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FlashReport

The evolution of decision-making under risk: Framing effects in monkey risk preferences

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ABSTRACT

When making choices between risky options, human decision-makers exhibit a number of framing effects. One of the most prominent framing effects is the tendency for decision makers to evaluate gambles relative to a reference point, and to act risk-seeking when prospects are framed as losses but risk-averse when identical prospects are framed as gains. This tendency for risk-preferences to reverse between loss and gain frames has been termed the *reflection effect*, and is one of the primary predictions of Prospect Theory. Here, we explore whether non-human primates exhibit a similar reflection effect. Using a token-trading task, we show that capuchin monkeys (*Cebus apella*) exhibit an analogous reversal of risk preferences depending on whether outcomes are presented as gains or losses, suggesting that similar framing effects also influence choice in non-human primates. This finding suggests that the mechanisms that drive framing effects in humans may be evolutionarily ancient, extending broadly across the primate order.

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Introduction

Considerable empirical effort in human decision-making has been devoted to the question of how individuals judge the value associated with a variable, or risky, prospect. A large body of studies has demonstrated that decision-makers systematically violate the predictions of expected-utility theory in response to payoff-irrelevant framing effects (Gilovich, Griffin, & Kahneman, 2002; Hastie & Dawes, 2001; Kahneman & Tversky, 1979; Kahneman, Slovic, & Tversky, 1982; Tversky & Kahneman, 1981). In one famous example, Tversky and Kahneman (1981) presented participants with a scenario (Fig. 1A) in which subjects faced a hypothetical choice between two methods to combat a deadly disease: one was a safe bet, and the other was a risky strategy. When the two outcomes were described in terms of the number of people who would die, participants were risk-seeking, preferring Program B to Program A. Surprisingly, when presented with consequentially-identical options described in terms of the number of people who would be saved, subjects preferred to be risk-averse, typically preferring Program C to Program D. Participants were therefore risk-averse when dealing with gains, but risk-seeking when the same problem was presented to emphasize losses. This *reflection effect* has been observed in important real-world market anomalies, even when financial stakes are high. Most notably, stock-market investors have a tendency to hold assets that have declined in value and sell assets that have appreciated. This reluctance for

investors to realize losses is known in finance as the disposition effect (Odean, 1998). Additionally, house sellers have been shown to leave their houses on sale longer when market prices are currently below their buying price (Genesove & Mayer, 2001). Both of these examples have been attributed to asymmetric risk-preferences over gains and losses, suggesting that this bias does not disappear as stakes increase and is present in important market settings.

Although most researchers agree that humans display risk-preferences reversals when outcomes are framed differently, a less-researched but nevertheless central question is how these preference-reversals arise in the first place. One possibility is that such preference-reversals are an artifact of the populations typically studied by researchers interested in risk-preferences. Although economists have traditionally viewed preferences as stable across cultures and invariant across experimental contexts (Becker, 1976), it is nevertheless an open question whether specific sets of experiences are necessary in order to observe preference biases such as reversals of risk preferences. Put another way, is it possible that experience throughout a decision-maker's lifetime — exposure with risk-taking, familiarity with financial markets, or other aspects of modern economic settings — might have led to these behaviors? If this were the case, then researchers might find that preference-reversals do not exist among individuals with radically different cultural backgrounds than those typically asked to participate in studies.

Alternatively however, such preference asymmetries may be more basic, resulting from more fundamental human choice strategies. If this were the case, we would expect preference-reversals based on framing to occur even outside of the specific experimental contexts in which researchers have seen them before. Additionally, we would

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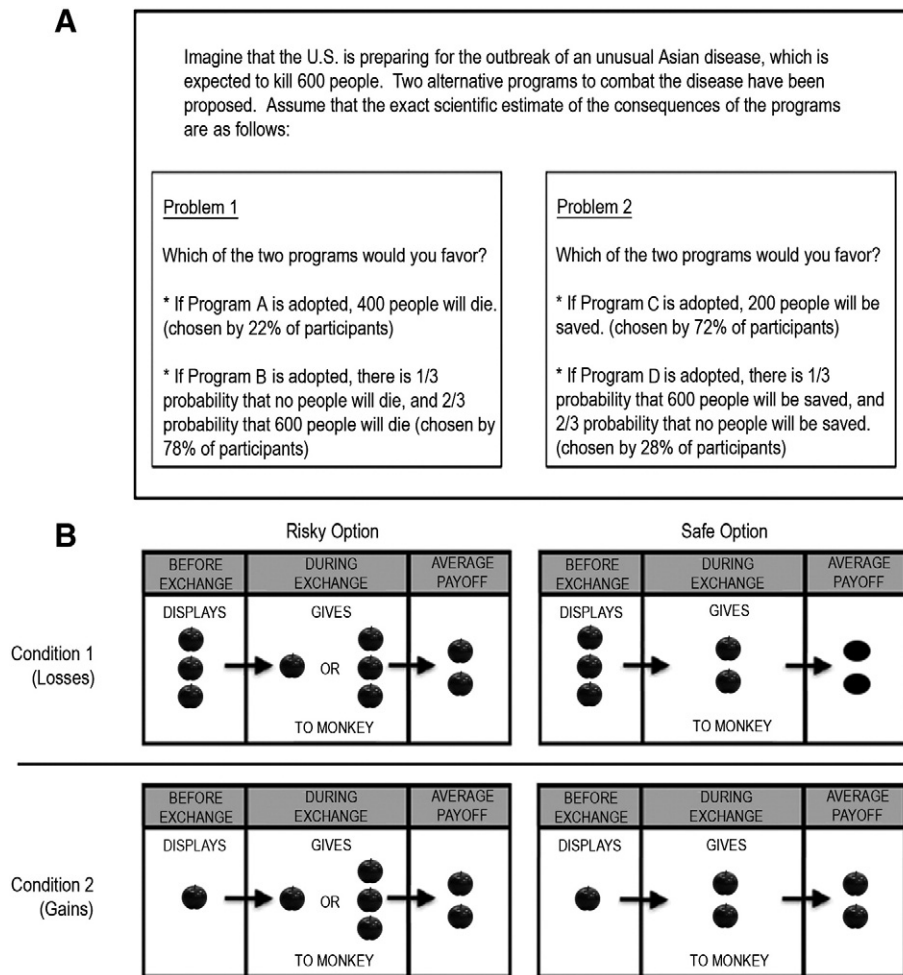


Fig. 1. Four scenarios involving safe and risky choices, with the resulting outcomes framed either as losses or gains. (A) The two scenarios presented to subjects in Tversky and Kahneman (1981)'s Asian Disease problem. Subjects' choice across the two sets of options changed depending on whether choices were framed in terms of lives lost or lives saved. (B) Trading options across experiment and condition. In both experiments, monkeys faced a choice between safe and risky experimenters. In Condition 1, experimenters presented monkeys with a loss relative to their initial offer of three apple pieces. In Condition 2, experimenters presented a gain relative to their initial offer of one apple piece.

expect that subjects with drastically different economic experiences – non-human animals that completely lack human-like education or culture – would display the same decision-making biases that occur in our species. Under this view, such preference asymmetries may be the result of a correspondingly old evolutionary history.

One way to examine this issue is to determine whether similar preference reversals can be observed more broadly across the animal kingdom. Although little work has addressed this question directly, there is much work in the field of optimal foraging theory suggesting that an animal's willingness to forage in high-risk sites is affected by contextual factors and prior reward histories. A number of bird species, for instance, tend to change their preference for a high-variance reward option depending on the stability of their feeding context (Bateson, 2002; Caraco, 1981; Hurlly & Osssen, 1999; Marsh & Kacelnik, 2002). In an elegant study, Marsh and Kacelnik (2002) investigated these context effects directly using a framing manipulation. They presented starlings with a choice between a risky and fixed reward with the same average expected payoff of four reward pellets. Before this choice, however, starlings performed a training task that gave them a reward history involving one of two possible payoff amounts: either a small payoff of one pellet or a large payoff of seven pellets. This initial payoff history allowed the starlings to frame the choice condition's payoff of four pellets as either more or less than what they usually experienced. The authors found that starlings

became more risk-seeking when facing a loss context than a gain context. Specifically, starlings preferred the risky option in the loss context but showed no significant risk preference in the gains condition. The starling study provides some evidence that non-human animals may also change their risk preferences based on framing; starlings switch from risk-neutral to risk-seeking depending on their history with the decision problem.

The goal of the present study was to explore whether a more robust reflection effect is present in animals closely-related to humans, one in which we might reliably observe a true shift from risk aversion to risk-seeking based only on a problem's framing. To do so, we examined framing effects in a more closely related taxonomic group, the non-human primates. We focused specifically on one primate species – the capuchin monkey (*Cebus apella*) – because this species is adept at reasoning about payoffs and gambles in a token trading context (Addessi, Crescimbeni, & Visalberghi, 2007; Addessi, Crescimbeni, & Visalberghi, 2008; Addessi, Mancini, Crescimbeni, Padoa-Schioppa, & Visalberghi, 2008; Brosnan & de Waal, 2004; Brosnan & de Waal, 2003; Chen, Lakshminarayanan, & Santos, 2006; Lakshminarayanan, Chen, & Santos, 2008). Indeed, recent work suggests that this species is sensitive to how food rewards are framed in a token trading situation (Chen et al., 2006; Lakshminarayanan et al., 2008). Capuchins avoid trading with an experimenter who initially offers more food than he actually provides – thus, providing a

loss relative to the capuchins' expectation – and instead prefer to trade with an experimenter who provides more food than he initially offered, thus providing the same reward, but framed as a gain (Chen et al., 2006). In addition, capuchins show evidence of an endowment effect in this trading context; they avoid losing items that they have previously had in their possession (Lakshminarayanan et al., 2008).

Unfortunately, these past studies did not provide monkeys with a direct choice between a risky gamble and an equivalent low-risk option. As such, previous work has left open the question that is central to the research presented here – namely, do capuchins exhibit a reflection effect, switching from being risk-averse to risk-seeking depending simply on how these rewards are framed? Here, we adapt methods previously used to elicit framing effects in order to investigate whether framing influences risk-taking in a primate model. Monkeys were given “budgets” of tradable tokens, with pairs of experimenters offering rewards in exchange for tokens. Monkeys signaled their preference by trading more often with the preferred experimenter, as in previous work (Chen et al., 2006). In the present study, we examined whether monkeys demonstrate a reflection effect when risky and safe prospects are framed differently.

Material and methods

Participants

We tested five capuchins with prior trading experience (Chen et al., 2006; Lakshminarayanan et al., 2008). For more information on the experimental history of these subjects, see Chen et al. (2006).

Materials

As in previous studies (Chen et al., 2006; Lakshminarayanan et al., 2008), testing occurred in a wire-mesh trading chamber attached to subjects' home enclosure. In all exchanges, subjects traded inch-wide metal disks for apple pieces.

General procedure

We used a token-trading procedure similar to that used in previous studies (Chen et al., 2006; Lakshminarayanan et al., 2008). Subjects “purchased” rewards by placing a token into the hand of one of the two experimenters. During each trial, the experimenters positioned themselves outside the trading chamber and prepared to trade: one hand was open to receive the monkey's token, while the other displayed a dish of apple pieces. This initially-offered quantity served as the reference point. The subject then chose between these options by handing a token to one of the two experimenters, who then provided apples to the subject. After each trade, experimenters switched sides, and replenished their rewards to begin a new trial.

Using this trading set-up, we presented capuchins with choices between safe and risky traders whose payoffs could be framed either as losses (e.g., reward reductions) or gains (e.g., reward bonuses). Subjects performed two conditions: one in which both experimenters subtracted apple pieces from their dish (Condition 1: Losses) and one in which both experimenters added pieces to their dish (Condition 2: Gains). In this way, each experimenter presented a subject with an initial reference point, then delivered either a loss or a gain relative to that number of pieces.

In Condition 1, subjects were presented with 60 choices (five 12-trial sessions) between a sure “loss” and a risky “loss” of equivalent expected value. Experimenter 1 initially displayed three pieces of apple, but after being presented with a token, always subtracted one piece. Experimenter 2 also initially displayed three pieces of apple, but represented a risky chance to obtain all three: after taking the subject's token, with equal probability Experimenter 2 would subtract two pieces or subtract none. Experimenter 2 represented an equal

chance at a payoff of either one or three pieces, while trading with Experimenter 1 represented a certain payoff of two apple pieces.

Similarly, Condition 2 presented subjects with 60 choices (five 12-trial sessions) between a certain “gain” and a risky “gain” of equivalent expected value. Experimenter 1 initially displayed one piece of apple, but after being presented with a token, always added a second “bonus” piece. Alternatively, Experimenter 2, who also initially displayed one piece of apple, represented a risky shot at a two-piece bonus: after taking the subject's token, Experimenter 2 would either add two “bonus” pieces or add no bonus.

Results and discussion

We compared our monkeys' risk-preferences across the losses (Condition 1) and gains (Condition 2) framing conditions. When presented with a choice between safe and risky losses in Condition 1, capuchins, like humans (Tversky & Kahneman, 1981), preferred the risky loss to the sure loss. This effect was highly significant for our monkeys collectively (pooled: $M = 71\%$, $p = 0.0001$, $N = 300$), and was significant individually at the five-percent level for four out of our five monkeys (NN: 90%, $p = 0.0001$, MD: 65%, $p = 0.027$, JM: 67%, $p = 0.013$, HG: 58%, $p = 0.25$, FL: 73%, $p = 0.0004$, $N = 60$ for each subject, two-sided binomial test).

Condition 2 presented capuchins with a choice of safe and risky payoffs that were identical to those of Condition 1 except that both payoffs were framed as gains (see Fig. 1B). In contrast to Condition 1, monkeys were generally risk-averse when presented with gains in Condition 2. Monkeys significantly preferred the safe gain over the risky gain (pooled: $M = 57\%$, $p = 0.018$, $N = 300$), though this effect is only marginally significant at the individual level (NN: 60%, $p = 0.155$, MD: 60%, $p = 0.155$, JM: 65%, $p = 0.027$, HG: 60%, $p = 0.155$, FL: 40%, $p = 0.155$, $N = 60$ for each subject, two-sided binomial test).

Consistent with the reflection-effect, monkeys also demonstrated a reliable switch in their risk preferences across the two conditions. Monkeys were significantly more risk-seeking when problems were framed as losses than when they were framed as gains, both as a group (increase in risky choice: $M = 28\%$, $p = 0.0001$, $N = 300$, $z = 6.84$), and on the individual level (NN: 50%, $p = 0.0001$, MD: 25%, $p = 0.006$, JM: 32%, $p = 0.0005$, HG: 18%, $p = 0.045$, FL: 13%, $p = 0.121$, $N = 60$ for each subject, two-sample z-test of proportions) (Figs. 2 and 3).

Overall, the pattern of decision-making in monkeys mirrors human choice: most subjects were risk-seeking when deciding between options framed as losses, but were risk-averse when deciding between options framed as gains. This pattern of results was observed even when controlling for the order of sessions and any pre-existing trend in subjects' behavior; see supplement for details.

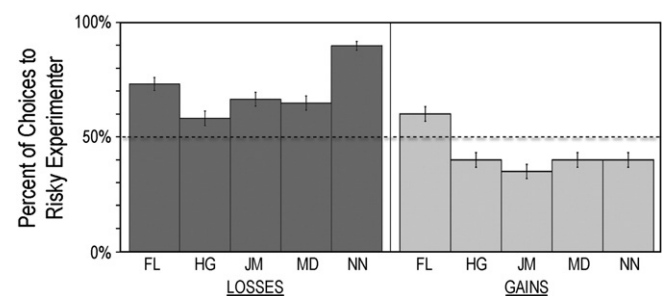


Fig. 2. Results of Conditions 1 and 2. Subjects significantly preferred to trade with the risky experimenter in Condition 1 when faced with losses, and significantly preferred to trade with the safe experimenter in Condition 2 when faced with gains. Error bars represent binomial standard errors. For each subject in a condition, $N = 60$ trades (each subject's first five sessions).

Conclusions

The pattern of risk-taking termed the 'reflection effect' in our species (Tversky & Kahneman, 1981), in which humans switch from risk-seeking to risk-averse behavior depending simply on how the same outcomes are presented, also appears to exist in non-human primates. Capuchin monkey subjects choose a risky gamble over a safe alternative when the outcomes of these choices are framed as losses relative to an initial reference-point; in contrast they prefer the safe bet when payoff-identical outcomes are presented as gains. Put differently, both humans and capuchin monkey subjects seek the certainty of obtaining something that they like (namely a gain relative to a reference-point), and also avoid the certainty of avoiding something that they dislike (namely a loss relative to a reference point).

These results suggest that monkeys also take into account subjective features of prospects that are irrelevant to the consequences of their choices. In this way, it is likely that the cognitive (and possibly neural) architecture that gives rise to frame-dependent risk preferences is present in our common primate ancestors, and thus may be evolutionarily quite ancient. Furthermore, the present results make less likely the possibility that preference reversals involving risky decisions are artifacts of the particular methods (such as verbal questionnaires) or subject pools used in human studies.

Our results additionally extend previous work investigating framing effects in monkeys (Chen et al., 2006; Lakshminarayanan et al., 2008) as well as risky decision-making in distantly-related animal species (Bateson, 2002; Caraco, 1981; Hurly & Ossen, 1999; Marsh & Kacelnik, 2002) in several critical ways. First, we demonstrate that non-human animals exhibit framing effects even in the absence of extensive training. Previous studies in animals have created reference points through the use of relatively lengthy reward histories (e.g., Marsh & Kacelnik, 2002). Here, capuchins exhibit human-like reversals in their risk preferences based on expectations that we set in a simple and direct way, merely based on the presentation of the outcomes of their actions, just as typically done in human studies (Kahneman et al., 1982; Tversky & Kahneman, 1981; Tversky & Kahneman, 1986).

Second, and perhaps more importantly, we provide the first demonstration that framing effects can elicit a complete risk preference reversal in a nonhuman animal. The importance of this is twofold: first, it suggests that the cause of reversals of risk-preferences in humans such as the disposition effect (Odean, 1998) might be explained by the same simple mechanisms that drive similar preference-reversals in non-human animals. Thus, simple low-level explanations for phenomena such as the disposition effect (i.e., stock-sellers, like non-human primates, are reluctant to realize losses) are plausible alternatives to previous high-level explanations of why humans might exhibit such economic irrationalities (for example, that they are reluctant to close mental accounts in cases of loss). Second, the present behavioral results provide a new avenue for neurophysiological investigations of subjective and contextual aspects of decision-making under risk. Non-human primates have consistently served as neurophysiological models for explorations of the neural basis of decision-making under uncertainty (Glimcher, 2003; Lee, 2006; McCoy & Platt, 2005; McCoy, Crowley, Haghghian, Dean, & Platt, 2003; Platt & Glimcher, 1999) but much of this work has focused on simpler aspects of primate decision-making, such as deciding where and when to saccade. Accordingly, a sharp disconnect exists in the methodologies employed in these studies and those used in neuroimaging work concerning complex decisions undertaken by humans (see Camerer, Loewenstein, & Prelec, 2005 for review). The present work provides novel behavioral evidence that measures of preference, such as purchasing behavior when provided with a scarce budget of tokens, can also be used to test the predictions of prospect theory in a non-human primate model. We hope that combining these

new behavioral measures with neurophysiological techniques (Tom, Fox, Trepel, & Poldrack, 2007; Trepel, Fox, & Poldrack, 2005) can yield a more unified study of primate decision-making via the use of analogous behavioral tasks in human and non-human populations.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at doi:10.1016/j.jesp.2010.12.011.

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