BRIEF REPORT

Priming Memories of Past Wins Induces Risk Seeking

Elliot A. Ludvig
University of Warwick

Christopher R. Madan and Marcia L. Spetch
University of Alberta

People are often risk averse when making decisions under uncertainty. When those decisions are based on past experience, people necessarily rely on their memories. Thus, what is remembered at the time of the choice should influence risky choice. We tested this hypothesis by priming memory for past outcomes in a simple risky-choice task. In the task, people repeatedly chose between a safe option and a risky option that paid off with a larger or smaller reward with a 50/50 chance. Some trials were preceded by a priming cue that was previously paired with one of the outcomes. We found that priming cues associated with wins caused people to become risk seeking, whereas priming cues associated with relative losses had little effect. These results suggest that people can be induced to be more risk seeking through subtle reminders of previous winning experiences.

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In decisions under uncertainty, people are typically risk averse for gains, preferring, for example, a guaranteed $50 over a 50/50 chance at $100 (Kahneman & Tversky, 1979). If people repeatedly make such choices, however, the decisions they make can be sensitive to their memories of past outcomes (Weber, Goldstein, & Barlas, 1995; Weber & Johnson, 2006; Madan, Ludvig, & Spetch, 2014). These memory effects should be particularly acute for decisions from experience, in which the outcomes and odds are not explicitly described; instead, all information must be gleaned from the reward history (Hertwig & Erev, 2009; Ludvig & Spetch, 2011). In such decisions from experience, strong memory biases

do indeed develop, and these biases correlate with risky choice (Ludvig, Madan, & Spetch, 2014; Madan et al., 2014). Here, we show that explicitly priming memories for recent winning outcomes can induce people, who are ordinarily risk averse, to exhibit risk seeking in decisions from experience.

One prominent strand in modern theories of risky choice is that people make decisions by internally sampling from the possible outcomes for each option at choice time (e.g., Busemeyer & Townsend, 1993; Biele, Erev, & Ert, 2009; Ratcliff & Smith, 2004; Stewart, Chater, & Brown, 2006). For example, in Decision-by-Sampling (DbS), these samples are used to guide a decision process by successively comparing their relative ranks (Stewart et al., 2006; Stewart, 2009). Similarly, in Decision Field Theory (DFT), sequential samples are accumulated as evidence until a threshold is reached triggering a decision (Bhatia, 2014; Busemeyer & Townsend, 1993). Query Theory also relies on a conceptually similar mechanism, whereby buying/selling decisions are made through the sequential enumeration of positive and negative aspects of the options in the transaction (Johnson, Häubl, & Keinan, 2007).

These sampling theories are further bolstered by evidence that, in making decisions, people only take into account a subset of their past experience (Hertwig & Erev, 2009) and are sensitive to the real-world distribution of outcomes (Stewart, 2009; Pleskac & Hertwig, 2014). Moreover, when integrating new information about well-learned options, preferences only shift incrementally as though a sampling process is driving any revaluation (Gershman, Markman, & Otto, 2014). This internal sampling process shares a goal with the explicit sampling observed in decisions from experience (Hertwig & Erev, 2009; Hills & Hertwig, 2010): Both processes serve to gather information to guide future choice, but from different sources. The internal sampling retrieves information from memory, whereas explicit sampling gathers information from the environment.

Sequential sampling processes also have a strong biological grounding, serving as key models for choice in the brain (e.g., Gold & Shadlen, 2007). Moreover, these mechanisms that drive decisions from experience seem to be phylogenetically widespread. Many non-human animal species, from bees to pigeons to monkeys, show similar patterns of choices to humans on a variety of risky-choice tasks (e.g., Hayden & Platt, 2009; Heilbronner & Hayden, 2013; Ludvig, Madan, Pisklak, & Spetch, 2014; Weber, Shafir, & Blais, 2004).

This reliance on sampled outcomes opens the possibility that the sampling could be biased, leading to changes in risky choice. Indeed, Stewart, Reimers, & Harris (in press) recently showed that changing the skew in the distribution of experienced outcomes shifts risk preferences. Our previous work also provided support for the notion that sampling can be biased. In particular, we showed that, in decisions from experience, people's memories for past outcomes were biased toward the most extreme outcomes in the context, and their risk preference correlated with these memories (Ludvig, Madan, & Spetch, 2014; Madan et al., 2014). This possibility of memories biasing what is sampled also gains support from recent work in neuroscience, showing that the degree of hippocampal memory activation correlates with how strongly a rewarded item influences later choice (Wimmer & Shohamy, 2012).

Here, we attempt to establish a more causal link between memory and choice through associative priming (e.g., Meyer & Schvaneveldt, 1971; Schreuder, Flores d'Arcais, & Glazenborg, 1984). Though associative priming is typically evaluated through implicit memory tests—here we extend the procedure to manipulate risky choices. To do so, we first establish associative links between neutral images and the different possible outcomes in a simple risky-choice task (see Figure 1). We then explicitly manipulate which outcomes are most accessible to memory at choice time through priming with the different neutral images and evaluate the effects on risky choice.

Methods

Participants

Eighty-six participants (63 females; mean age = 19.4 ± 1.6 sd) were drawn from the University of Alberta introductory psychology undergraduate subject pool, and informed consent was obtained. All research procedures were approved by the University of Alberta Human Research Ethics Board. In the absence of a suitable estimate of expected effect size, the sample size was derived from a previous study using a similar protocol (Madan et al., 2014). The number was picked to meet or exceed the 72 participants in Experiment 2 of that paper. Participants were each tested individually in enclosed rooms, but were recruited and briefed of the instructions in groups of up to 15. In advance, we set a fixed number of groups to recruit, which, from prior experience with this subject pool, we knew would be sufficient to collect at least 72 participants, though we could not know exactly how many participants would show up. To avoid any possibility of inadvertent p-hacking, data were sealed and not examined until data collection was complete.

Procedure

Participants completed the task on Windows computers running E-Prime 2.0 (PST Inc., Sharpsburg, PA). Figure 1A illustrates the core task. On each trial, people chose between two doors, which were selected from the four possible doors in the experiment. Three doors always led to a fixed gain (0, 40, or 80 points), and the fourth, risky door led to a 50/50 chance of 20 or 60 points. Selections were made through a mouse click. After selection of a given door, the doors disappeared and feedback appeared for 1.2 s. The feedback consisted of the amount earned along with an image of a fruit—a different one for each of the five possible outcomes (0, 20, 40, 60, or 80 points). Assignment of fruit images and doors to particular outcomes was randomly counterbalanced across participants.

The experiment was divided into five runs, totaling 304 trials. The first run was a training run and consisted of 64 total trials split among three types: 16 *decision trials* pitted the safe 40-point door against the risky door that yielded a 50/50 chance of 20 or 60 points, and 16 *catch trials* pitted two doors of unequal objective value against one another (e.g., 0 vs. 40). Finally, 32 *single-door trials* (8 for each door) were included to ensure adequate exposure to the reward contingencies and the associations between the fruit images and outcomes. On these trials, only one door appeared, and participants had to click on that door to continue, receiving the same 1.2 s of reward/image feedback. The number of trials was selected so that each door would be paired equally often with each other door and would appear equally often on both sides of the screen.

The remaining four runs each consisted of 60 trials. As in the first run, there were 16 decision trials and 16 catch trials, but now only eight single-door trials. The remaining 20 trials were *primed decision trials*. These trials were identical to the decision trials, except that, prior to the appearance of the two doors,
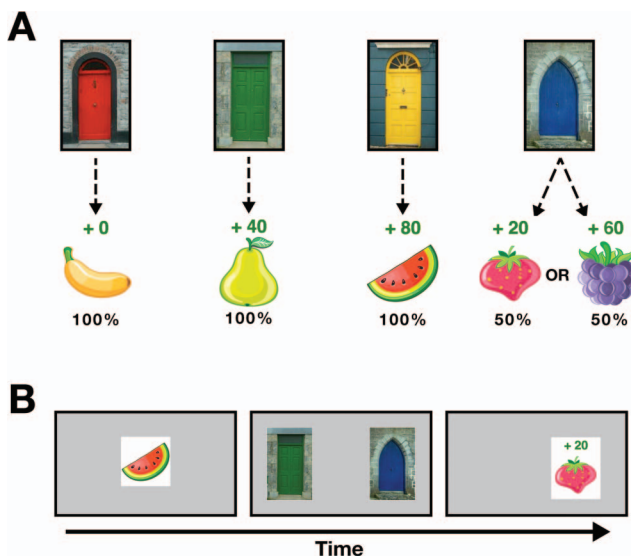

Figure 1. Experiment design (**A**). On most trials, participants were shown two doors selected from a set of four. Each door led to a different outcome: a fixed 0, 40, or 80 points or a 50/50 chance at 20 or 60 points. Each outcome was paired with a fruit image. Some trials were primed with a fruit image immediately preceding presentation of the doors and the opportunity to choose. (**B**). Screenshots from the time course of an example primed decision trial. First, the prime appears; then the choice stimuli are presented, and a selection is made, followed by feedback about the reward received with associated fruit image. See the online article for the color version of this figure.

one of the fruit images (without its associated outcome) was displayed in the center of the screen for 0.5 s. Each of the five fruit images primed four of these decisions per run. Runs were separated by a brief break. At the end of the experiment, participants' explicit recall of the outcome values associated with each fruit image and door was assessed by asking which outcome was the first to come to mind for each image. In addition, for the doors, people were asked to explicitly judge the frequency of each outcome.

Across the experiment, the outcomes for the risky door (20 or 60 points) were randomly shuffled, such that every 20 selections of the risky door was guaranteed to have each outcome occur 10 times. The trial order was randomized in each run. Performance of lower than 60% on catch trials across the whole experiment was used as an exclusion criterion, following the established protocol from previous experiments (Ludvig, Madan, Pisklak et al., 2014; Ludvig, Madan, & Spetch, 2014; Madan et al., 2014). The data from two participants were thus excluded; none of the major conclusions are altered if the data from these participants are included. At the end of the experiment, one trial was selected at random for realization. Participants were paid $1.25 for every 20 points they earned on that trial, up to a maximum of $5.

The critical comparisons were between baseline decision trials without a prime and decision trials preceded by a prime. We expected that presentation of the 60 or 20 prime would facilitate recall of past instances where the risky door led to that outcome. Thus, people would be more risk seeking after the 60 prime and more risk averse after the 20 prime. The other fruit primes served as a control for nonspecific effects, and presentation of these primes was not expected to systematically alter decisions. Statistical results are reported as unstandardized effect sizes in units of percentage chosen with corresponding 95% confidence intervals (Cumming, 2014). In addition, for completeness, inferential statistics for null-hypothesis significance testing are reported (calculated with SPSS v21; IBM Inc., Armonk, NY).

Results

Figure 2 (left) shows how people were generally risk averse when not primed, picking the risky option $41.1 \pm 5.7\%$ of the time. As predicted, people were considerably more risk seeking after observing the 60 prime, picking the risky option 15.7 ± 4.8 percentage points more often than when not primed (Figure 2, right; $t(83) = 6.41$, $p < .001$, Bonferroni corrected, Cohen's $d = .59$). The 60 prime even induced outright risk seeking with people selecting the risky option on average $56.8 \pm 5.9\%$ of the time, $t(83) = 2.28$, $p = .025$, $d = .25$. This risk seeking induced by the 60 prime increased slightly over the experiment from $52.9 \pm 7.3\%$ to $60.7 \pm 7.3\%$, $t(83) = 1.96$, $p = .053$, $d = .24$. The 80 prime also induced an increase of 4.5 ± 3.0 percentage points over baseline ($t(83)$ 2.90, $p < .001$, $d = .17$), but that increase was 11.2 ± 4.4 percentage points smaller than that induced by the 60 prime, $t(83) = 4.94$, $p < .001$, $d = .42$. Contrary to expectation, the 20 prime yielded no change in risk sensitivity ($0.0 \pm 3.7\%$; $p = .98$, $d = .0015$). The remaining two primes (0 and 40) also did not induce any change from the unprimed baseline ($0.7 \pm 3.4\%$; $0.0 \pm 3.3\%$; both p's>.1, d's <.03).
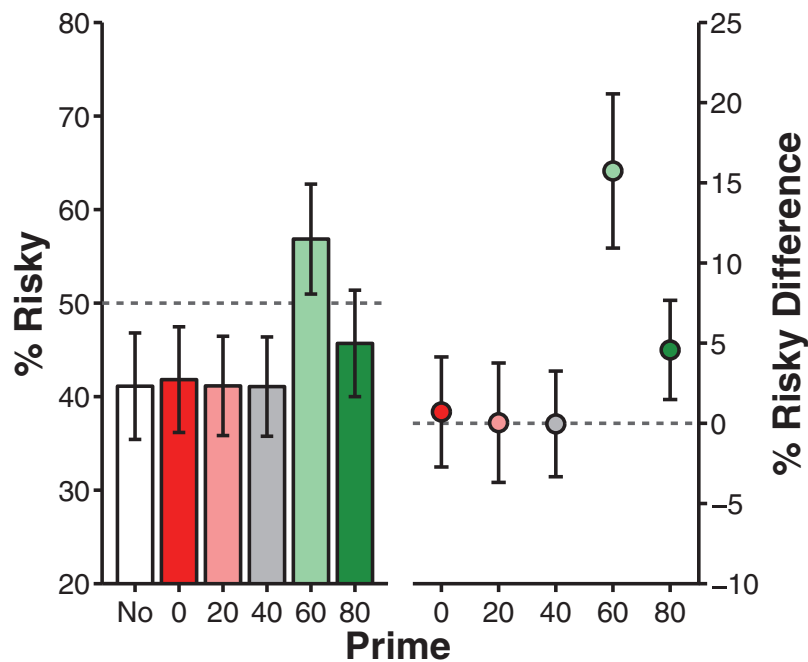

Figure 2. Mean percent of risky choice for all prime conditions (left axis) and mean difference from the no-prime condition (right axis; ± 95% confidence intervals). People were generally risk averse but were more risk seeking when primed with positive outcomes. When primed with the winning outcome (60), people were over 15% more likely to select the risky option than with no or low primes. See the online article for the color version of this figure.
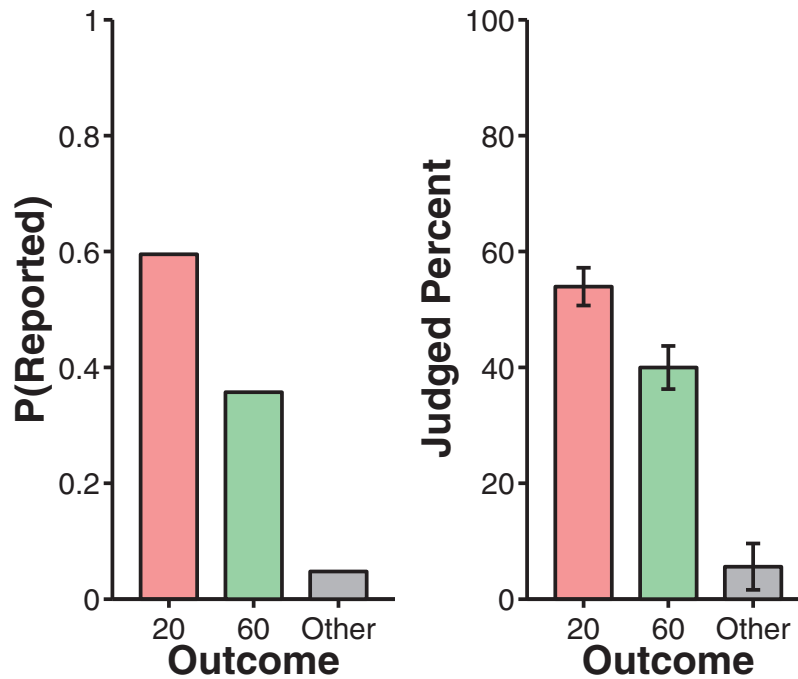
Figure 3. Results from memory tests for risky door. A higher proportion of people reported the losing outcome (20) as the first outcome to come to mind (left), and, on average, people reported the same losing outcome (20) as having occurred more frequently (right panel; ± 95% confidence intervals). See the online article for the color version of this figure.

Post experiment, people correctly remembered the outcome associated with the fruits 93.1 ± 3.7% of the time. Figure 3 shows how for the risky option, participants were both more likely to report 20 as the first outcome to come to mind ($\chi^2(1, N = 80) = 5.00$, $p = .025$) and judged the risky option as leading to 20 more frequently than leading to 60, $t(83) = 4.78$, $p < .001$, $d = .86$, even though the experiment led to both items equally often as planned, $t(83) = 0.24$, $p = .81$, $d = .03$.

Discussion

In this experiment, we demonstrated that associatively priming memories for recent outcomes can shift people to be risk seeking in a simple risky-choice task. Reminders of past wins increased the likelihood of gambling by around 15 percentage points, but reminders for past losses did not alter risk preference. This asymmetry may arise because, when faced with the risky option, people were already focused on the losses, akin to loss aversion (Kahneman & Tversky, 1979; Tom, Fox, Trepel, & Poldrack, 2007; Yechiam & Hochman, 2013). As a result, without any reminders or with only reminders of past losses, people were moderately risk averse (see Figure 2). Indeed, when queried afterward, people more often reported the losing outcome for the risky option and overestimated its frequency (see Figure 3). They could, however, be nudged toward greater risk seeking by reminders of past winning outcomes from the risky option. This finding builds on recent work, which showed how risky decisions from experience are susceptible to memory biases, such as the tendency to remember extreme outcomes (Lieder, Hsu, & Griffiths, 2014; Madan et al., 2014; Redelmeier & Kahneman, 1996).

These results have considerable implications for theories of decision-making. For theories that rely on sequential sampling, such as DbS (Stewart et al., 2006) or DFT (Busemeyer & Townsend, 1993), these results suggest that the sampling process need not be veridical and can be manipulated through explicit cues. Alternatively, within Query Theory, queries are ordered such that the negative aspects of an item to be chosen are considered before the positive ones (Johnson et al., 2007). In the context of this study, this ordering implies that, for the risky option, the negative aspect (a 20-point outcome) is considered before the positive aspect (a 60-point outcome), leading to overall risk aversion. The positive priming stimuli, however, may have reversed the order of the queries, such that the positive 60-point outcome is more likely to be considered first, leading to risk-seeking behavior.

Two features of our results argue against the alternative possibility that participants treated the prime as a predictive or instructional cue about which outcome was about to occur. First, if this were true, the low-value (20) prime should also serve as an instructional cue, leading to increased risk aversion on those trials. This increase did not occur; the 20 prime had no significant effect on choice. Second, if participants interpreted the 60 prime as an instructional cue, it should have a diminished effect over time as participants realized that the prime was not predictive of trial outcome. Instead, the risk seeking induced by the 60 prime increased over the session despite the lack of any predictive relationship between the prime and the outcome of the choice on that trial.

In this study, both the above-average primes (60 and 80) led to increased risk seeking, though the effect was much larger with the 60 prime than the 80 prime (see Figure 2). The general increase with

above-average primes is congruent with several possible interpretations. For example, the above-average primes may set a high expectation for that trial, thereby creating a framing effect (Tversky & Kahneman, 1981). This high expectation would cause both options to be perceived as losses, which would make people more risk seeking, as in Prospect Theory (Kahneman & Tversky, 1979). Similarly, people may have relied on a simple heuristic that the above-average primes cued generic good outcomes, independent of identity, leading to more risk seeking. Finally, according to risk-sensitivity theory, animals gamble more when needing to get above a certain minimum threshold for survival or reproduction (Stephens, 1981; Kacelnik & Bateson, 1996). Applied to this experiment, the above-average prime may have induced a transiently high target threshold for people, leading them to be more risk seeking.

Although providing plausible explanations for the general increase with both the 60 and 80 primes, all three of these interpretations fail to explain why the effect was much bigger with the 60 prime. Indeed, the increase of the 60 prime over the 80 prime is about twice the size of the increase of the 80 prime over no prime (see Figure 2). This aspect of the data is more congruent with an increased likelihood to retrieve the 60-point outcome from memory, as in the sequential sampling theories (e.g., Stewart et al., 2006; Busemeyer & Townsend, 1993), and not explicable by a possible framing effect, the use of a good-outcome heuristic, or risky-sensitivity theory.

These results provide a striking example of how memories can bias risky choice. They further suggest that the memory sampling process often presumed to underlie risky choice (Biele et al., 2009; Bhatia et al., 2014; Busemeyer & Townsend, 1993; Stewart et al., 2006) does not necessarily sample veridically from past experience, but can be swayed by reminders of past outcomes.

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