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Brief article

Probability matching in choice under uncertainty: Intuition versus deliberation

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ABSTRACT

Gaissmaier and Schooler (2008) [Gaissmaier, W., & Schooler, L. J. (2008). The smart potential behind probability matching. *Cognition, 109,* 416–422] argue that probability matching, which has traditionally been viewed as a decision making error, may instead reflect an adaptive response to environments in which outcomes potentially follow predictable patterns. In choices involving monetary stakes, we find that probability matching persists even when it is not possible to identify or exploit outcome patterns and that many "probability matchers" rate an alternative strategy (maximizing) as superior when it is described to them. Probability matching appears to reflect a mistaken intuition that can be, but often is not, overridden by deliberate consideration of alternative choice strategies.

1. Introduction

Consider a simple choice task, in which participants are asked to guess whether a green or a red light will appear on the next trial, and are paid for correct guesses. One outcome appears with a higher probability than the other (e.g., the green light appears on 75% of trials and red on only 25%). Assuming serial independence of outcomes, choosing the more probable outcome on every trial (henceforth referred to as maximizing) is the best strategy in terms of expected payoffs. Instead, however, many people match their choice probabilities to the relevant outcome probabilities (in the example above, predicting the green outcome on 75% of trials and red on the remaining 25%). Because it returns lower expected payoffs, this phenomenon, called probability matching, remains a longstanding puzzle in psychology and economics (for a review, see Vulkan (2000)).

Gaissmaier and Schooler (2008) recently argued that probability matching may be "smart", i.e., an adaptive response to environments in which outcomes potentially follow predictable patterns. In the extreme case, using our earlier example, if there was a consistent, deterministic pattern in the sequence of red and green outcomes, then a participant could exploit it to achieve perfect predictive accuracy (and maximum payoffs), and in doing so would "match" choice probabilities to outcome probabilities. The notion that probability matching is related to a search for patterns has also been suggested by other researchers (Unturbe & Corominas, 2007; Vulkan, 2000; Wolford, Newman, Miller, & Wig, 2004). As evidence for this claim, Gaissmaier and Schooler reported that those participants who used a matching strategy in a standard probability learning task (with serially independent outcomes) were more likely to identify and exploit a pattern when they encountered a sequence that was non-random. By this account, even somebody who recognized that maximizing is the appropriate strategy when faced with a truly random (i.e., serially independent) sequence might engage in probability matching in an attempt to identify and exploit potential patterns in a sequence that might not be truly random.

While Gaissmaier and Schooler's results are suggestive, it remains an open issue the extent to which people

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selectively engage in probability matching in the presence of potential outcome patterns. Clearly the pattern search "strategy" was overextended by their participants to a setting in which there were, in fact, no patterns to be exploited, even after they had observed several hundred outcomes. But perhaps use of a pattern search strategy is restricted to settings in which there is at least the possibility of identifying and exploiting potential patterns. To test this *selective pattern search* hypothesis, we compared choices under conditions in which it either was or was not possible to identify and exploit potential patterns in outcome sequences. If probability matching results from selective pattern search, then it should be less prevalent when pattern information cannot be used.

An alternative interpretation of probability matching is that it is simply a mistake. A specific version of this account, which might be called *expectation matching*, is that probability matching arises from a fast, relatively effortless intuitive assessment (Kogler & Kuhberger, 2007; West & Stanovich, 2003) that generates expected outcomes based on relevant probabilities (Tversky & Kahneman, 1971), e.g., that the green light is expected on 3 of the next 4 trials. Clearly the ability to rapidly generate expected outcomes has adaptive value for many decisions made under uncertainty. Because they come so readily to mind, however, these expected outcomes, in turn, serve as a natural candidate for setting choice proportions, e.g., that one should guess green on 3 of the next 4 trials. This is a form of "attribute substitution" (Kahneman & Frederick, 2002) in which the answer to a relatively difficult question (how many green and red guesses should be made?) is replaced by the answer to an easier one (how many green and red outcomes are expected?). A slower, deliberative evaluation might also be undertaken that could potentially identify an alternative strategy, maximizing, that returns higher expected payoffs. Often, however, the initial intuitive response dominates final choices, either because the participant deliberates very little prior to making the choice, or because such deliberation fails to produce the alternative maximizing strategy (Kahneman & Frederick, 2002). One piece of evidence supporting this dual-system account is that individuals who are higher in cognitive ability, and thereby presumably more efficient in deliberative reasoning, are more likely to maximize and less likely to probability match than are those of lower cognitive ability (Stanovich & West, 2008; West & Stanovich, 2003).[1]

On the expectation matching account, the unavailability of potential pattern information should not influence probability matching behaviour as it is not, by this account, grounded in any kind of search for patterns. Instead, by this account, it is the unavailability of an alternative choice strategy (maximizing), either because deliberation fails to produce it or because the individual fails to deliberate in the first place, that leads to the "endorsement" of the intuitive probability matching strategy in choice behaviour. This raises the possibility that people who probability match in the standard choice task might acknowledge the superiority of the maximizing strategy when it is explicitly presented for evaluation.

2. Method

2.1. Participants

Participants were 120 undergraduate students (53 female) recruited from a campus student centre, who were told that they could receive up to $10 for their participation depending on their performance.

2.2. Procedure

The computer-based choice task was described as a game in which participants were to guess the color of marbles that were to be drawn from a bag containing a mix of red and green marbles. The task consisted of a learning phase followed by a test phase.

In the serial learning condition, participants saw 40 marbles drawn, one at a time, from the bag; in total they saw 30 green and 10 red marbles[2] drawn in a randomized order. This condition allowed participants to search for patterns should they be inclined to do so, though in fact the outcomes were serially independent. In the aggregate learning condition, participants were told that a total of 30 green marbles and 10 red marbles had been drawn from the bag, but they were not presented with trial by trial outcomes and so had no opportunity to observe potential patterns. In both learning conditions, participants were told that each of the 40 marbles had been drawn randomly, with replacement, from the bag.

In the test phase, participants were told that 20 more marbles would be drawn, with replacement, from the same bag, and that they would earn $0.50 each time they correctly guessed the color of a marble drawn from the bag. In the serial test condition, participants were asked to guess the color of each marble drawn, one at a time, without feedback regarding the color that was actually drawn on each trial. The serial test condition allowed participants to order their guesses to follow a pattern, should they choose to do so. In the aggregate test condition, participants were asked to indicate how many times, across the 20 draws, they would guess red, and how many times they would guess green. In this condition, even if participants suspected that that the outcomes might follow some sort of pattern, they had no way to exploit that pattern in making their responses.[3]

[1] Working memory capacity, by contrast, has been found in some probability learning studies (e.g., Gaissmaier, Schooler, & Rieskamp, 2006; Wolford et al., 2004) to be *negatively* correlated with the tendency to maximize, possibly because executing the probability matching strategy across learning trials is more complicated than executing the maximizing strategy.

[2] For ease of exposition, green will be referred to as the dominant color in the task; in fact, the dominant color was counterbalanced across participants.

[3] Subsequently, so that appropriate payoffs could be determined, participants were asked to make a series of serial guesses that maintained the number of red and green guesses they had initially indicated, but they were not aware that they would have the opportunity to do so at the time they indicated, in aggregate, how many times they would guess red versus green.