

# **Super-underweighting of rare events with repeated descriptive summaries**

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RUNNING HEAD: Super-underweighting of rare events

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# **Super-underweighting of rare events with repeated descriptive summaries**

Abstract:

Field studies suggest that providing summarized information concerning the prevalence of risks can increase risk taking when the hazard is rare. We study a simple experimental model of this phenomenon based on repeated descriptive summaries of past outcomes. Under cumulative prospect theory and experience sampling models, descriptions of rare events should increase the weighting of rare events. On the other hand, if individuals are sensitive to the frequency of events, then event summaries are expected to accentuate the underweighting of rare events despite adding descriptive information. These contrasting predictions were examined in three experiments using a multi-alternative decision task with two sets of options: safe and risky. In all three experiments, repeated descriptive summaries of past outcomes from all alternatives or from a randomly drawn alternative were found to accentuate the underweighting of rare events by a similar amount. The results shed light on the role of frequency-based judgments in the extreme underweighting of rare events, and highlight that providing information about the incidence of rare hazards can have the unintended effect of increasing, rather than decreasing, people's propensity to take risks.

Keywords: Decision making; risk preference; rare events; cumulative prospect theory; experience sampling; fuzzy trace theory; risk communication

In recent years, there has been a proliferation of systems that present geographical information concerning risk. Examples include information about vehicle accidents in a given area (e.g., Miller, 2000; Plug, Xia, & Caulfield, 2011; Zheng, 2007) and information concerning the risk of forest fire (Donovan, Champ, & Butry, 2007). Similarly, government systems, such as the US Traveler Enrollment Program, provide online information that includes the location and frequency of terrorist attacks. These systems rely on the notion that exposing people to a summary of the information concerning risk level would cause them to make decisions that reduce their exposure to relevant risks (e.g., by choosing not to travel to a risky location). While evaluations of the response to these systems are scarce (Donovan Champ, & Butry, 2007; Zheng, 2007), the hoped-for positive effect of summarized information is *inconsistent* with well-known studies in the area of earthquake insurance. These studies suggest that media released information summaries concerning catastrophic events sometimes have the paradoxical effect of decreasing the overall risk estimate (Beron, Murdoch, Thayer, & Vijverberg, 1997; Palm, 1981). For example, following the Loma Prieta earthquake in northern California, risk estimates of those insuring their property lowered as information concerning the location and rate of earthquakes was publicized (Beron et al., 1997). In order to shed more light on the possible causal effect of summaries of information concerning rare negative events, the present study examined people's responses to such summaries in an experimental simulation. In this simulation participants repeatedly selected between multiple options (or parcels) contained in two "areas": one ('risky') entailing rare but considerable penalties, and the other ('safe') with low variability in

outcomes. We tested whether summary information concerning outcomes produced by all options in the risky area would increase or decrease the appeal of this area.

Several theoretical models are relevant to people's response to summarized information concerning rare events. First of all, the studies used to validate prospect theory imply a tendency to over-weight rare events when presented with descriptive accounts of the relevant probabilities and outcomes (Kahneman & Tversky, 1979),<sup>1</sup> and this is consistent with the analysis of cumulative prospect theory (Tversky & Kahneman, 1992). Research usually attributes this to a tendency to allocate a disproportionately large amount of attention to the consequences of a rare event simply because that event is known to be possible (Erev, Glozman, & Hertwig, 2008; Burns, Chiu, & Wu, 2011). Indeed, even when decision makers have some experience with task outcomes, the addition of descriptive accounts of relevant probabilities and outcomes was found to increase the impact of rare events on choices, though this effect was more prominent when people had little experience to rely on (Barron, Leider, & Stack, 2008).

Secondly, under theories of experience sampling (e.g., Fox & Hadar, 2006; Hau, Pleskac, & Hertwig, 2009) summaries of information can increase the salience of negative events, which might not be encountered without this additional information. For example, if there is a 1/200 chance of catching a tropical disease for every day in a given area, then a tourist who remains in this area for several days may never experience this adversity. However, summary information (e.g., of other individuals' health status) is expected to increase the sensitivity to the rare occurrence, since such information makes clear that on a given day several people are likely to catch the disease. This heightened

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<sup>1</sup> Kahneman and Tversky (1979), however, carefully suggested that "highly unlikely events are either ignored or overweighted" (p. 283).

sensitivity to the possibility of a rare negative event is expected to increase the avoidance of this event. Thus, by providing exposure to a rare event, summary information is also expected to increase the overweighting of rare events.

Alternatively, when processing summarized information concerning the frequencies of different outcomes, individuals may use a “frequency-based” judgment (Estes, 1976; Wells & Windschitl, 1999; Reyna & Brainerd, 2008), and base their response primarily on the frequency of positive and negative outcomes rather than on expected value calculations. For instance, say that in the example above the tourist got the information that 1 out of 10 friends caught the disease. Given that staying in the disease area is fun (as long as one doesn’t catch the disease), this implies that for 9 out of 10 cases staying results in better outcomes than not staying. If people rely on frequency judgments, then the information from the single (1/10) case is discounted relative to the common case. Estes (1976) argued that more frequent events (e.g., multiple friends) are more easily retrieved from memory, which leads to a bias of overweighting the outcome of these frequent events when making a decision.<sup>2</sup> Wells and Windschitl’s (1999) analysis points out that that frequency attributes may be particularly powerful when pertaining to *different* instances of a given environment. The degree to which an outcome is considered typical of a particular stimulus is naturally facilitated by the frequency of different instances that are sampled. Possibly, individuals might even apply a majority vote heuristic where the odd case is not even considered. This kind of heuristic is often

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<sup>2</sup> For instance, Estes (1976) demonstrated that an event A that is sampled 200 times and “wins” 50% of the time is preferred over event B which is sampled 100 times and wins 75% of the time. The frequency of event A wins is 100 which surpasses the frequency of event B (75), and this provides a sufficient condition for preferring A over B. Additional examples are reviewed in Reyna and Brainerd (2008).

applied when summarizing information across different social agents (see Hastie & Kameda, 2005; Reimer & Hoffrage, 2012).

Consequently, if people use frequency-based judgment or a majority vote, then additional summary information is expected to emphasize the relative attraction of the risky alternative. As found previously, when such additional information is presented on every trial, regardless of a person's choice, it accelerates the underweighting of rare events (Yechiam & Busemeyer, 2006; Yechiam, Druryan & Ert, 2008; Otto & Love, 2010).

Finally, we also examined whether the effect of information summaries is related to the gambler's fallacy, namely a belief that once a rare event has occurred in a given area, it is much less likely to re-occur (e.g., Morrison & Ordeshook, 1975; Ayton & Fischer, 2004). Under this model, discovering that a rare event has occurred on a given trial – rather than the common outcome of no rare event – is the critical factor leading to more risk seeking with descriptive summaries. In other words, people might reason that because the rare event has 'just happened' it is unlikely to happen again straight away, thereby licensing further risky choices (cf. Beron et al., 1997). We examine these contrasting predictions in three laboratory experiments.

### Experiment 1: Symmetric information for safe and risky options

Our experimental setup presented participants with a rectangular grid that was split into two areas - one 'safe' and one 'risky' - across which information was summarized. Each area constituted 130 cells (or parcels), ordered in a  $10 \times 13$  cell matrix. The cells represented single choice alternatives that delivered a payoff when selected. This enabled

studying summaries of information across spatially presented alternatives – as, for instance, might be the case when choosing to stay/forage in one of two regions that differ in their distribution of outcomes – though in a context-free and simplified environment.

Each cell contained a button, which participants pressed in order to select that cell – a process that was repeated for 200 trials. The two areas were marked in green and blue backgrounds. Descriptions of the probabilities and underlying payoffs for pressing buttons in each area were displayed underneath the area throughout the task (see Figure 1).<sup>3</sup> Two choice problems were implemented in this framework, as follows:

Problem 1: “Rare-loss risk”

Area S: .005 probability of losing 8 pennies and a loss of 2 pennies otherwise

Area R: .005 probability of losing 200 pennies and a loss of 1 penny otherwise

Problem 2: “Frequent-loss risk”

Area S: .005 probability of losing 8 pennies and a loss of 2 pennies otherwise

Area R: .5 probability of losing 3 pennies and a loss of 1 penny otherwise

In both problems the expected value of the different areas was about the same (-2.0 pennies). Our main focus was on Problem 1 (Rare-loss risk) whereas Problem 2 served as a control condition. In Problem 1, options in the risky area (denoted as Area-R)

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<sup>3</sup> The effect of frequency-based judgments may be masked when the baseline condition involves no information concerning the relevant probabilities and outcomes, and the summaries add this knowledge (Grosskopf et al., 2006). To avoid possible effects due solely to the lack of knowledge about what can occur, information about outcomes and their probabilities was always given to all participants. This also emulates some real world situations (e.g., a tourist could be informed of the likelihood of a terrorist attack in a certain country before visiting it, but may also receive online summaries of current information through the US Traveler Enrollment Program).

had a low frequency (rare) possibility of a relatively costly outcome (-200), while in the safe area (denoted Area-S) the rare outcome was much smaller (-8). By contrast, in Problem 2, Area-R resulted in larger losses than Area-S about half the time.

Pressing a button in a given area generated an independent draw from the payoff distribution for that area. The green and blue colored areas were randomly assigned to Area-S and Area-R. Each participant performed both Problem 1 and Problem 2 in a counterbalanced order. In order to conform to the regularities of a spatial environment, where movement is rarely discontinuous but rather requires one to traverse one region to reach another region, choices were constrained to nine adjacent cells: the cell chosen at the previous trial plus the surrounding eight cells. These nine available choices were marked with a red background. Introducing this movement constraint also allowed us to set a default option in Experiments 2 and 3, whereby participants had to travel across a safe region for some time in order to enter the risky region.

To examine the effect of descriptive summaries, three information conditions were compared, which added differing amounts of feedback (over and above the payoff distribution information that all participants were shown). In the Descriptive-0 condition, no descriptive information was added at a given trial; players only saw the payoff from the selected button (presented on the button face). In the Descriptive-1 condition, on every other trial, players were shown the outcome of one randomly chosen cell in each of the two areas. Finally, in the Descriptive-130 condition, on every other trial, players were given summary information concerning the payoff from all of the 130 alternatives in each of the two areas (see examples below).

The payoff scheme of Problem 1 implies that both cumulative prospect theory and experience sampling predict fewer selections from Area-R in the Descriptive-130 conditions than in the baseline Descriptive-0 condition. This is because the Descriptive-130 condition provides a descriptive account of the rare events occurring on a given trial. By contrast, the frequency-based judgment model predicts that people will take more risk in the Descriptive-130 than in the Descriptive-0 condition. This is because under this model individuals receive information that for most of the risky area units, the rare negative event does not occur, and outcomes are advantageous. The gambler's fallacy account further implies that within the Descriptive-130 condition, more risk will be taken following rare events presented in the summary information for Area-R.

Additionally, we compared the effect of the descriptive summary of all outcomes, to a description of a single outcome from a randomly drawn alternative in each area (Descriptive-1 condition). In Problem 1, such single outcomes are more advantageous for Area-R than for Area-S in 199/200 trials. In a binary choice problem, this one-outcome information is reduced to the obtained and foregone outcomes (the foregone outcome is the outcome from the unselected alternative).<sup>4</sup> Previous studies that examined the effect of displaying foregone outcomes in addition to the obtained outcome have found that people show more accentuated underweighting of rare events with foregone outcomes, even as compared to the regular underweighting observed with obtained outcomes (e.g., Yechiam & Busemeyer, 2006; Yechiam et al., 2008). We refer to this phenomenon as “super-underweighting” of rare events. We expected that since the Descriptive-1

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<sup>4</sup> Technically, the Descriptive-1 condition is not exactly the same as a foregone outcome condition because there is a small probability that the information is from the selected option (rather than the unselected options).

condition conveys the advantage of the risky alternative in most trials (similar to a foregone payoff), people would exhibit super-underweighting of rare events in this condition as well (i.e., an elevated proportion of selections from Area-R compared to the Descriptive-0 condition in Problem 1). Note that under the frequency-based model the summary information in the Descriptive-130 condition is likewise more favorable for the risky area in practically all cases. This implies a similar extreme level of underweighting rare events in the Descriptive-1 and Descriptive-130 conditions.

Under all of these contrasting models, the predicted effects were expected to be minimized in Problem 2, where the risky alternative does not include rare negative events. Problem 2 thus controls for any risk-related effects of descriptive summaries that are not due to the underweighting and/or overweighting of rare events.

## Method

*Participants.* Eighty-nine undergraduate students from the University of Essex (26 males and 63 females) participated in the experiment. Their average age was 21 years, ranging from 18 to 35. They were paid a sum of £2.00 to £8.60 (median = £4.60) for their participation, depending on their success in the experimental task and a separate study that followed. Participants were randomly assigned to the three task conditions, with the Descriptive-130, Descriptive-1 and Descriptive-0 conditions having 30, 29 and 30 participants, respectively (with 21, 22 and 20 females, respectively). Four further participants completed the task but their data were incomplete due to technical reasons; and so their data were not analyzed.

*Procedure and Apparatus.* Participants were asked to read the on-screen instructions, and were encouraged to ask questions. The complete instructions appear in the Appendix. Briefly, participants were informed that their task was to select buttons in 200 trials and that they could only press the red colored buttons adjacent to their previous selection (which were updated on every trial). Additionally, they received an explanation concerning the area description and summary information (if relevant). The experimenter checked each participant's understanding of the task before allowing them to proceed.

Next, participants were asked to press the "Start the task" button. This presented the game (Figure 1). Players' initial position was the middle row and the column closest to the adjacent area. The starting area (Area-S or Area-R) was randomly determined for each participant. Payoffs were contingent upon the area chosen (Area-S or Area-R) and were calculated in each trial as per the instructions. Two types of feedback immediately followed each choice: (1) The payoff for the choice, which appeared on the selected button until the next button was selected, and (2) an accumulating payoff-counter, which appeared at the top of the screen.

The crucial difference between the Descriptive-1 and Descriptive-130 conditions was that the former provided a single (random) outcome for each area, whereas the latter gave a full summary of all outcomes in both areas. For example, in the Descriptive-1 condition an individual could have been informed that "A random press in the blue area got -1; a random press in the green area got -2" (see top panel of Figure 1). In contrast, in the Descriptive-130 condition an individual could have been told that "The blue area had 67 results of -1 and 63 results of -3; the green area had 130 results of -2 and 0 results of -8". This information was presented above each respective area (see bottom panel of

Figure 1). The task was self-paced, and the payoff feedback information remained until the participant made their next choice.

*Design.* The study used a  $3 \times 2 \times 8$  mixed design, with task condition (Descriptive-0, Descriptive-1, Descriptive-130) as a between-subject variable, and decision problem (Problem 1 vs. 2) and trial block of 25 trials as within-subject variables. The order of Problem 1 and 2 was counter-balanced. A Mixed Analysis of Variance (ANOVA) was used to analyze the results.

## Results

Figure 2 presents the proportion of selections from Area-R of the matrix in the two decision problems and three task conditions. Focusing on Problem 1, a marked increase in risk taking was observed for the Descriptive-130 and Descriptive-1 conditions compared to the Descriptive-0 condition. The mean proportion of risky selections in the Descriptive-130 and Descriptive-1 condition was higher by 34% and 39%, respectively. By contrast, in Problem 2 (frequent-loss risk) there was very little difference between conditions. The supplementary section presents the distribution of individual participants' choice proportions in all conditions. There were large individual differences across the central tendency but for conciseness we focus on the predicted group-level effects.

An analysis of variance conducted for both problems together showed the following significant effects. First, there was a main effect of decision problem ( $F(1, 86) = 30.87, p < .001$ ), with participants taking more risk when it included a rare negative event than for a frequent negative event (as in Newell & Rakow, 2007; Yechiam, Barron

& Erev, 2005). Secondly, there was a decision problem by block interaction ( $F(7, 602) = 5.47, p < .001$ ), marking the accentuation of this difference over time. Thirdly, we observed the expected interaction of condition by choice problem ( $F(2, 86) = 4.01, p = .02$ ). Specifically, for Problem 2 there was no significant difference between conditions ( $F(2, 86) = 0.36, p = .70$ ), whereas for Problem 1 this difference was significant ( $F(2, 86) = 4.06, p = .02$ ).

LSD tests showed that the effect of task condition in Problem 1 was due to the difference between the Descriptive-0 condition and the Descriptive-1 condition ( $p = .01$ ) and between the Descriptive-0 condition and the Descriptive-130 condition ( $p = .03$ ). There was no significant difference between the Descriptive-130 and Descriptive-1 conditions ( $p = .71$ ). Thus, the information summary afforded by the Descriptive-130 condition led to a similar increase in underweighting rare events as in the single payoff-description condition.<sup>5</sup>

In order to understand the mechanism leading to the extreme underweighting observed in the Descriptive-130 condition, we examined choices contingent on the different possible summaries of rare negative events. Specifically, we examined the response in trial  $t$  given different frequencies of the -200 outcome in trial  $t-1$ , and also given an initial safe or risky position in trial  $t-1$ . In order to calculate this, we examined trials where on trial  $t-1$  participants were positioned at the two columns closest to the adjacent area, thereby allowing them to move from the safe to the risky area or vice versa

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<sup>5</sup> To verify that these results are not due to the imposed spatial constraints we replicated Problem 1 in a smaller sample ( $n = 36$ ), using a version of the task where any button could be pressed at any time point. As previously, participants were randomly allocated into the three experimental conditions. In this setting the mean (SE) of risky selections in the Descriptive-0 condition was 0.52 (0.11), compared to 0.77 (0.05) and 0.81 (0.08) in the Descriptive-130 and Descriptive-1 conditions, respectively ( $F(2, 33) = 3.29, p < .05$ ). The learning curves appear in the supplementary section. These findings suggest that the increased risk taking in the Descriptive-1 and Descriptive-130 conditions was not due to the imposed movement constraints.

(see procedure). This constituted 51.0% of the trials of the experiment; consequentially, data were available for only 81% of the participants. The analysis was conducted for each participant, and then aggregated across individuals in the Descriptive-130 condition of Problem 1. The results are shown in Figure 3, which indicates that – inconsistent with the gambler’s fallacy account – there was no increase in risk taking upon being presented with a rare event. Instead, people took slightly *less* risk following the occurrence of one or more rare events than following no rare events, though this effect was marginal ( $F(1,20) = 3.14, p = .09$ ). There was virtually no difference in risk taking between trials following a single rare event and those following two or more rare events ( $F(1,15) = 0.38, p = .55$ ). Thus, participants seemed to process the summary Descriptive-130 information coarsely, with the presence of rare events leading to some decrease in risk taking level, but two or more rare events leading to similar levels of risk taking as for a single rare event.

We also similarly examined the Descriptive-1 condition, where there were fewer participants for whom the additional description included rare events ( $n = 11$  with one rare event,  $n = 4$  with more). When examining those who got a single rare event we find a similar pattern of reduced risk taking immediately following the rare event (for a rare event occurring on trial  $t-1$ ,  $P(\text{Area R})$  changed from 0.67 in trial  $t-2$  and trial  $t-1$  to 0.50 in trial  $t$ ). We also examined long term effects of this exposure for this small sub-sample, and found no differences between those trials before the first occurrence of a rare event and all subsequent trials ( $P(\text{Area R}) = 0.62$  and  $0.60$ , respectively).

## Experiment 2: Asymmetric information for safe and risky options

The next two experiments examined the robustness and boundary conditions of the findings observed in our initial experiment. In Experiment 1 participants exhibited extreme underweighting of rare events in the condition with a full summary of outcomes, as predicted by the proposition that people rely on frequencies of events when processing summaries. One could argue, though, that the apparent frequency-based judgment in the Descriptive-130 condition was facilitated by a simple strategy of counting afforded by the availability of a full summary both for the safe and risky sets of alternatives. Specifically, participants might have simply counted the number of cells for which the risky area was relatively favorable compared to the safe area. When summary information is available from both areas, one can tally the exact number of cells that are advantageous in the risky area relative to the safe area. In Experiment 2 we therefore provided information only from the risky set of alternatives, thereby disabling this simple counting strategy. The experiment used Problem 1 (above), but this time participants were forced to make their first nine selections from the safe area (by setting a starting position as far as possible from the border between areas), and summary information pertained only to the risky area. The pull of the summary information towards risk taking was therefore further counter-acted by a default position in the safe area (Samuelson & Zeckhauser, 1988).

### Method

*Participants.* Ninety-three undergraduate students at Indiana University (42 males and 50 females) participated in the experiment. Their average age was 21, ranging from 18 to 54. They were paid a sum of \$5 to \$10, depending on their success in the experimental task.

Participants were randomly assigned to the three experimental groups. Thirty-one participants were assigned to each of the three experimental groups, with an equal proportion of males and females in each condition.

*Procedure and Apparatus.* The procedure and apparatus were as in Experiment 1 with the following exceptions: First, in the Descriptive-1 and Descriptive-130 conditions information was only shown for Area-R. Second, the participants' initial position was set to the middle row and outer most column of Area-S.<sup>6</sup> Finally, since the study was run in the US, the currency was cents.

*Design.* The study used a  $3 \times 8$  between and within design, with task condition (Descriptive-0, Descriptive-1, Descriptive-130) as a between subject variable, and trial block of 25 trials as a within-subject factor.

## Results

Figure 4 presents the proportion of selections from Area-R in each of the three task conditions. As can be seen, though weaker, the difference between conditions was in the same direction as in Experiment 1, with both the Descriptive-130 and Descriptive-1 conditions elevating risk taking to a similar degree (by 22% and 17%, respectively).

An ANOVA showed that the effect of condition was marginally significant ( $F(2, 90) = 2.34, p = .096$ ). LSD tests showed that the only significant difference was between the Descriptive-130 and Descriptive-0 conditions ( $p = .03$ ) while the differences between

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<sup>6</sup> Due to this starting position, participants could not select from Area-R in the first 9 trials. These trials were therefore omitted from the first block.

the other two conditions were not significant (Descriptive-1/0:  $p = .12$ , Descriptive-1/130:  $p = .57$ ). Thus, the condition with complete descriptive summaries of outcomes in the risky region led to the most distinct underweighting of rare events in this experiment.

### Experiment 3: Asymmetric information, adverse risk

Experiment 1 and 2 focused on decision problems where the risky options had about the same expected value as the safe options. In the final experiment, we examined whether these results hold for a case where taking risk is disadvantageous. Indeed, one might argue that the increased risk taking due to descriptive summaries only emerges when the expected value are the same, but when the risky alternative is disadvantageous, the additional information afforded by the summary would have the reverse effect, namely towards less risk taking and more expected value maximization (see related findings in Grosskopf et al., 2006). To examine this possibility, Experiment 3 employed a variant of Problem 1 where the risky alternative was disadvantageous. Crucially, this is the kind of situation where one would seek to dissuade people from persisting with risky behavior.

### Method

*Participants.* Seventy undergraduate students at Indiana University (33 males and 37 females) participated in the experiment. Their average age was 22, ranging from 17 to 36. They were paid \$5 to \$14 for their participation, depending on their success in the task. Participants were randomly assigned to the three experimental groups. Twenty-four participants (11 males and 13 females) were assigned to the Descriptive-1 condition.

Twenty-three participants were assigned to each of the task conditions (with 11 males and 12 females in each group).

*Procedure and design.* The experimental settings were similar to those of Experiment 2, except for the use of a slightly modified decision task:

Problem 3: “Adverse rare-loss risk”

Area S: .005 probability of losing 8 pennies and a loss of 2 pennies otherwise

Area R: .005 probability of losing 300 pennies and a loss of 1 penny otherwise

This problem is almost identical to Problem 1 but for the fact that the highly negative outcome in Area-R was decreased from  $-200$  to  $-300$ . This reduces the expected value of selections in area R, which becomes approximately 25% lower than in area S ( $-2.495$  compared to  $-2.03$ ).

An additional change that was implemented is that the number of trials was increased to 400 to examine longer-term effects.

## Results

Figure 5 presents the proportion of selections from Area-R in each of the three task conditions. As can be seen, again the effect had the same trend as in Experiment 1. The Descriptive-130 and Descriptive-1 conditions increased risk taking beyond the Descriptive-0 condition in an approximately similar manner (by 16% and 22%, respectively) and this pattern was observed throughout the 400 trials.

An ANOVA showed that the effect of condition was marginally significant ( $F(2, 67) = 2.47, p = .093$ ). LSD tests showed that this time the only significant difference was between Descriptive-1 and Descriptive-0 conditions ( $p = .04$ ) while the differences between the Descriptive-130 condition and Descriptive-0 conditions did not reach significance ( $p = .12$ ).

Across Experiment 2 and Experiment 3 the effect of the Descriptive-130 and Descriptive-1 conditions were almost identical, as they increased the level of risk taking beyond the baseline (Descriptive-0) condition by 19% and 20%, respectively. To examine this statistically, we combined the data of the first 8 trial blocks of both experiments, while adding choice problem (which was different in each experiment) as an additional independent factor in the ANOVA. The results showed a close to significant effect of task condition across experiments ( $F(2, 157) = 2.99, p = .05$ ). LSD tests indicated that both the Descriptive-130 and Descriptive-1 conditions significantly differed from the Descriptive-0 condition ( $p = .02, p = .04$ , respectively), while these two conditions were not significantly different ( $p = .82$ ). There was no interaction between the choice problem (Problem 1 vs. Problem 3) and the effect of task condition ( $F(2, 157) = 0.29, p = .74$ ).<sup>7</sup>

## General Discussion

Across the three experiments reported here, adding summaries of information about recent outcomes accentuated the degree of risk taking in decisions from experience in the face of small probability losses. We further compared the effect of summary information

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<sup>7</sup> We also obtained a significant study by block interaction ( $F(1, 157) = 8.62, p < .01$ ), which is consistent with the observation that the learning rate of Area-R selections was steeper in Problem 1 than in Problem 3 (see Figures 3, 4).

from all alternatives to information from a single randomly determined alternative (in each choice set). We observed an equivalent degree of risk taking in the response to complete summaries as for information from single alternatives.

Our results from Experiment 1 further indicate that, other than differentiating between zero rare events and a single rare event, the number of rare events in the complete summary had little effect on participants' contingent responses. This finding suggests that while participants did not consistently use a majority vote rule, they did apply a rather coarse information processing strategy which treats small rates (above zero) in a similar manner. This conforms to the idea of a some-none gist in fuzzy trace theory (see Reyna & Brainerd, 1991; Reyna, 2012; Reyna, Chick, Corbin, & Hsia, 2014), under which people treat quantities in an identical manner unless there is a compelling reason to do otherwise, but they do differentiate those quantities from zero. Additionally, the mean contingent response to the number of rare events was in the direction of taking less risk, suggesting that the increased risk taking in the full summary condition was not because participants assumed that the risky region was a good bet if a bad event had just occurred (as the gambler's fallacy would prescribe) but, rather, was due to the common good outcome afforded by the risky alternative. This is consistent with the use of frequency-based judgments, under which individuals are oversensitive to frequent outcomes and underweight rare events.

The effect of summarized information in Experiment 1 did not pertain to risk taking in general. When about half of the cases in the summary of information for the risky region had advantageous outcomes, and the other half had disadvantageous outcomes, this did not have any significant effect on risk taking. Summarized information

only considerably increased risk taking when the common outcome in the risky region was advantageous.

In Experiment 2 we showed that this effect was not the result of using a simple counting strategy, as it was replicated when only descriptive information from the risky area was available. Moreover, in this experiment we created a strong default for the safe option, by giving players a starting position as far as possible from the risky area. Even so, participants showed an overwhelming preference for the risky option when provided with descriptive summaries.

In Experiment 3 we found that this effect was replicated when the risky alternative was disadvantageous in terms of its expected value. Specifically, in this experiment the risky alternative providing negative rare events had an expected value 25% lower than that of the safe alternative. Nevertheless, summary information also moved people towards risk taking. This suggests that the effect of the summary information also emerges in cases where alternatives have different expected values. Of course, given a large enough difference in expected value, the effect may diminish (see Reyna & Brainerd, 1991). Still, the impact of differences in expected value may be less apparent in situations involving small probabilities in light of the difficulty of reacting based on expected value in such cases (Kahneman & Tversky, 1979).

Taken together, the results show the limitations of predictions based on cumulative prospect theory and experience-sampling theories (e.g., Fox and Hadar, 2006) to a setting involving information summaries. Specifically, under the idea of experience-sampling, the underweighting of rare events depends on incomplete information concerning the choice outcomes due to limited sampling (cf. Rakow, Demes, & Newell,

2008). Contrary to this notion, the present studies have shown that in decisions from experience providing further correct information to the participants concerning the outcomes accelerated the tendency to underweight rare events. Possibly, this behavioral pattern may be different when descriptive summaries are presented without experience; and this is an interesting topic for further research. In particular, the frequency-based approach presented here predicts that summaries will increase the underweighting of rare events regardless of one's experience. Although we did not examine the role of summaries without experience, the difference between conditions in Experiment 1 and 2 (in the direction predicted by the frequency-based judgment model) appeared from the very first block of trials, suggesting that it may emerge with very little experience.

Our experiments focused on a decision environment in a spatial context. For this purpose, we used multiple choice alternatives distributed across visually segregated regions and constrained the movement to be between adjacent choice options. It could be argued, though, that these aspects reduce the generality of the findings. However, we replicated the pattern of effects found in Experiment 1 in a task without movement constraints (see Footnote 5). Additionally, the current task clearly replicates the underweighting of rare events commonly reported in the decisions from experience literature (especially in Experiment 3), and the results of the Descriptive-1 condition are consistent with the extreme underweighting found in binary tasks when information from the obtained and foregone options is presented (e.g., Yechiam & Busemeyer, 2006). We add that providing descriptive information summaries from multiple alternatives does not alleviate this latter tendency despite the fact that the participant is exposed to the complete distribution of events.

Our findings clarify a major limitation concerning the use of summarized information for the purpose of reducing risk-taking behavior. They suggest that a summary of information which includes the distributions of events is not likely to reduce risk taking in the face of rare hazards. Beron et al.'s (1997) examination of the Loma Prieta earthquake in northern California is considered a classic example for a paradoxical effect of information on insurance behavior. The common explanation for this effect is that before the incident, people over-estimated the level of earthquake-related risk. Here we have shown that in an abstract setting, summarized information alone produces extreme underweighting of rare events, even when decision makers are explicitly informed about prior risk levels.

## Appendix: Experimental instructions (for Problem 1)

“Your payoff in this experiment will be £12 minus your losses during the experiment. Losses will be accumulated during 200 trials. In each trial you will have to click a button. The payoff for your selection will appear on the button that you selected. You will immediately see a form with many buttons like the one in the picture below. You can press only the buttons in the red color, which represent the buttons that are close to where you clicked previously.” (An image of the screen was presented next in the instructions. The right blue side and left green side were randomly paired with Area-S and Area-R, and the instructions were modified in accordance).

“The form is divided into two squares, a blue area and a green area. The payoff for choosing a button in each area appears below the respective area. For example: Green side: Lose 8 pennies (probability of  $1/200$ ); lose 2 pennies otherwise. Blue side: Lose 200 pennies (probability of  $1/200$ ); lose 1 penny otherwise.”

Participants in the Descriptive-130 condition were further instructed as follows: “In addition, every two rounds you will see information about what is happening in the green and blue areas. This will appear in boxes above each area. The two boxes would indicate how many cells lost different amounts of money (e.g., lost 1) in the blue area and how many cells lost different amounts of money in the green area.”

For participants in the Descriptive-1 condition the last sentence was amended to: “For example, the box could say that a randomly chosen press of a button in the green area lost a certain number of points while a random press in the blue area lost a different number of points.”

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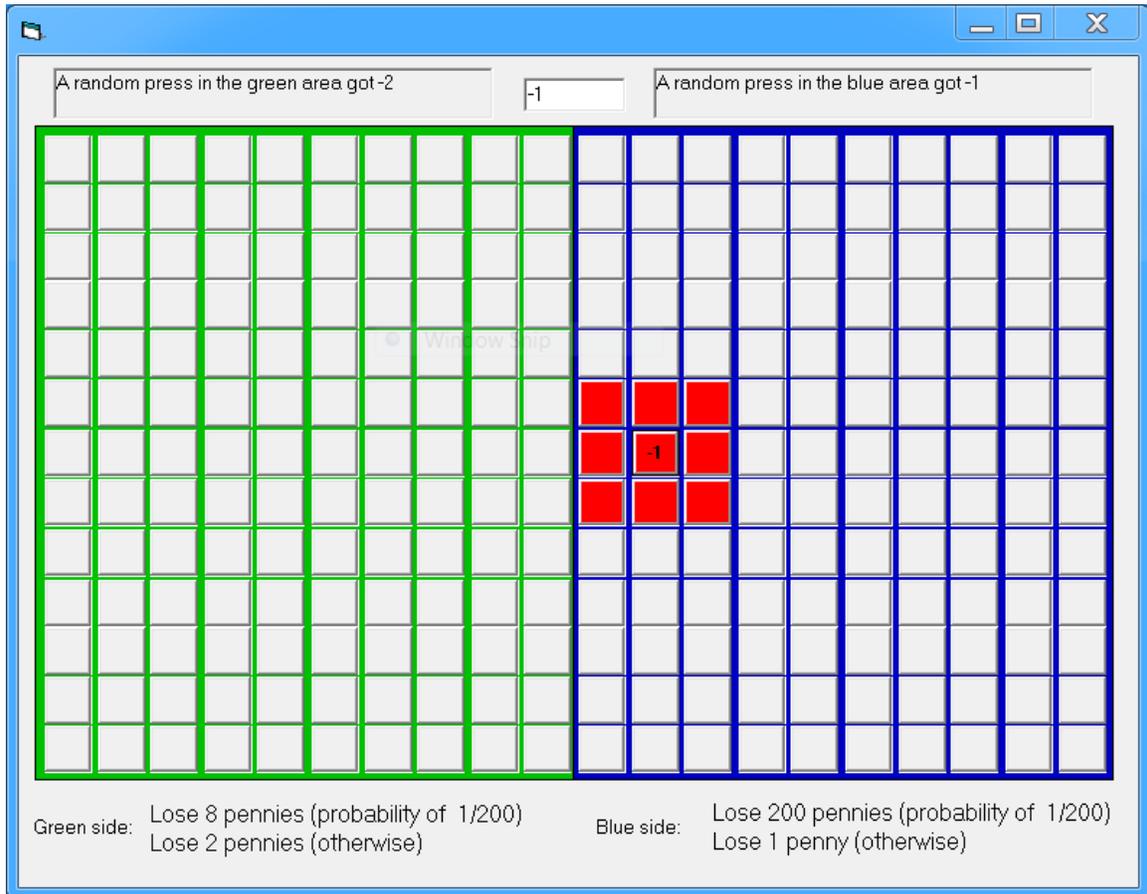
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Figure 1. A screen capture of the experimental task. In these examples the green area was set as Area-S and the blue area was set as Area-R. This pairing was randomized for each participant and kept constant throughout the task. The red cells denote the allowable selection positions. Information was obtained from the selected button and the accumulated payoff box (middle top of form). Additionally, descriptive information was available in some conditions. Top: A single outcome from each area in the Descriptive-1 condition (for Problem 1). Bottom: A summary of outcomes from each area in the Descriptive-130 condition (for Problem 2).



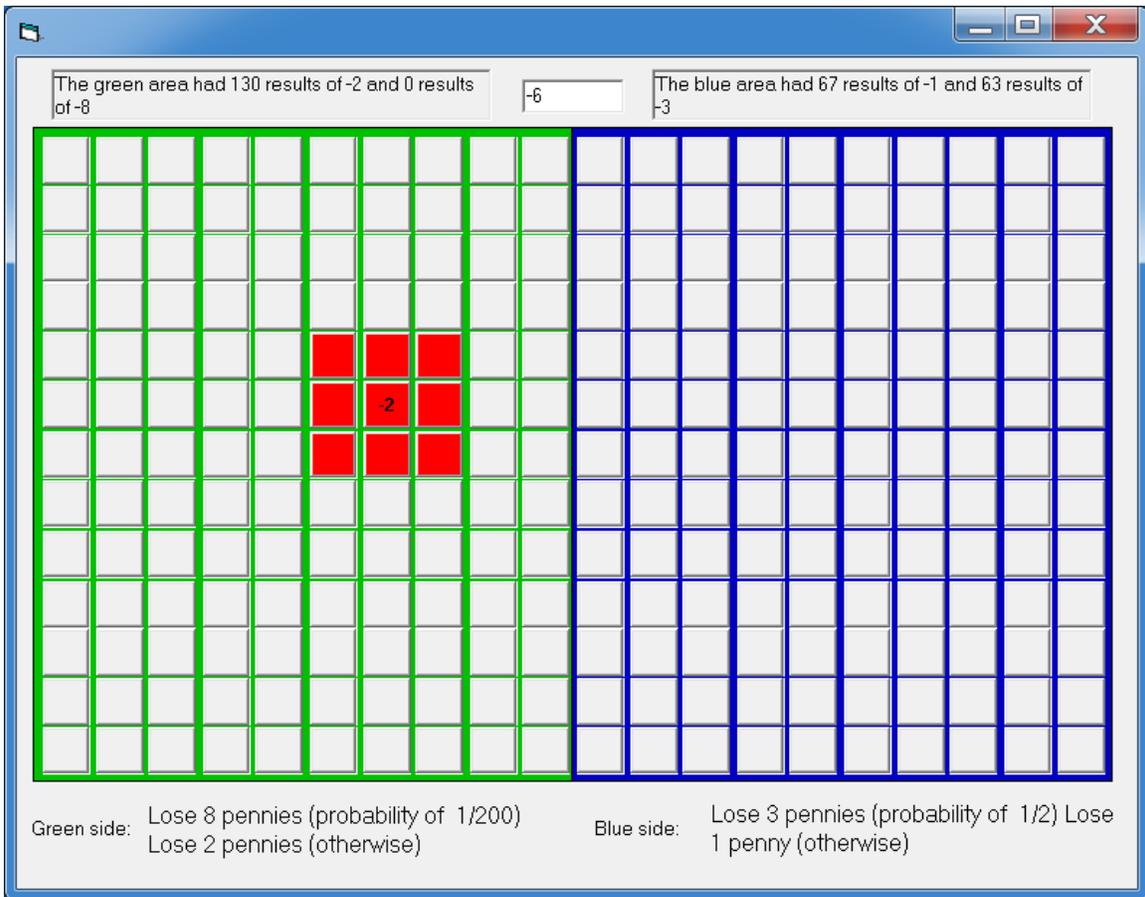
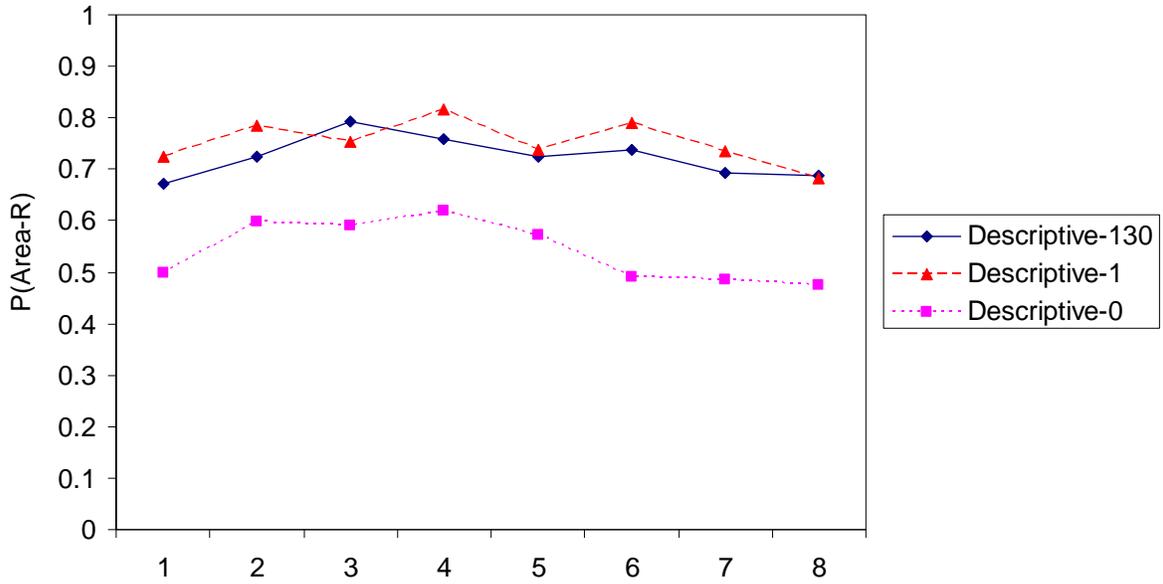


Figure 2. Experiment 1 results: Proportion of selections from Area-R (the set of risky options) as a function of experience (8 blocks of 25 trials) in the three experimental conditions and two choice problems.

Problem 1: Rare-loss risk



Problem 2: Frequent-loss risk

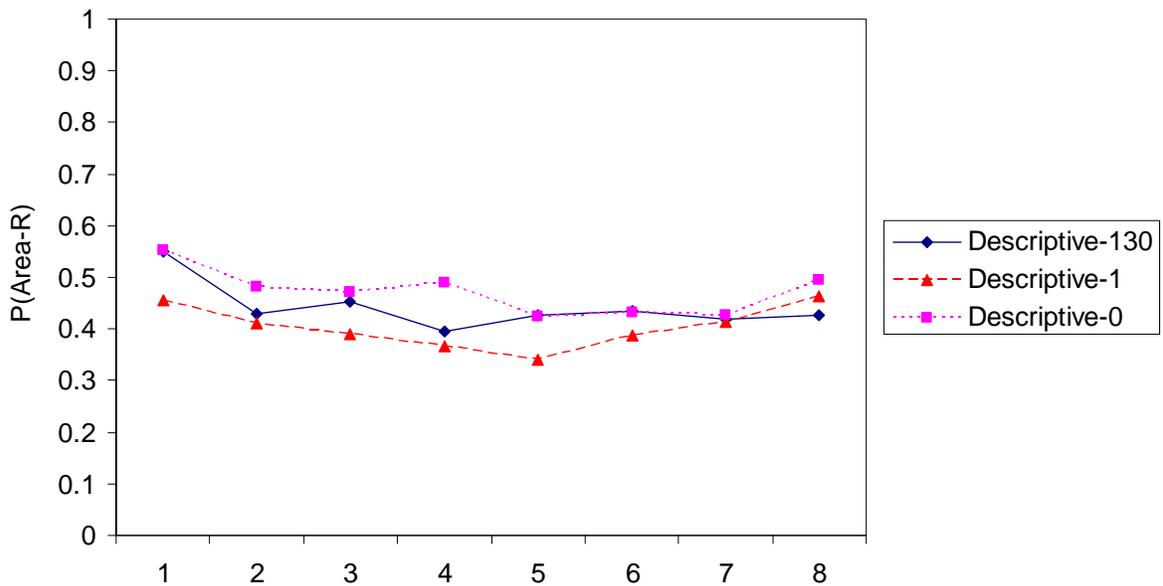


Figure 3. Analysis of contingent responses (proportion of Area-R choices on trial  $t$ ) in the Descriptive-130 condition as a function of the number of rare events in the summary information on trial  $t-1$ ; and the choice (safe or risky) on trial  $t-1$ . The error terms denote the standard error.

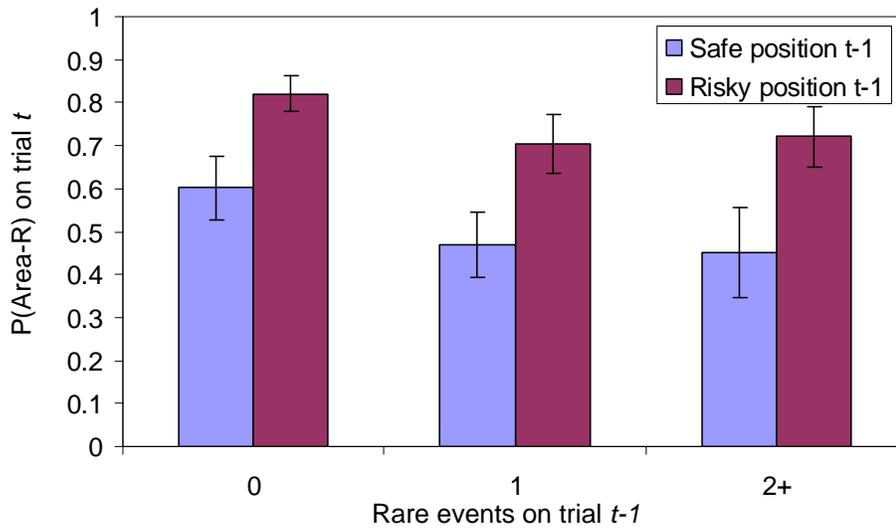


Figure 4. Experiment 2 results: Proportion of selections from Area-R (the set of risky options) as a function of experience (8 blocks of 25 trials) in the three experimental conditions.

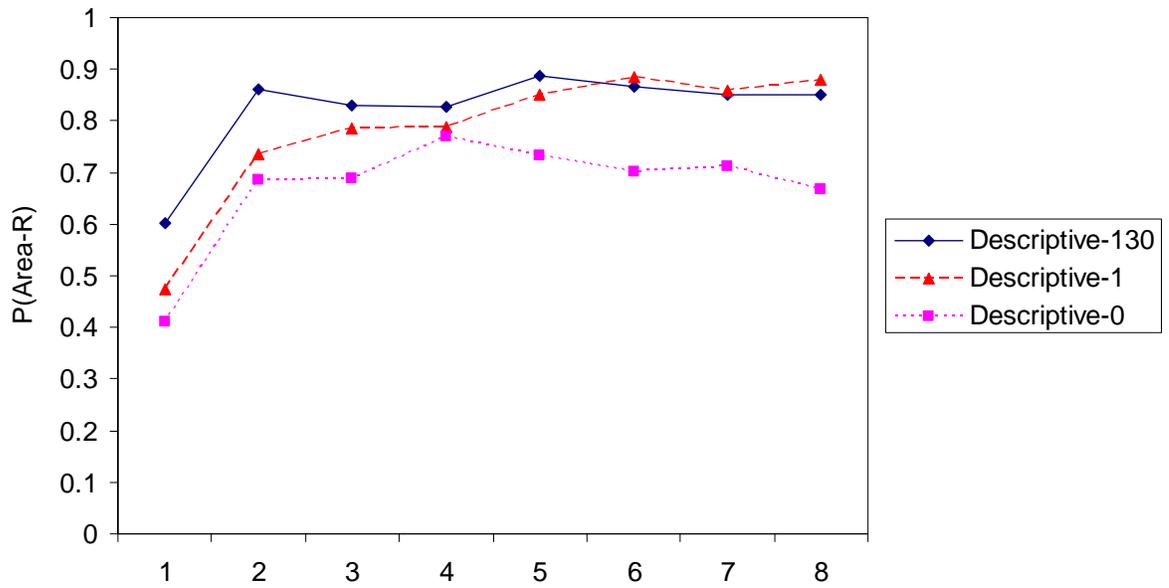


Figure 5. Experiment 3 results: Proportion of selections from Area-R (the set of risky options) as a function of experience (16 blocks of 25 trials) in the three experimental conditions.

