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The role of memory in distinguishing risky decisions from experience and description

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ABSTRACT

People's risk preferences differ for choices based on described probabilities versus those based on information learned through experience. For decisions from description, people are typically more risk averse for gains than for losses. In contrast, for decisions from experience, people are sometimes more risk seeking for gains than losses, especially for choices with the possibility of extreme outcomes (big wins or big losses), which are systematically overweighed in memory. Using a within-subject design, this study evaluated whether this memory bias plays a role in the differences in risky choice between description and experience. As in previous studies, people were more risk seeking for losses than for gains in description but showed the opposite pattern in experience. People also more readily remembered the extreme outcomes and judged them as having occurred more frequently. These memory biases correlated with risk preferences in decisions from experience but not in decisions from description. These results suggest that systematic memory biases may be responsible for some of the differences in risk preference across description and experience.

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Risk preferences often differ depending on whether people make choices based on described probabilities versus direct experience of the odds and outcomes. These differences have most often been shown in studies of risky choice involving rare events (e.g., Barron & Erev, 2003; Hertwig, Barron, Weber, & Erev, 2004), but are also sometimes present when the risky outcomes occur with equal probabilities (e.g., Ludvig & Spetch, 2011). Here, we evaluate to what degree risky choices in description and experience are driven by independent processes. In particular, we evaluate the role of memory biases in risky choice in these two domains.

When people make decisions from described probabilities, they tend to be more risk averse for gains than losses (e.g., Kahneman & Tversky, 1979). For example, given a choice between a guaranteed win of $20 or a 50% chance of winning $40, most people choose the guaranteed win. In contrast, when faced with a choice between a guaranteed loss of $20 or a 50% chance of losing $40, most people choose the gamble. This pattern of results (risk aversion for gains; risk seeking for losses) is known as the reflection effect.

When people make decisions from experienced outcomes, however, they sometimes show a reversal of this reflection effect and are more risk seeking for gains than for losses (e.g., Ludvig & Spetch, 2011). In decisions from experience, participants are often presented with two options and make repeated choices (i.e., a partial-feedback design; see Hertwig & Erev, 2009). The odds and outcomes of these options are initially unknown, but feedback is provided for the chosen option. As participants continue to make choices, they accumulate information about the outcomes of the options and can make subsequent choices based on these learned experiences. This design contrasts with the sampling procedure, where participants first learn about the outcomes from each option by sampling and then make a

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single consequential choice (e.g., Camilleri & Newell, 2011; Hertwig & Erev, 2009). In previous work with such a partial-feedback design, we showed that when these experienced risky options potentially lead to an extreme, but common, outcome (i.e., the highest and lowest outcomes in a context), people are more risk seeking for gains than for losses—the opposite of the usual reflection effect in description (e.g., Ludvig, Madan, & Spetch, 2014). Moreover, the degree of risk preference in both the gain and loss domains for these decisions from experience correlates with inter-individual differences in the memory for the extreme outcomes (Madan, Ludvig, & Spetch, 2014).

Most demonstrations that people behave differently in decisions from description and experience have used between-subject designs (e.g., Barron & Erev, 2003; Camilleri & Newell, 2011; Hertwig et al., 2004). These designs limit the evaluation of what factors differentially affect risk preference in description and experience within individuals. The few studies to date that have tested the same individuals with both types of decisions found similar patterns to those for the between-subject designs (Camilleri & Newell, 2009; Kudryavtsev & Pavlodsky, 2012; Ludvig & Spetch, 2011; Ungemach, Chater, & Stewart, 2009). For example, Camilleri and Newell (2009) observed a description–experience gap within subjects using a set of 10 problems, each with different odds and outcomes. Similarly, without any rare events, Ludvig and Spetch (2011) found that people exhibited a clear description–experience gap, despite repeatedly encountering the exact same gambles in the different information formats. In that experiment, in both description and experience, the risky options consisted of 50/50 gambles between the same outcome values. Such differences due to information format are not limited to humans: Individual monkeys have also been shown to exhibit differences in risk preference between described and experienced conditions (Heilbronner & Hayden, 2016).

Why does this difference in risk preference emerge between description and experience even within individuals? Hertwig and Erev (2009) suggested several possible reasons why experience and description might differ, including sampling error, recency effects, and estimation error. Other recent studies have investigated how different aspects of memory influence decisions from experience (e.g., Frey, Mata, & Hertwig, 2015; Gibson & Zielaskowski, 2013; Gonzalez & Dutt, 2011; Ludvig, Madan, & Spetch, 2015; Madan et al., 2014; Plonsky, Teodorescu, & Erev, 2015; Rakow, Demes, & Newell, 2008). For example, outcome recency generally impacts choice in decisions from experience, with more recent outcomes influencing choice more strongly (e.g., Frey et al., 2015; Hertwig et al., 2004; Madan et al., 2014; Rakow et al., 2008; but see Abdellaoui et al., 2011). Working memory capacity, however, seems to have little influence on decisions from experience in the sampling protocol (e.g., Frey et al., 2015; Wulff, Hills, & Hertwig, 2015a, 2015b). Here we focus on the potential role of a specific memory bias: a bias toward remembering the extreme outcomes (highest and lowest in a context). These extreme outcomes are overweighted in memory, and this overweighting correlated with risk preference in decisions from experience (e.g., Madan et al., 2014). These results suggest that some of the observed differences in risky choice between description and experience might be due to this memory bias.

Memory also probably plays a significant role in decisions from description. Many prominent theories of choice behaviour in decisions from description contain mechanisms related to memory sampling, such as the availability heuristic (Tversky & Kahneman, 1973, 1974), the decision-by-sampling framework (Stewart, Chater, & Brown, 2006), and query theory (Johnson, Häubl, & Keinan, 2007). Thus, one possibility is that a common underlying process—such as one related to an effect of extreme outcomes on valuation, probability estimation, or attentional capture—may influence both memory and choice in both decisions from description and those from experience. For example, in a series of studies, Yechiam and Hochman (2013) found that an attentional bias for loss outcomes influenced both decisions from description and those from experience. Similarly, some people may generally be relatively more attentive to extreme outcomes and thus both remember them better and weight them more heavily in decision making across both domains. As a result, a memory bias observed in decisions from experience may also appear in decisions from description. If instead this memory bias is specific to decisions from experience and is not caused by a common underlying process, then it should not correlate with risk preference in decisions from description.

Here, we used a large-scale within-subject design, testing both decisions from description and those from experience in the same subjects, where the risky outcomes occurred equiprobably (as in Ludvig

& Spetch, 2011). A partial-feedback procedure was used for the decisions from experience, where participants received feedback after each choice for the selected option. After the risky decision-making task, memory tests were administered to evaluate participants' ability to access information about the risky outcomes in decisions from experience, as well as their ability to estimate the frequency at which each outcome occurred (as in Madan et al., 2014).

We hypothesized that these memories for extreme outcomes might be one of the ways that decisions from experience and description differ from one another. Specifically, we predicted that people would show a memory bias in which the extreme outcomes would be more accessible in memory, and their frequency would be over-estimated relative to the equiprobable non-extreme outcomes, as has been found in our previous work (e.g., Madan et al., 2014). Importantly, for decisions from experience, we also predicted that a memory bias for the extreme gain outcome (i.e., for the best possible outcome in the decision context) would correlate positively with selection of the risky option on gain decisions and that a memory bias for the extreme loss outcome (worst possible outcome) would correlate negatively with selection of the risky option on loss decisions. That is, any bias toward over-remembering the best outcome would make the risky option on gain choices more attractive, and a bias toward over-remembering the worst outcome would make the risky option on loss choices less attractive. Memory was therefore separately tested for the risky gain and the risky loss, and these analyses were conducted separately in the gain and loss domains. Correlations between these memory measures and experience, but not description, would thus provide evidence for the unique importance of memory processes in decisions from experience.

Experimental study

Method

Participants

A total of 256 participants (146 females; $M_{age} = 19.3$, $SD = \pm 2.6$) were drawn from the University of Alberta psychology participant pool, and informed consent was obtained. Participants received course credit and a cash bonus for participating. Sample size was determined based on Schönbrodt and Perugini (2013), who demonstrated that, for typical psychological variables, correlations stabilize at $N = 250$. Participants were tested individually in enclosed rooms, but were recruited and briefed of the instructions in groups of up to 15. Procedures were approved by the University of Alberta Human Research Ethics Board.

Data for risk-related personality traits were also collected in a preceding online session that included questionnaires from a number of psychology laboratories at the University of Alberta; analyses incorporating those questionnaires are not reported here.

Procedure

The experiment consisted of five blocks of trials that alternated between two blocks with decisions from description and three blocks with decisions from experience. The extra block of decisions from experience was included because past research indicated that decisions from description remain relatively stable across blocks, whereas preferences develop over training for decisions from experience as the outcomes associated with each option are learned (Ludvig, Madan, Pisklak, & Spetch, 2014; Ludvig, Madan, & Spetch, 2014; Ludvig & Spetch, 2011).

Decisions from description. On each trial, people chose between pairs of described options, which were selected from four possible options: a fixed gain (+20), risky gain (0 or + 40, 50% chance of either), fixed loss (−20), and risky loss (0 or −40, 50% chance of either; see Figure 1A). Fixed options were displayed as text (e.g., "Win 20 points"), and risky options were displayed as pie charts. After a choice, the options disappeared, but no feedback was given.

Each block consisted of 52 trials and included a mixture of trial types: There were 32 *decision trials*, which required a choice between either the two gain options or the two loss options (16 of each). In both cases, the *fixed* option always led to the same outcome (+20 or −20), and the *risky* option led with a 50/50 chance to double the fixed outcome (+40 or −40) or nothing (0). There were 20 *catch trials,* which pitted a gain versus a loss or offered a choice between two gains or losses of different objective values (e.g., "Win 10 points" vs. "Win 20 points", or a pie chart depicting a 75% chance of losing −40 points vs. "Lose 20 points"). These catch trials were designed to ensure that participants were engaged in the task.

Decisions from experience. On most trials, people chose between pairs of doors, which were selected

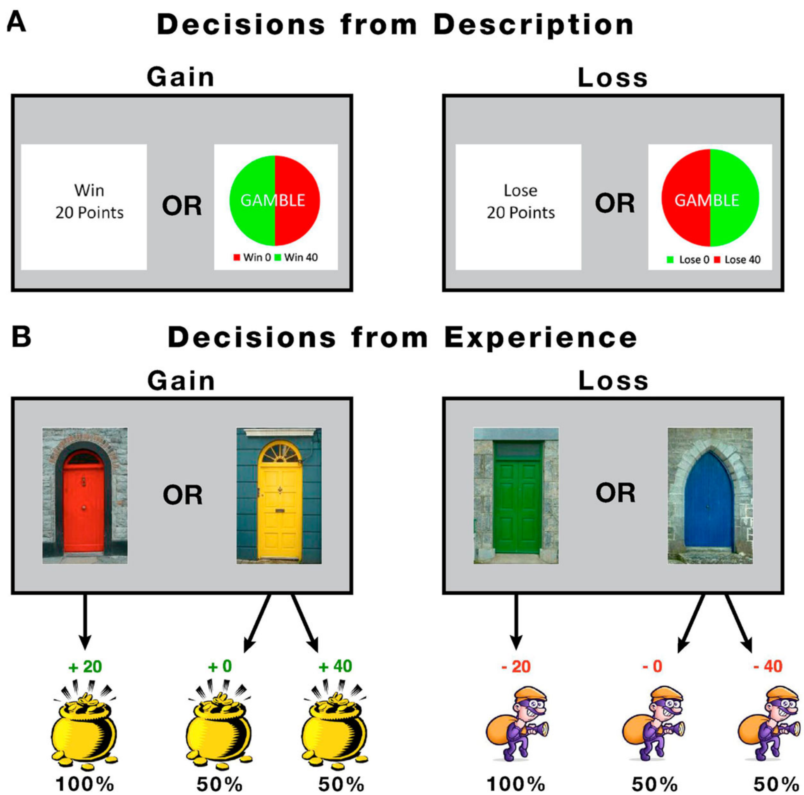

Figure 1. Example of decision trials. A. *Decisions from description* involved choices between described outcomes and probabilities. B. *Decisions from experience* involved choices between two gain or two loss doors. One door always led to a gain (or loss) of a fixed number of points, and the other door led equiprobably to one of two possible outcomes. Choices were followed by feedback about the amount gained (or lost). To view this figure in colour, please visit the online version of this Journal.

from four possible doors, which led to a fixed gain (+20), a risky gain (0 or + 40, 50% chance of either), a fixed loss (−20), or a risky loss (0 or −40, 50% chance of either; see Figure 1B). Participants could only learn about the odds and outcomes by selecting the doors. After a choice, the doors disappeared, and feedback appeared for 1.2 s for the chosen option. Feedback consisted of the points earned or lost along with an image of a pot of gold or robber, for gain and loss doors, respectively. Assignment of doors to particular outcomes was counterbalanced across participants.

Each experience block consisted of 56 trials and included a mixture of trial types: There were 32 *decision trials*, which required a choice between either the two gain doors or the two loss doors (16 of each). The *fixed* doors always led to the same outcome (+20 or −20), and the *risky* doors led with a 50/50 chance to double the fixed outcome (+40 or −40) or nothing (0). There were 16 *catch trials*, which required a choice between a gain door and a loss door. On 8 *single-door trials*, there was only one door, which had to be selected to continue. These trials guaranteed that all reward contingencies were experienced, even if the doors were initially unlucky, thereby limiting any hot-stove effects (Denrell & March, 2001).

Prior to the first block, participants were presented with 24 single-door trials to provide experience with the experimental procedure. For these trials, the outcomes associated with the risky doors occurred equally often, further preventing differences in initial experiences from influencing risk preferences (e.g., hot-stove or primacy effects). Within this block, each gain door appeared eight times and each loss door appeared four times, such that participants ended the block with a positive number of points.

In all blocks, trial order was randomized. Each door/option appeared equally often on either side of the screen. Performance of lower than 60% on catch trials in either decisions from description or experience across the whole experiment was used as an exclusion criterion, following established protocol from previous experiments (Ludvig, Madan, Pisklak et al., 2014; Ludvig, Madan, & Spetch, 2014; Ludvig et al., 2015; Ludvig & Spetch, 2011; Madan et al., 2014, 2015). Data from 18 of the 256 participants were thus excluded. Participants won or lost points on all trials and were paid $1 for every 300 points to a maximum of $5.

Memory tests. After the choice task, participants' memory for the outcomes associated with each door was tested in two ways. First, participants were shown the four doors in random order and were asked to report for each the first outcome that came to mind. Second, participants were again shown the four doors in random order and were asked to judge the frequency in percentage of each of the possible outcomes (−40, −20, 0, +20, +40). For each door, these five possible outcomes were displayed simultaneously, and participants typed a number from 0 to 100 below each outcome.

Results

Risk preferences

Figure 2A plots the mean proportion of risky choices in the final described and experienced blocks. Participants showed the usual reflection effect in description (more risk seeking for losses than gains), but a reversed reflection effect in experience (more risk seeking for gains than losses). These differences were corroborated through a 2 × 2 repeated measures analysis of variance (ANOVA) with decision type (description, experience) and outcome type (gain, loss) as factors. There was an interaction of decision type and outcome type, $F(1, 237) = 34.93$, $p < .001$, $\eta_p^2 = .13$, but no main effects [decision type: $F(1, 237) = 0.37$, $p = .55$, $\eta_p^2 = .002$; outcome type: $F(1, 237) = 0.37$, $p = .82$, $\eta_p^2 < .001$]. In decisions from description, participants were 8.7 ± 5.5% (M ± 95% CI) more risk seeking for losses than for gains, $t(237) = 3.10$, $p = .002$, Cohen's $d = 0.23$. In contrast, in decisions from experience, participants were 9.7 ± 5.2% more risk seeking for gains than for losses, $t(237) = 3.69$, $p < .001$, $d = 0.29$.

As intended, this result replicates the central finding from Ludvig and Spetch (2011). Similar results were found when only looking at choices on the first decision from description (see Appendix). We additionally examined risk preferences across blocks for both types of decisions as shown in Figure 2B. Individual risk preferences were consistent across the blocks—participants who demonstrated a large reflection effect in one block also did so in the other block of the same decision type (i.e., test–retest reliability) [description (Blocks 2–4): $r(236) = .69$, $p < .001$; experience (Blocks 3–5): $r(236) = .67$, $p < .001$].

Next, we tested the relationship between risk preferences in decisions from description and experience. First we examined the overall levels of risk preference (collapsed across gains and losses) for the two decision types. This analysis tested whether someone who was more risk seeking in description was also more risk seeking in experience. Figure 2C shows how there was a strong positive correlation between overall risk preferences for the two decision types, $r(236) = .51$, $p < .001$.

We further parsed these results by running separate correlations for gains and losses. As shown in Figure 2D, people who were more risk seeking for gains in description were also more risk seeking for gains in experience, $r(236) = .44$, $p < .001$; Figure 2E shows that this relationship also held for losses, $r(236) = .47$, $p < .001$. As is apparent in Figures 2D–2E, there was an overall shift in risk preference between gains and losses (i.e., the y-intercepts), but the relationship across individuals between risk preferences in description and experience was similar (i.e., the slopes).

Risk preference and memory

Next we examined performance on the memory tasks (first outcome and frequency judgment) and the correlations with risk preferences. To control for variability in the actual outcomes experienced, partial correlations were also calculated and reported; these measure the relationship between risk preference and memory independent of any effect of the actual outcomes experienced (see Madan et al., 2014). The partial correlations reported also controlled for risk preference in the other type of decision (description, experience) of the same outcome type (gain, loss). This refinement allows assessment of the relationship between memory and risk preference specifically in one type of decision, rather than more general risk preferences. All analyses were separately conducted for gains and losses as the memory tests queried gains and losses separately.

First outcome. Figure 3A shows how, when asked the first outcome to come to mind for the risky door, more people reported the extreme outcome (+40 or −40)

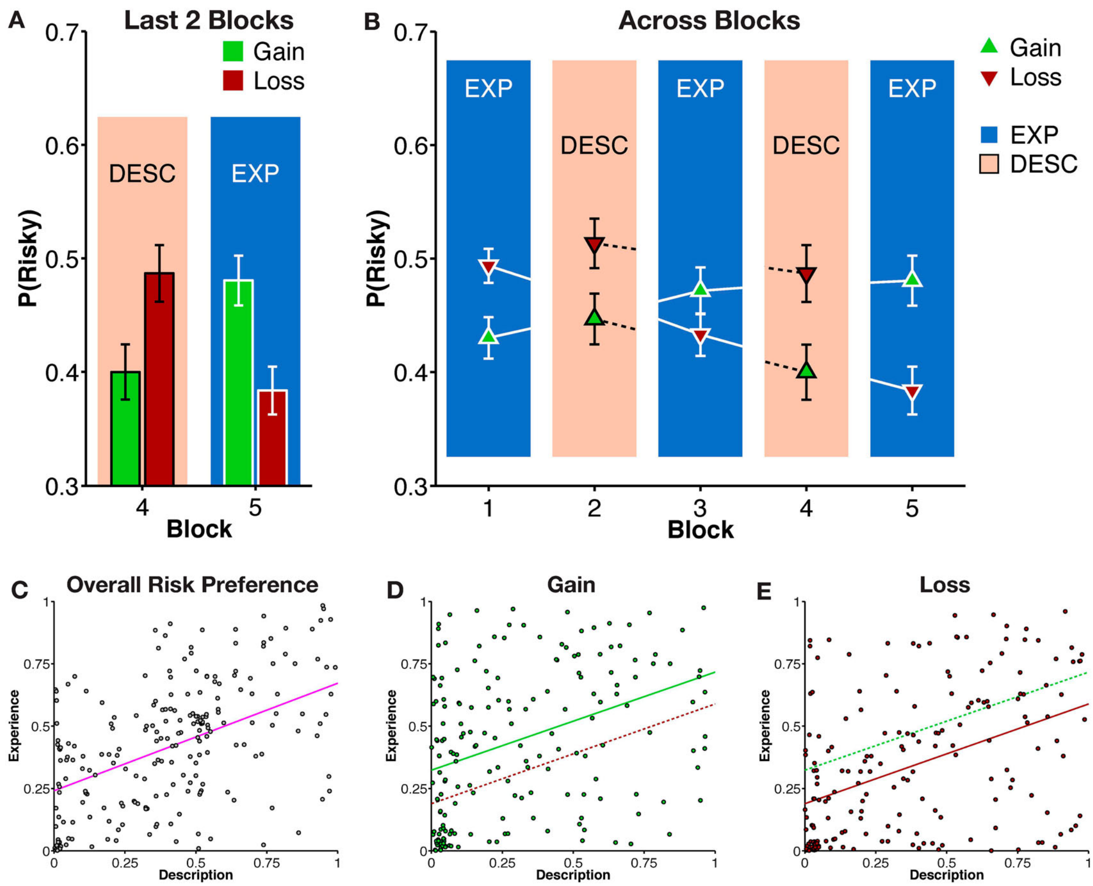

Figure 2. Risk preference results. A–B. Mean risk preference (±*SEM*) for gain and loss decision trials for both description and experience blocks, for the last two blocks of decisions (Panel A) and across all blocks (Panel B). C–E. Scatterplot of individual risk preferences for decisions from description and experience across participants, for overall risk preference (Panel C), only gains (Panel D), and only losses (Panel E). Each dot represents a participant; dot locations are jittered to reduce overlap. To view this figure in colour, please visit the online version of this Journal.

than the zero outcome for both gains, $\chi^2(1, N = 187) = 36.78$, $p < .001$, and losses, $\chi^2(1, N = 181) = 68.07$, $p < .001$.

Figure 3B plots risk preference in the last block of experience based on responses to this first-outcome question. For gains, people who reported +40 were 37.4 ± 9.6% more risk seeking than those who reported 0, $t(185) = 7.70$, $p < .001$, $d = 1.24$, even after controlling for outcomes experienced and risk preference in description, $r_p(183) = .40$, $p < .001$, and for losses, people who reported −40 were 28.8 ± 10.4% less risk seeking than those who reported 0, $t(179) = 5.30$, $p < .001$, $d = 1.00$; $r_p(177) = -.29$, $p < .001$. Figure 3C plots risk preference in the last block of description based on participants' first outcome reported. For both gains and losses, there were consistent, but weaker, relationships between the first-outcome question and risk preference in description [gains: $t(185) = 2.85$, $p = .005$, $d = 0.45$; losses: $t(179) = 2.76$, $p = .006$, $d = 0.52$]. These effects, however, were eliminated with the partial correlations that controlled for risk preference in experience [gains: $r_p(183) = -.02$, $p = .75$; losses: $r_p(177) = -.05$, $p = .49$].

Next, we more specifically tested for a relationship between memory and the difference in risk preference between the two decision types (i.e., the description–experience gap), separately for gains and losses. As this measure is based on differences between risk preferences in decisions from description versus experience, it is not affected by inter-individual differences in overall risk preference. For gains, participants who reported +40 had a 20.8 ± 11.7% larger description–experience gap than those who reported 0, $t(185) = 3.51$, $p < .001$, $d = 0.56$; $r_p(184) = .21$, $p = .004$. For losses, participants who reported −40 had a 9.4 ± 13.8% larger description–experience gap; however,

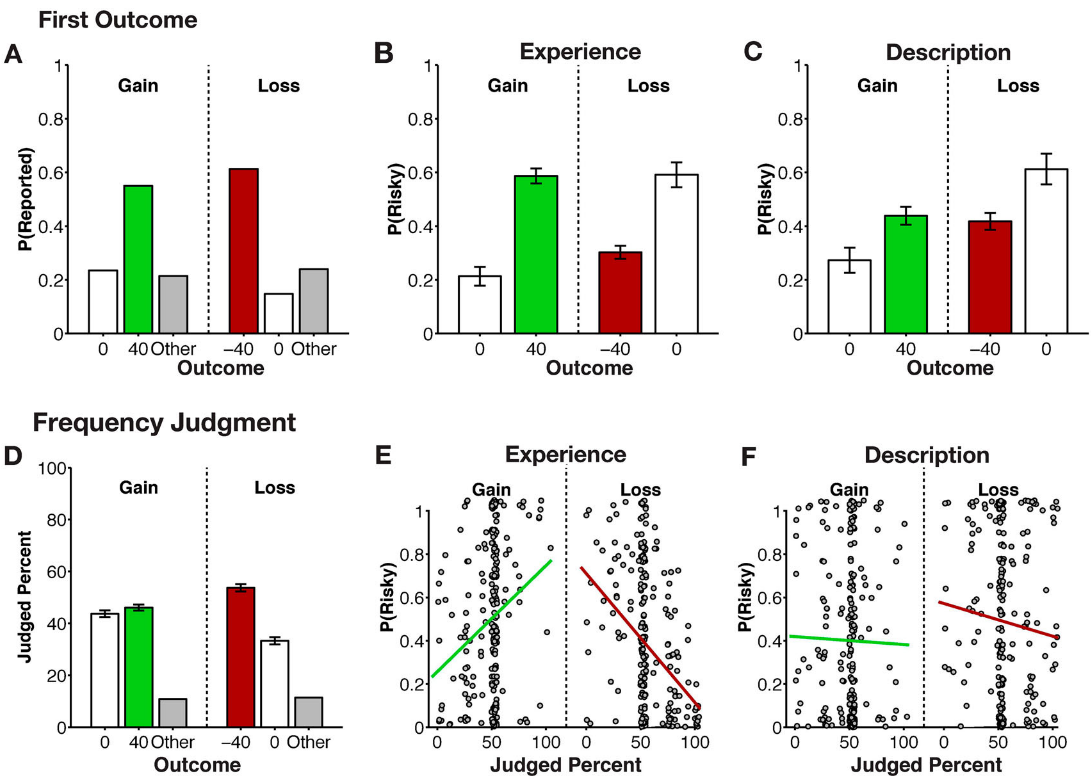

Figure 3. Results from the memory tests. A. Proportion of participants who responded with ±40, 0, or neither in the first-outcome questions. B. Mean risk preference (±*SEM*) for gains and losses in the last block of experience trials, split on the basis of what the participant reported to the first-outcome question. C. Mean risk preference (±*SEM*) for gains and losses in the last block of description trials, split on the basis of what the participant reported to the first-outcome question. D. Mean judged percentage (±*SEM*) for the ±40 and 0 outcomes from the frequency judgment question. For simplicity, all other values were coded as "Other". E. Scatterplot of risk preference in the last block of experience trials and frequency judgment responses for the gain and loss doors. F. Scatterplot of risk preference in the last block of description trials and frequency judgment responses for the gain and loss doors. Note that the frequency judgments are for the stimuli from the experience trials, but the risk preference is from the description trials. For the scatterplots, each dot represents an individual participant; dot locations are jittered to reduce overlap. To view this figure in colour, please visit the online version of this Journal.

this difference was not significant, $t(179) = 1.35$, $p = .18$, $d = 0.25$; $r_p(178) = -.08$, $p = .30$.

Frequency judgments. Ten additional participants with total frequencies above 150% were excluded from this analysis.

Figure 3D shows frequency judgments for the risky doors. On gain trials, participants judged the +40 outcomes as occurring only 2.4 ± 4.1% more frequently than the 0 outcome, $t(227) = 1.13$, $p = .26$, $d = 0.12$. On loss trials, however, participants judged the −40 outcome as having occurred 20.4 ± 4.7% more frequently than the 0 outcome, $t(227) = 8.59$, $p < .001$, $d = 0.97$.

Figure 3E plots risk preference in the last block of experience trials against frequency judgments for the extreme outcomes (+40 or −40). For gains, risk seeking increased with the judged frequencies of +40, $r(226) = .26$, $p < .001$, whereas for losses, risk seeking decreased with the judged frequency of −40, $r(226) = -.39$, $p < .001$. When controlling for outcomes experienced and risk preferences in description, both effects persisted [gains: $r_p(224) = .26$, $p < .001$; losses: $r_p(224) = -.35$, $p < .001$]. Figure 3F plots risk preference in the last block of description trials against frequency judgments for the extreme outcomes (+40 or −40). Risk preference in description was not directly correlated with judged frequency of the experience outcomes [gains: $r(226) = -.02$, $p = .79$; losses: $r(226) = -.08$, $p = .21$]. When controlling for outcomes experienced and risk preference in experience, the partial correlations were small in magnitude [gains: $r_p(224) = -.16$, $p = .014$; losses: $r_p(224) = .12$, $p = .077$], and in the opposite direction to the correlations with risk preference in experience (and the plotted lines in Figure 3F).

The observed description–experience gap also correlated with the judged frequency of the experienced outcomes for risky gains, $r(226) = -.26$, $p < .001$; $r_p(224) = -.16$, $p = .014$. For risky losses, while the relationship was initially statistically significant, the correlation was no longer significant after accounting for inter-individual differences in the outcomes experienced, $r(226) = .26$, $p < .001$; $r_p(224) = .059$, $p = .38$. Thus, memory responses for the risky gain door using both first-outcome reported and frequency judgment correlated reliably with the description–experience gap, but neither memory measure for the risky loss door was reliably related to the size of the description–experience gap.

Correspondence between memory tasks

Both memory tasks aim to measure memory for the outcomes from the risky doors, but it is unknown how closely these two measures correspond. We therefore examined whether differences in the first outcome provided led to different frequency judgments for the respective extreme outcome. For gains, participants who reported +40 provided a 12.3 ± 5.8% higher frequency judgment for +40, $t(177) = 4.19$, $p < .001$, $d = 0.69$; $r_p(176) = .24$, $p < .001$. For losses, there was also a correspondence between frequency judgments and first-outcome reported. People who reported −40 provided a 14.8 ± 7.3% higher frequency judgment for −40, $t(173) = 4.01$, $p < .001$, $d = 0.76$; $r_p(172) = -.25$, $p < .001$.

As can be observed from Figure 3E, many participants reported the veridical exact frequency of the outcomes for the risky doors (50/50). Out of the 228 participants who were included in the frequency judgment analyses, 140 (61.4%) correctly reported 50/50 odds for gains, and 124 (54.4%) did so for losses; 103 participants (45.2%) correctly reported 50/50 odds for both gains and losses. Nonetheless, as shown in Figure 4A, these participants also showed the same memory biases in the first-outcome question: For gains, 27/140 participants reported 0, and 79 participants reported +40 as the first outcome, $\chi^2(1, N = 106) = 25.51$, $p < .001$ (34 participants reported neither); for losses, 81/124 participants reported −40, and 13 participants reported 0, $\chi^2(1, N = 94) = 49.19$, $p < .001$ (30 participants reported neither).

These individuals also showed the same difference in risk preference between description and experience as the full sample. Figure 4B plots the risk preferences for the sub-sample of 103 participants that correctly reported 50/50 for both gains and losses. These participants still demonstrated the usual reflection effect in description and reversed reflection effect in experience. Again, these differences were corroborated through a 2 × 2 repeated measures ANOVA with decision type and outcome type as factors. There was an interaction of decision type and outcome type, $F(1, 102) = 14.83$, $p < .001$, $\eta_p^2 = .13$, but no main effects [decision type: $F(1, 102) = 2.26$, $p = .14$, $\eta_p^2 = .02$; outcome type: $F(1, 102) = 0.08$, $p = .78$, $\eta_p^2 < .001$], confirming a significant description–experience gap. In decisions from description, participants were 7.2 ± 8.9% more risk seeking for

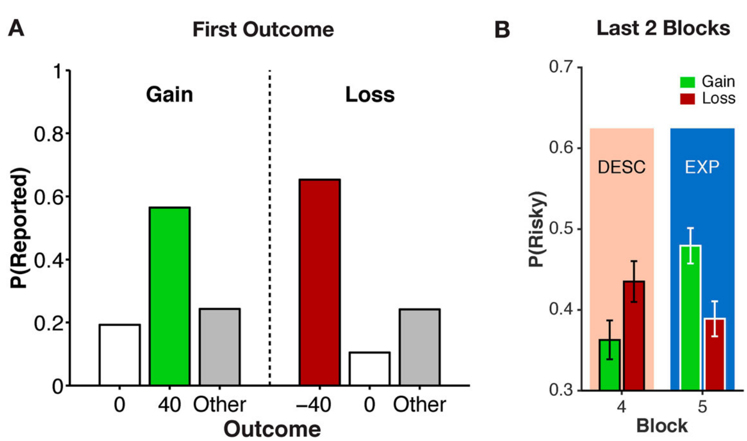

Figure 4. Results for the participants who responded 50/50 in the frequency judgment question. A. Proportion of participants who responded with ±40, 0, or neither in the first-outcome questions. B. Mean risk preference (±*SEM*) for gain and loss decision trials for both description (DESC) and experience (EXP) blocks, for the last two blocks of decisions. To view this figure in colour, please visit the online version of this Journal.

losses than for gains, though this difference was not statistically significant, $t(102) = 1.60$, $p = .11$, $d = 0.19$. In decisions from experience, participants were 9.0 ± 6.7% more risk seeking for gains than for losses, $t(102) = 2.63$, $p = .010$, $d = 0.27$.

Discussion

In this study, by analysing individual differences in a within-subject design, we found that memory biases correlated with risk preferences in decisions from experience, but not description. The relationship between memory and decisions for experience supports a number of current theories, which suggest that the valuation of options is related to a memory sampling process, including the decision-by-sampling framework (Stewart et al., 2006), query theory (Johnson et al., 2007), instance-based learning (Gonzalez & Dutt, 2011), and the drift-diffusion model (Ratcliff & Smith, 2004). The importance of memory in value-based decision-making is also supported by neuroimaging and patient studies (see Palombo, Keane, & Verfaellie, 2015; and Shohamy & Daw, 2015, for recent reviews). Specifically, it has been found that the hippocampus, a brain region critical to the formation of integrated memory episodes, also plays an important role in a variety of decision-making tasks.

Here, we present clear empirical evidence for this important role for memory in decision making, but with some boundary conditions. In the task, participants made decisions from both description and experience, yet inter-individual variability in memory biases were only related to decisions from experience. This divergence makes sense because the odds of each potential outcome are explicitly stated in decisions from description, whereas in decisions from experience, the odds of each outcome can only be assessed through memories of past experiences.

Unlike most studies of the description–experience gap, which tend to focus on rare events (e.g., Hertwig et al., 2004; Hertwig & Erev, 2009), this study did not involve any rare events. All the risky options here (both described and experienced) led to one of two equiprobable outcomes, yet there was still a clear difference in risk preference. With all outcomes following the risky options occurring 50% of the time, concerns about an asymmetric sampling error potentially driving the gap (e.g., Fox & Hadar, 2006) are muted. In addition, this distribution of outcomes is already the maximum entropy distribution, so the differences between experience and description cannot be due to regression toward the mean (e.g., Glöckner, Hilbig, Henninger, & Fielder, 2016). This point is especially notable amongst the subset of participants who correctly articulated the 50/50 distribution for the risky options in experience, yet still showed a difference in risk preference between description and experience (see Figure 4B). The correlations with memory raises the interesting possibility that other aspects of the description–experience gap, such as rare-event weighting, may also be partly determined by memory biases. Indeed, prior studies have suggested that a bias toward remembering recent outcomes does influence choice in sampling-based protocols (e.g., Hertwig et al., 2004; Rakow et al., 2008; Wulff et al., 2015a; but see Abdellaoui, L'Haridon, & Paraschiv, 2011).

Our findings suggest that different processes underlie decisions from description and experience, which is convergent with results from recent modelling competitions (e.g., Erev et al., 2010; see also Hau, Pleskac, Kiefer, & Hertwig, 2008). In those competitions, different, non-overlapping models produced the best fits to decisions from description (modified prospect theory) and experience (small-sample, instance-based model). These competitions, like most of the literature, used aggregate data across different groups of individuals in description and experience. A similar distinction occurs with the DOSPERT risk-attitude questionnaire (Blais & Weber, 2006), where scores correlate with risk preference in decisions from description, but not decisions from experience (Camilleri & Newell, 2009).

Another recent study examined individual differences in a series of 40 different decisions from description and 10 different decisions from experience (Kudryavtsev & Pavlodsky, 2012). They fit distinct valuation models to the data for decisions from description (prospect theory; Kahneman & Tversky, 1979) and experience (expectancy-valence model; Busemeyer & Stout, 2002) and found that loss-weighting parameters were relatively consistent within individuals across the decision types. No other parameters, however, were reliably correlated between description and experience in their sample.

In addition to distinct, memory-related differences between decisions from description and experience, we also found evidence of a common underlying process. People who were more risk seeking in one decision type were generally more risk seeking in the other decision type. These commonalities were observed both in overall risk preference (Figure 2C) and separately in risk preference for gains and losses (Figures 2D–2E). Moreover, this commonality occurred despite the presence of overall differences in risk preference between decisions.

Less is known about the nature of these shared processes. Numerous processes could be common to decisions from description and experience, including loss weighting (Kudryavtsev & Pavlodsky, 2012), probability estimation, option valuation, risk sensitivity, and/or evidence accumulation. Further research is required to disentangle exactly which psychological processes underlie the shared component of risk preference across description and experience. Providing some direction, Kudryavtsev and Pavlodsky (2012) found that despite different models providing the best fits for decisions from description (prospect theory) and experience (expectancy-valence model), there was consistency in that loss weighting parameters were correlated between the two models across individuals, suggesting a shared process. A consistent loss weighting across description and experience, as found by Kudryavtsev and Pavlodsky (2012), could account for some but not all of the present results. In particular, there was a significant correlation even for choices that only involved gains (Figure 2D). Thus, these findings suggest the commonalities between description and experience extend beyond loss weighting alone.

The experimental procedure used here, however, potentially inflated the degree of commonality between decisions from description and experience. Specifically, the experiment was designed to minimize the procedural differences between the two types of decisions. For example, the same outcome values were used, and the two types of decisions were alternated in blocks. Thus, it is quite plausible that participants were more aware that they were making the same decisions in both domains. As such, participants may have attempted to be more consistent in their risk preferences across decisions from description and experience. Indeed, the different patterns of risky choice that emerged for decisions from description and experience are all the more striking given these procedural commonalities.

Because the experiment involved probing memory after the choice task was completed, we cannot conclude that the memory biases causally drive choice behaviour in decisions from experience. In recent work, however, using a similar procedure, we found that presenting outcome-related cues prior to a decision can prime participants to make riskier choices (Ludvig et al., 2015). Priming effects on risky choice have also been demonstrated by others using varied procedures (e.g., Erb, Bioy, & Hilton, 2002; Gibson & Zielaskowski, 2013; Newell & Shaw, in press), demonstrating that memory accessibility is related to choice behaviour and can play a causal role.

Many psychological mechanisms have been proposed to account for the gap between risky decisions from description and experience, but, thus far, there has been limited evidence for their operation. Here, we provide clear empirical evidence that a memory bias for extreme outcomes uniquely influences decisions from experiences, possibly driving one aspect of the description–experience gap. Future work will need to determine the involvement of memory processes in other aspects of the description–experience gap, such as the relative weighting of rare events, as well as the proximal mechanisms through which memories influence choice.

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Appendix

First decision from description

In the task, participants made repeated decisions from description, rather than presenting multiple problems with only a single trial of each. This task made decisions from description procedurally more comparable to decisions from experience. There is evidence, however, that choices in repeated decisions from description can differ from choices where only a single choice is made (Barron & Erev, 2003; Keren & Wagenaar, 1987; Lejarraga & Gonzalez, 2011; Lopes, 1981). To determine whether the first described choice was consistent with subsequent described choices, the data were re-analysed using only the first choices that participants made for the gain and loss description decisions.

On the very first described gain trial, 42.4% of participants selected the risky option, whereas 56.7% of participants selected the risky option on the very first described loss trial, recapitulating the refection effect observed across all trials [McNemar's $\chi^2(1, N = 238) = 9.80$, $p < .01$]. Choices on these first decisions were highly consistent with the mean risk preference in the last block of the decisions from description. On gain trials, participants who selected the risky option on the first decision were 22.7 ± 9.3% more risk seeking in the last block, $t(236) = 4.82$, $p < .001$, $d = 0.64$. On loss trials, participants who selected the risky option on the first decision were 25.9 ± 9.4% more risk seeking in the last block, $t(236) = 5.44$, $p < .001$, $d = 0.71$. In terms of the correspondence between decisions from description and experience, in the gain domain, participants who chose the risky option on their first description trial were 14.5 ± 8.6% more risk seeking in the experience trials than those that chose the safe option, $t(236) = 3.32$, $p < .01$, $d = 0.44$. This correspondence, however, was not statistically significant in the loss domain, where participants who chose the risky option on the first description decision were only 4.3 ± 8.4% more risk seeking in the corresponding experience trials, $t(236) = 1.01$, $p = .31$, $d = 0.13$.