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Banking on a Bad Bet: Probability Matching in Risky Choice Is Linked to Expectation Generation

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Abstract

Probability matching is the tendency to match choice probabilities to outcome probabilities in a binary prediction task. This tendency is a long-standing puzzle in the study of decision making under risk and uncertainty, because always predicting the more probable outcome across a series of trials (maximizing) would yield greater predictive accuracy and payoffs. In three experiments, we tied the predominance of probability matching over maximizing to a generally adaptive cognitive operation that generates expectations regarding the aggregate outcomes of an upcoming sequence of events. Under conditions designed to diminish the generation or perceived applicability of such expectations, we found that the frequency of probability-matching behavior dropped substantially and maximizing became the norm.

Keywords

decision making, heuristics, prediction

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Which would you prefer, an option offering a 70% chance of winning $1 or an option offering a 30% chance of winning $1? It may seem difficult to imagine circumstances under which people would systematically choose the lower-probability option. Yet when that choice is repeatedly presented in a sequence of decisions, people do. Suppose, for instance, that a 10-sided die will be rolled 10 times. The die has 7 green sides and 3 red sides. You are to predict, for each roll, whether a green or a red side will come up, and for each correct prediction you will be paid $1. Many people, when faced with this binary prediction task, predict green for 7 rolls and predict red for the other 3 rolls (e.g., Koehler & James, 2010). This phenomenon, called probability matching, is a robust finding that dates back to the probability-learning literature of the 1950s and 1960s. Each time a probability matcher chooses to bet on red rather than on green, he or she is effectively choosing an inferior gamble offering a 30% chance of winning $1 over a superior gamble offering a 70% chance of winning $1.

Probability matching represents a long-standing puzzle in the field of decision making, because an alternative prediction strategy (referred to as *maximizing*), in which the individual in our example would predict green on all 10 rolls, offers superior expected returns. Understanding why probability matching occurs is important because it is not readily accommodated even by prominent psychological models of decision making, such as prospect theory (Kahneman & Tversky, 1979), that share with the normative economic model the assumption that people will choose a gamble offering a higher probability of winning over an otherwise equivalent (and equivalently framed) gamble that offers a lower probability of winning.

In a previous article, we argued that probability matching arises from an asymmetry in the availability of alternative prediction strategies: The probability-matching strategy comes to mind more readily than does the superior maximizing strategy (Koehler & James, 2010). Consistent with this claim, the results of our previous experiments showed that when both strategies were described to participants and thereby equated in availability, the maximizing strategy was used more frequently than when it had not been described.

But why is the probability-matching strategy more available in memory in the first place? We suggested that the generation of expectations, a generally adaptive cognitive function (e.g., Bar, 2007), may be the culprit (Koehler and James, 2009). In the 10-sided-die problem, when thinking about the series of rolls as a whole, an expectation of 7 green outcomes and 3 red outcomes is readily evoked. The availability of this expectation, in turn, is hypothesized to make salient a

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congruent strategy of predicting green on 7 rolls and red on the remaining 3 (i.e., matching probabilities); consequently, this strategy is likely to be employed, particularly if alternative strategies do not come to mind.

The link between the generation of expectations and probability matching has not been tested in previous research. We hypothesized that blocking the generation of expectations or their perceived applicability should reduce the tendency to engage in probability matching. In the 10-sided-die example, the expectation that is generated comes from an evaluation of anticipated outcomes over a sequence of events. According to our account, manipulations that make it less likely that participants will think about the sequence as a whole and, instead, focus on each of its component outcomes individually, ought to disrupt the influence of sequence-wide expectations and thereby reduce probability matching.

Experiment 1

In Experiment 1, we evaluated the effect of individuating the decisions in the sequence on probability matching. Doing so was expected to make it less likely that a sequence-wide expectation would be generated or applied to the binary prediction task.

Method

Participants were 132 undergraduates from the University of Waterloo, who completed the study online for course credit. They were asked to play a series of 10 guessing games, in which they were to predict which of two possible outcomes would occur. They were told in advance that, in each of the 10 games, one outcome would occur with 70% probability and the other with 30% probability. Participants were asked to imagine that they would be paid $1 for each correct prediction and to indicate their prediction in each of the 10 games. They were not informed of the game outcomes.

Participants were assigned to one of two conditions. In the unique-games condition, participants were told they would be playing 10 different games, the specifics of which would be described to them as they played each game. They then made predictions for 10 games that had superficial individuating characteristics but in which the outcome probabilities were mathematically equivalent. For example, one game involved drawing ping-pong balls from a bingo cage, another involved spinning a wheel of fortune, and another involved rolling a 10-sided die. Order of game presentation was randomized across participants. In the repeated-games condition, 1 of the 10 games from the unique-games condition was randomly selected for each participant and presented to him or her 10 times.

Results

Data from 2 participants who predicted the unlikely outcome more often than the likely outcome were excluded from further analysis, as were data from 3 additional participants who did not complete the entire prediction task.

Figure 1 shows the full distribution of the number of times each participant predicted the more-likely outcome rather than the less-likely outcome in each condition. Participants in the unique-games condition (n = 66) were more likely than those in the repeated-games condition (n = 61) to engage in strict maximization, that is, to predict the more-likely outcome in all

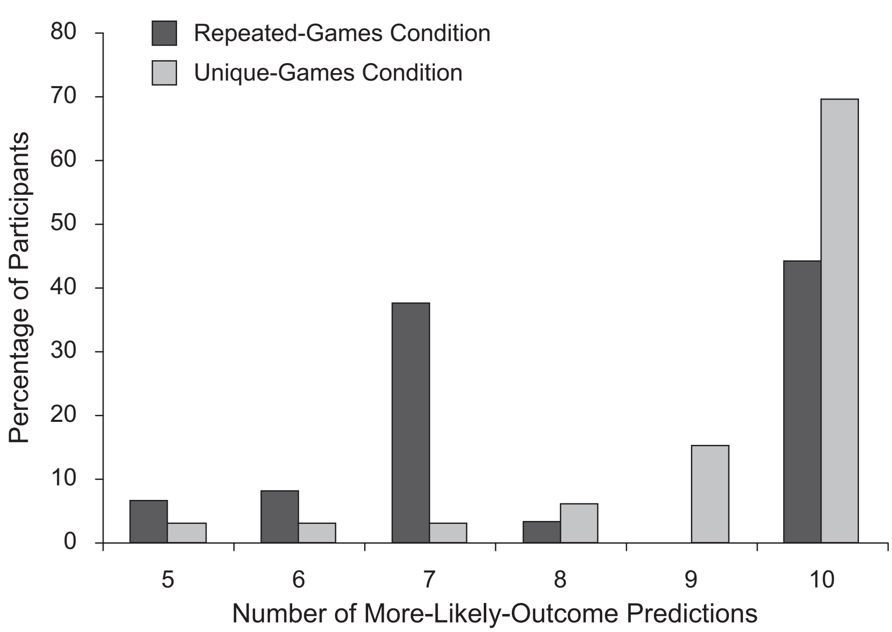

Fig. 1. Results from Experiment 1: distribution of the number of predictions of the more-likely outcome (rather than the less-likely outcome) across participants in the two conditions.

10 choices (70% vs. 44% of participants, respectively), $\chi^2(1, N = 127) = 8.4$, $p = .004$. Strict probability matching (predicting the more-likely outcome on 7 of 10 choices), by contrast, was common in the repeated-games condition but not in the unique-games condition (38% vs. 3% of participants, respectively), $\chi^2(1, N = 127) = 24.1$, $p < .001$.

Experiment 2

In Experiment 1, the various games presented in the unique-games condition all shared common outcome probabilities of 70% and 30%. This was noted in the instructions given to participants, but how these probabilities were presented varied across the games. In some games, these probabilities were stated directly or given as relative frequencies of occurrence; in other games, the probabilities could be inferred from characteristics of the chance device (e.g., a draw from a bag of 100 tickets, of which 70 were orange and the other 30 were black). Experiment 2 tested whether individuating the outcomes in the sequence would decrease probability matching and increase maximizing even when the games were all based on a common chance device.

Method

University of Waterloo undergraduates ($N = 129$) completed Experiment 2 online in exchange for psychology course credit. They were asked to consider a game involving 10 rolls of a 10-sided die and to predict the outcome of each roll. Seven sides of the die, they were told, were marked one way, and the remaining 3 sides were marked another way. In the repeated-games condition, all 10 rolls involved a die with 7 red sides and 3 green sides. In the unique-games condition, each roll was said to involve a different die with unique markings. For instance, in addition to the die marked with red and green sides, another die had 7 sides marked with triangles and 3 sides marked with squares. Other markings included letters and icons, such as flowers and hearts.

Results

Data from 1 participant who predicted the unlikely outcome more often than the likely outcome were excluded, as were data from a second participant who did not complete the entire prediction task. For some participants in the repeated-games condition, the sequence was described as a single game consisting of 10 rolls of the die, and for other participants, it was described as 10 games of 1 roll each. This factor had no influence on the results.

As Figure 2 shows, participants in the unique-games condition ($n = 38$) were more likely than those in the repeated-games condition ($n = 89$) to engage in strict maximization, that is, to predict the more-likely outcome in all 10 choices (76% vs. 56% of participants, respectively), $\chi^2(1, N = 127) = 4.6$, $p = .03$. Strict probability matching, by contrast, was more prevalent in the repeated-games condition than in the unique-games condition (18% vs. 3% of participants, respectively), $\chi^2(1, N = 127) = 5.4$, $p = .02$.

Experiment 3

In Experiments 1 and 2, introducing individuating features to the outcome sequence reduced probability matching and increased rates of maximizing. We suggest that this is because

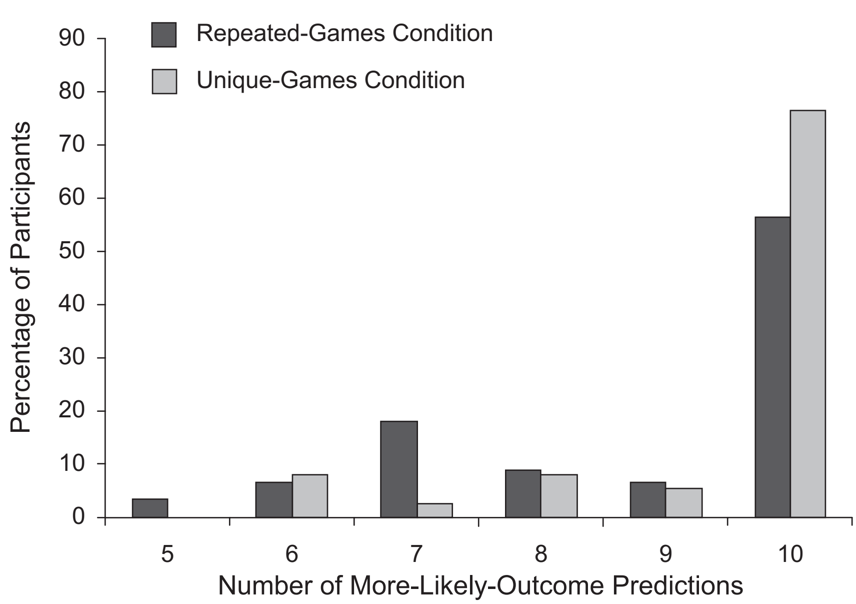

Fig. 2. Results from Experiment 2: distribution of the number of predictions of the more-likely outcome (rather than the less-likely outcome) across participants in the two conditions.

the individuating features made it less likely that participants would generate and apply sequence-wide expectations to the binary prediction task. In Experiment 3, we sought convergent evidence for this interpretation by keeping the features of the sequence itself fixed but preceding it with a priming manipulation designed to draw focus on either the sequence as a whole or on the individual outcomes within the sequence.

Method

University of Waterloo students (N = 84) were recruited at a public location on campus and asked to complete a brief questionnaire. The questionnaire asked participants to consider a game like that from Experiment 2, in which a 10-sided die with 7 green sides and 3 red sides would be rolled 10 times, and each correct prediction would yield a $1 payoff. Participants indicated their predictions for each of the 10 rolls on a grid by circling either green or red.

Participants were assigned to one of two conditions. Before playing the game, participants in the global-focus condition were asked, "In 10 rolls of the die, how many times would you expect each outcome?" This question was intended to encourage generation of a sequence-wide expectation. Participants in the local-focus condition were asked, "On any individual roll of the die, which color is more likely to be rolled?" This question was intended to focus participants on the contingencies of an individual trial rather than on a sequence-wide expectation, and thereby to reduce the tendency to probability match. More than 80% of participants in the global-focus condition and all participants in the local-focus condition answered the priming question correctly.

Results

Incomplete data from 1 participant were excluded. As Figure 3 shows, participants in the local-focus condition (n = 42) were more likely than those in the global-focus condition (n = 41) to engage in strict maximization, that is, to predict the more-likely outcome in all 10 choices (48% vs. 20% of participants, respectively), $\chi^2(1, N = 83) = 7.3$, $p = .007$. Strict probability matching, by contrast, was more prevalent in the global-focus condition than in the local-focus condition (61% vs. 38% of participants, respectively), $\chi^2(1, N = 83) = 4.3$, $p = .04$.

Discussion

In the experiments reported here, we tested the hypothesis that the generation of an expectation regarding the aggregate outcomes of a sequence of chance events plays a role in probability-matching behavior. This hypothesis was supported in all three experiments, in which manipulations designed to reduce the generation or perceived applicability of such an expectation led to lower rates of probability matching and higher rates of maximizing.

We should offer a few caveats. First, our prediction task differed from the probability-learning paradigm, in which probability matching was first observed, in that the relevant probabilities were known from the outset rather than learned through direct observation of outcomes (which were not presented in our task). The extent to which expectation generation drives matching in probability-learning tasks remains an open question. Second, there were no actual monetary payoffs for correct predictions. It is possible that the results might have

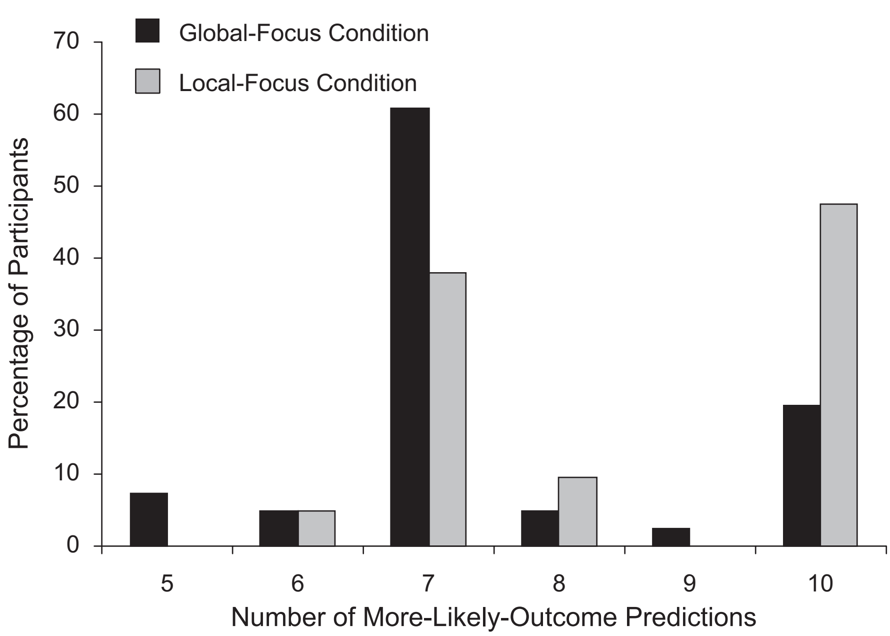

Fig. 3. Results from Experiment 3: distribution of the number of predictions of the more-likely outcome (rather than the less-likely outcome) across participants in the two conditions.

differed if payoffs had been given, but the rate of maximizing here and in a similar task in our past research with real payoffs (Koehler & James, 2010) is quite comparable; if anything, maximizing was more prevalent in the present experiments even though they involved hypothetical payoffs. Third, we cannot say whether the manipulations we introduced in the present experiments prevented the generation of an expectation in the first place or, instead, reduced the perceived applicability of that expectation to the prediction task.

Recently, researchers have offered a dual-system account of probability matching, in which probability matching is the consequence of a fast, effortless evaluation carried out by the intuitive system (Koehler & James, 2009, 2010; Kogler & Kuhberger, 2007; West & Stanovich, 2003). According to this account, maximizing by adult humans is the result of the deliberative system correcting or overriding an initial impulse to engage in matching. The results of our experiments are compatible with such an account, and they suggest that sequence-wide expectations may serve as a source of the intuitive appeal of matching. When contemplating a strategy for making predictions across a sequence of 10 die rolls, this expectation (expect 7 greens and 3 reds), in turn, evokes from the intuitive system a congruent choice strategy (predict 7 greens and 3 reds)—this type of process is referred to by Kahneman and Frederick (2002) as *attribute substitution*. Attribute substitution is likely to take place when an associatively related response, in this case an expectation, is highly accessible, and it often occurs without effort or awareness (Morewedge & Kahneman, 2010).

One apparent challenge to the dual-system account of probability matching, in which maximizing is viewed as the outcome of effortful deliberation to override the initial intuition to match, is that young children (Derks & Paclisanu, 1967) and many nonhuman animals (Parducci & Polt, 1958; Wilson & Rollin, 1959) are more likely to maximize and less likely to match than are adult humans. Another apparent challenge is that working memory load has been found, in some studies at least, to increase rates of maximizing (e.g., Wolford, Newman, Miller, & Wig, 2004).

How can such findings be squared with the claim that probability matching arises from a failure of deliberation to override an initial expectation-based intuition? We suggest that, for adult humans, expectations for the outcome of a sequence of chance events are spontaneously generated as a consequence of their (perhaps implicit) grasp of and experience using basic probabilistic principles (in particular, translating likelihood or probability into expected frequencies). Children and nonhuman animals may not have developed the capacity to generate such a sequence-wide expectation and, ironically, thereby may be less prone to probability matching. Likewise, working memory load may lead to a narrowed focus on individual outcomes rather than expected outcomes of the entire sequence, again with the consequence of reducing rates of probability matching.

This account suggests that the relation between probability-matching prevalence and cognitive development or statistical sophistication may follow an inverted U pattern: At the low end of the continuum, maximizing is the norm because of the absence of an expectation that outcome relative frequencies over the sequence will match their probabilities of occurrence; at the high end, by contrast, the expectation is readily generated but the individual is able to override it, arriving at the optimal maximizing strategy through more effortful deliberation. Probability matching may predominate in the middle of the continuum, where the expectation underlying the intuition to match is readily generated but not reliably overridden by the deliberative system.

Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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