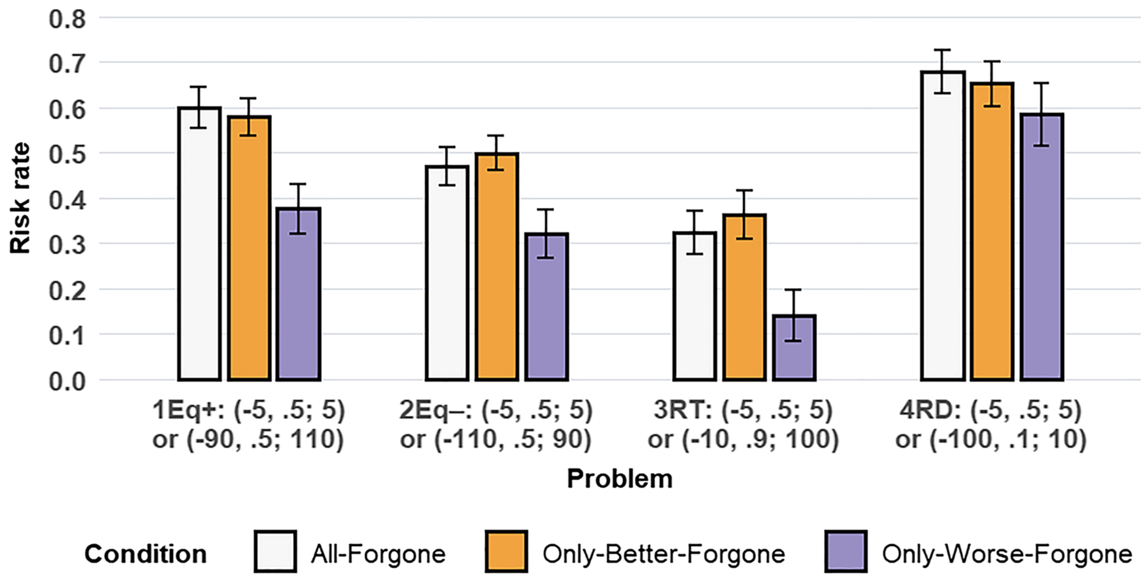


**FIGURE 4** Mean aggregate rates of Risky choice in Study 3 that included choice between two risky options. The notation *(x, p; y)* refers to an option that provides *x* with probability *p*, and *y* otherwise. In problems 1Eq+ and 3RT, the risky option has a higher expected value; in problems 2Eq– and 4RD, the safe option has a higher expected value. Error bars indicate 95% CI for the mean accounting for the within-subject design as in Morey (2008) and Cousineau (2005)

0.057]; $b_2$ = 0.028, 95% CI [−0.050, 0.105]; $b_3$ = 0.039, 95% CI [−0.038, 0.116]; and $b_4$ = −0.027, 95% CI [−0.104, 0.050].

Problem has a main effect on choice, $\chi^2(3) = 256.14$, $p < .001$. The estimated marginal means of the risky choice rate in the four problems are 0.517 in Problem 1Eq+, 0.429 in Problem 2Eq–, 0.274 in Problem 3RT, and 0.638 in Problem 4RD. All pairwise comparisons between these means are highly significant (*ps* < .001).

## 7 | SUMMARY OF THE MAIN FINDINGS ACROSS ALL STUDIES

Table 2 summarizes the main findings. It shows that in all studies, (a) biased exposure to forgone outcomes had an impact on choices in the direction of the bias (more risky choices in Condition Only-Better-Forgone than in Condition Only-Worse-Forgone), and (b) this impact

**TABLE 2** Summary of main findings across the studies

| | | | Difference in risky rates between conditions Only-Better-Forgone and Only-Worse-Forgone[a] | | | Difference in risky rates from All-Forgone condition | |
|---|---|---|---|---|---|---|---|
| Study | Participants | Setting | Mean of all problems | In problem 4RD | Effect significantly different in 4RD? | Only-Better-Forgone | Only-Worse-Forgone |
| 1a | 123 Technion students (lab) | Experience only; Safe vs. Risk | 0.153 ($p < .001$) | 0.017 | +++ ($p = .009$) | 0.092 ($p = .019$) | −0.061 ($p = .086$) |
| 1b | 186 Prolific workers (online) | Experience only; Safe vs. Risk | 0.160 ($p < .001$) | 0.023 | +++ ($p < .001$) | 0.039 ($p > .1$) | −0.121 ($p < .001$) |
| 2 | 360 Prolific workers (online) | Experience + Description; Safe vs. Risk | 0.122 ($p < .001$) | 0.058 | + ($p = .092$) | 0.007 ($p > .1$) | −0.115 ($p < .001$) |
| 3 | 180 Prolific workers (online) | Experience only; Risk vs. Risk | 0.167 ($p < .001$) | 0.067 | ++ ($p = .020$) | 0.005 ($p > .1$) | −0.162 ($p < .001$) |

[a]Left column refers to the differences between the mean choice rates in all four problems combined; middle column refers to the differences in only the rare disasters problem; and right column refers to the post hoc test comparing the effect in the rare disasters problem to the effect in the other three problems, correcting for multiple comparisons.

was moderated by the type of problem participants faced, such that it was diminished in the rare disasters setting (Problem 4RD). Last, compared with the baseline All-Forgone condition, in three of the four studies, the effect of biased exposure in the Only-Worse-Forgone condition was greater than in the Only-Better-Forgone condition.

## 8 | WHY IS THE EFFECT OF FORGONE-WORSE INFORMATION DIFFERENT IN RARE DISASTERS ENVIRONMENTS?

Results from all three studies (and a pilot study) suggest that in most settings, biased exposure to forgone feedback has relatively large effects on choice behavior. However, in rare disasters settings (Problem 4RD from Table 1), the effect of biased exposure to forgone outcome feedback is considerably smaller, as indicated by the interactions between condition and problem in each study.

We believe that there are several contributors for these differences. First, choice rates of the risky option in Problem 4RD are generally higher than in the other problems. The higher risky rates (which are consistent with underweighting of rare events) imply that in this problem, unlike the other three problems, forgone outcome feedback is given mostly concerning the status quo option. Because of the very low variance in its outcomes (e.g., 0 in Studies 1 and 2), feedback information concerning the status quo option is less valuable than feedback concerning the outcomes in the risky option. Therefore, a change in the nature of feedback mainly concerning the status quo should impact behavior less. Indeed, in Study 3, when the value of getting feedback concerning the status quo option increased, condition had a larger effect on choice in that problem as well. This is evident by the much larger difference between the choice rate of Condition All-Forgone and Condition Only-Worse-Forgone in Study 3 than in the other studies. However, the high choice rates cannot alone explain the difference in the impact of condition on choice across problems. For example, the risky choice rates in Problem 1Eq+ of Study 2 were as high as those of Problem 4RD, but the effect of condition differed between these problems.

A related contributor to the different effect in rare disasters problems is the fact that in this problem, when choosing the risky option, participants are very likely (90% of the time) to get a positive payoff (+1). This then means that participants that are in the Only-Worse-Forgone condition get forgone outcome feedback in 90% of the time that they choose the risky option (which, as mentioned, is relatively frequently). That is, it is rarely the case that after choosing the risky option, participants in the All-Forgone and the Only-Worse-Forgone conditions get different information, and so we can expect the effect of Only-Worse-Forgone to be smaller in this problem.

A third contributor to the different effect in rare disasters is a phenomenon called surprise triggers change. (Nevo & Erev, 2012) In decisions from experience, agents are commonly engaged in choice inertia (repeating the most recently chosen option (Ashby & Teodorescu, 2019; Biele et al., 2009): Model-based analysis of behavior in this paradigm estimated the likelihood of inertia at over 70% of the choices. (Plonsky & Erev, 2017) According to "surprise triggers change," rare (thus, surprising) events increase the likelihood that choice inertia discontinues. Therefore, rare events tend to increase the likelihood for a switch in choice (beyond the pure effect of the reinforcement). Note that because inertia is high when rare events are not encountered, just a few switches can have relatively large effects on behavior.

Specifically, consider participants who choose the status quo option in Problem 4RD and get feedback concerning outcomes worse than their obtained outcomes (i.e., Conditions All-Forgone and Only-Worse-Forgone) such that if a −10 is happened to be drawn in the risky option, they would observe it as a forgone loss. According to surprise triggers change, this surprising event would then increase the likelihood they would switch their choice to the risky option in the next trial (i.e., a negative recency effect (Plonsky et al., 2015; Plonsky & Erev, 2017)). That is, unlike in other problems, in rare disaster environments, exposure to worse forgone outcomes would tend to increase the risky rates. This is less likely to happen in Condition Only-Better-Forgone in which no feedback is provided when choosing the status quo. In that sense, surprise triggers change counteracts the basic effect of getting only better forgone outcome feedback, and we therefore may see a smaller effect in this problem.

Three clarifications regarding the contribution of surprise triggers change are in order here. First, note that in Problem 3RT, which also includes rare events, surprise triggers change also predicts more switches from the status quo to the risky option, which is in line with the basic effect of observing the positive +10 reinforcement. Therefore, in this problem, both being exposed to better forgone outcomes and surprise triggers change would predict the same pattern, and we would not expect the effect of biased exposure to diminish in this problem. Second, note that a related phenomenon, the Gambler's Fallacy, cannot account for the observed pattern of results. The Gambler's fallacy implies the same canceling effect for both rare positive and rare negative forgone outcomes. Specifically, similarly to surprise triggers change, in Problem 4RD, the Gambler's Fallacy implies more risky choices after seeing a large negative forgone outcome. Yet unlike surprise triggers change, in Problem 3RT, it implies less risky choice after seeing a large positive forgone outcome. Therefore, the Gambler's Fallacy predicts that the effect of biased exposure to forgone outcomes would be diminished in both Problems 3RT and 4RD, which is not supported by the results. Finally, obtained outcomes can also be surprising, and surprise triggers change can work on obtained outcomes as well. Yet in all conditions, participants always got feedback on obtained outcomes, and therefore, any effects of obtained outcomes cannot explain the differences in choice across conditions.

## 9 | GENERAL DISCUSSION

There are many situations in which explicit forgone outcome information is provided by external sources in a biased manner, and the prevalence of these situations is likely on the rise. As ever more businesses find ways to directly communicate with users and deliver personalized messages, the likelihood of biased exposure to forgone outcomes increases. For example, a retailer may be happy to use targeted ads to tell potential customers when the price for a certain product drops, but sharing this information with customers who only recently purchased the product is probably less appealing. Similarly, navigation applications may want to let users know how much time they saved by using the route suggested by the application rather than the common route, but only when it turns out the user indeed made the right choice by taking the prescribed route. Personalized messages allow businesses to provide information in a biased manner: only to specific customers in specific times.

Nevertheless, we lack a clear understanding of the basic influence of biased exposure to forgone outcomes on decision making. This paper aims to address this issue. A review of related literature hints that different lines of work would predict very different effects of such biased exposure. Our results suggest that people are influenced from biased exposure to forgone outcomes information, even when they are explicitly told that the feedback structure is biased, and accurate internal feedback can be constructed. When participants were exposed only to forgone outcomes that are better than the obtained outcomes, they exhibited riskier behaviors than participants who were exposed only to forgone outcomes that are worse than the obtained outcome (observed in three of the problems across all experiments, and in a pilot study). This difference between the two biased conditions did not diminish over time (if any, it became larger in the second half of the task). This finding is surprising, considering the fact that in the current setting, participants could have easily complemented the missing forgone information, providing in theory the same access to forgone information in the two biased conditions. The robust difference observed in the current studies therefore demonstrates a bounded ability of decision makers to overcome biases of outcome-contingent feedback in contrast to the success in overcoming biases of decision-contingent feedback. (Henriksson et al., 2010)

From a cognitive point of view, complementing missing information might require additional resources, which in turn creates a cognitive cost. Accordingly, a sufficient assumption to the emergence of differences between the two biased conditions is that people are not always willing or able to invest this additional cost. Yet the assumption that complementing missing information requires additional effort that is not always taken is not enough by itself in explaining all the effects of biased exposure to forgone outcomes observed in the current studies. For example, additional assumptions are needed in order to account for the asymmetry of the effect with respect to the direction of the bias: Compared with the baseline All-Forgone condition, the effect of the Only-Worse-Forgone condition was much larger than the effect of the Only-Better-Forgone condition (observed in all studies, except of Study 1a, see Study 1 discussion). This asymmetry is in line with the concept of information avoidance (Golman et al., 2017; Sweeny et al., 2010) and/or with the additional assumption that people are more likely to complement missing forgone information when this information implies that they made the right choice (rather than a bad one).

In addition, the above effects of biased exposure to forgone outcomes were not universal across all environments. In all experiments, biased exposure to forgone information had very little effect in a rare disasters environment that involves a frequent small gain and a rare large loss. We identified several potential contributors to this result, all related to the unique structure of such environments. Specifically, the frequent gains provided by the risky options in such settings lead to high choice rates for the risky options and to low informational value for the forgone outcome, whereas the rare losses lead to increased switches to the risky option after observing a forgone loss, consistent with surprise triggers change. (Nevo & Erev, 2012) Regardless of the underlying mechanisms, the near elimination of the effect in rare disasters environments questions the assumption (Donovan et al., 2007; Zheng, 2007) that increased awareness to potential disasters makes people more averse to risk. Other studies have shown that risk taking is not reduced in these settings with full feedback, (Newell et al., 2016; Oki & Nakayachi, 2012)[7] and here, we show that even biasing the observed outcomes such that they contain a disproportional number of disasters (relative to their true frequency) does not result in decreased tendency to take risks.

Our findings therefore support the third hypothesis presented above. Namely that the effect of biased exposure to feedback concerning forgone outcomes is different as a function of the environment and the direction of the bias. From a marketing perspective, retailers are more likely to consider providing only worse forgone feedback for their consumers (reinforcing the decision to buy their product or use their service). Thus, the finding that forgone-worse feedback had the larger effect on choice behavior can be considered as good news (for the retailers, perhaps less so for their customers). Yet our results suggest that campaigns aimed mainly for retention of current customer pool are only likely to be successful when the advantages of using the service are sufficiently frequent. Accordingly, when the biased exposure to forgone information is rare, very little effect is expected. For example, alerting users of a parking application that their car was inspected (a rare event) is unlikely to promote the desired behavior.

One theoretical contribution of our findings concerns the origins of "underweighting of rare events" in decisions from experience. (Barron & Erev, 2003; Hertwig & Erev, 2009; Hertwig et al., 2004) In a long-standing discussion in that literature, (Camilleri & Newell, 2011; Fox & Hadar, 2006; Glöckner et al., 2016; Hau et al., 2008; Ungemach et al., 2009; Wulff et al., 2018) it was argued that a major contributor to underweighting of rare events is their tendency to be underrepresented in observed samples. That is, because agents see less rare events than they objectively should, they behave as if they underweight them. In our study, however, biased exposure to forgone outcomes can imply overrepresentation of rare events in observed payoffs. For example, in Study 1b, participants in the Only-Forgone-Worse condition saw the rare (10% chance) −10 loss in 14.1% of the times that they saw the payoff from the risky option. Yet their mean

[8]In a registered report, Liang, Newell, Rakow, and Yechiam(Liang et al., 2019) failed to replicate(Newell et al., 2016) results.

rate of risky choice was 69%, which implies underweighting of the rare event although it was overly represented.

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## SUPPORTING INFORMATION

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