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Focus Issue: Overconfidence and deception in behaviour

Complexity and simplicity in the evolution of decision-making biases

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Marshall *et al.* [1] critique recent evolutionary explanations of decision-making biases, focusing on Johnson and Fowler's model of overconfidence [2] and Trivers' model of self-deception [3]. We agree with Marshall *et al.*'s central premise that a Bayesian decision-maker would also be able to optimize fitness in these settings (see their Box 2). However, as their Figure 1 makes clear, the point is that Bayesians require an extraordinary amount of information, as well as processing power, to achieve the same behavior. In the scenario that we modeled, actors were in competition over resources, fighting if both made a claim to a resource. To calculate the 'estimated [fitness] value of claiming' a resource, a Bayesian decision-maker would have to know (and process) not only: (i) costs and (ii) benefits, but also (iii) the prior probabilities of conflict payoffs, and (iv) the probability of winning, which is (v) a function of one's own, and one's opponent's strength. Moreover, as Marshall *et al.* themselves note, these variables would also have to be 'reliably estimated'; information might be available, but not accurately transmitted or perceived. In our model [2], individuals only require information about a single one of these five parameters, (v) their own and their opponent's strength. Not only is it simpler, but also it is readily gauged in nature, for example by size differences. As noted above, such measurements may be inaccurate, but measuring one thing is easier than measuring five things. The point of the Johnson and Fowler model was not that Bayesian decision-making is inefficient, but that organisms and natural selection would not need such complex decision-making algorithms to achieve optimal behavior.

Perhaps even more problematic is the assumption by Marshall *et al.* that a decision-theoretic approach is sufficient to characterize Bayesian decision-making; their actors do not take into account the possibility that they are interacting with non-Bayesians, in which case their estimates of probabilities resulting from strategic interaction will be incorrect. In essence, Bayesians must not only have a model of 'decisions' in their head, but also a model of opposing 'decision-makers', which depends on information about how those opponents are in turn coping with strategic interaction and possible information constraints. By contrast, the equilibrium approach in the Johnson and Fowler model [2] shows that individuals with a simple heuristic who have biased perceptions of their own capabilities are likely to survive when they interact with 'any' other type of individual, including those who have unbiased perceptions.

Given the reality of both cognitive constraints (limits on information and processing power) and evolutionary constraints (limits on efficiency, speed, evolvability, and the adaptive landscape [4]), humans and other animals are far from Bayesian decision-makers. Indeed, Nobel Laureates Daniel Kahneman and Amos Tversky concluded that humans are 'not Bayesian at all' ([5] p. 46). Nonhuman animals are likely much less so. The question, therefore, is what decision-making heuristics did natural selection generate to approximate that ideal? The Trivers, and Johnson and Fowler models show that optimal decision-making can be achieved with remarkably simple rules, and biases can be a key ingredient.

Having laid out why more variables may not necessarily aid decision-making, let us examine Marshall *et al.*'s

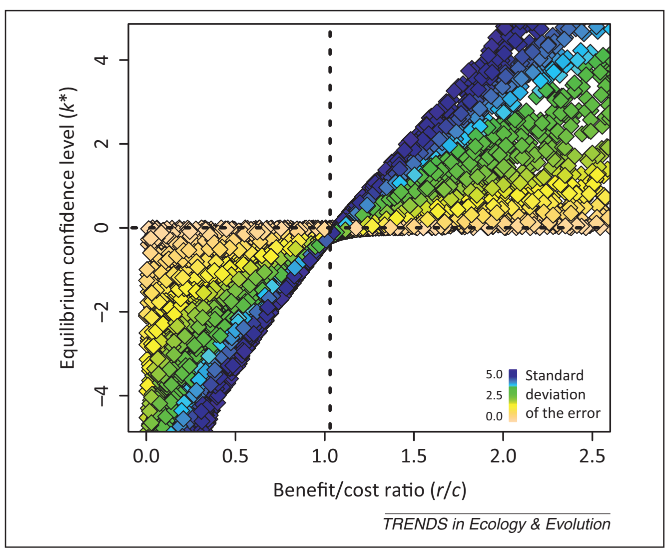

Figure 1. Marshall *et al.* claim that the results in Nettle [11] and Johnson and Fowler [2] arise because 'unlike the classical Hawk–Dove game, the benefit of not fighting is always zero.' However, here we show that biases still evolve in the Johnson and Fowler model even if the benefit is shared between individuals who choose not to fight. We incorporated this new assumption into the model described in [2] and used the same methodology to identify equilibria. The results show that equilibrium levels of confidence k^* are still increasing in the ratio between benefits of the disputed resource (r) and costs of fighting (c), and overconfident strategies ($k^* > 0$) are still the unique equilibrium when the benefit/cost ratio (r/c) is sufficiently high. By contrast, unbiased strategies ($k = 0$) are only possible under very limited conditions. Each point shows the results from a single simulation where the cost, benefit, and degree of uncertainty were drawn from a uniform distribution. There were 10 000 simulations in total. Colors indicate the degree of uncertainty about the capabilities of competitors.

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suggestion that costs and benefits, at least, should be added to the decision-making process. Johnson and Fowler [2] showed both analytically and computationally that equilibrium levels of overconfidence do vary given different values of costs and benefits. In fact, contrary to Marshall *et al.*'s assertion [1], the Johnson and Fowler model yields biased behavior even when changing assumptions about how costs and benefits are distributed (Figure 1). If benefits or costs change, the model predicts that confidence levels will also change and this, in turn, will affect the likelihood of conflict between individuals competing over resources (see Supplementary Figure 4 in [2]). Adaptation to these changes could happen slowly, via natural selection, or quickly, via a variety of learning mechanisms (both processes generate the same equilibria). To an external observer, it might seem that individuals are taking these shifting benefits, costs, and probabilities into account when in reality they are merely changing their perception of their own capabilities given the economics of the prevailing environment. In short, the model generates the same predictions as the literature cited by Marshall *et al.* (such as the observation [6] that conflict increases when resources become more valuable) while relying on a much simpler cognitive mechanism to achieve the same result. Due to cognitive and evolutionary limitations, humans and other animals must rely on heuristics that generate optimal behavior even when (or perhaps especially when) it involves risk or danger [7,8].

Marshall *et al.* envision individuals in the Johnson and Fowler model as 'constrained', in not being able to take into account the costs and benefits of a given contest. However, these individuals are in fact remarkably 'unconstrained' in being able to make fitness maximizing decisions without the complex information and processing demanded by the Bayesian model. Moreover, our model shows that optimal behavior can be achieved even when actors are faced with individuals who exhibit no bias in their choices. With sufficiently large prizes and any uncertainty at all, overconfidence is the winning strategy. Other studies using different modeling approaches, different assumptions, and different decision-making criteria have identified the same broad phenomenon ([4,9–12] and references therein).

As Tali Sharot recently wrote, a bias towards optimism 'is one of the most consistent, prevalent, and robust biases documented in psychology and behavioral economics' ([13] p. R941). The recent convergence of work on biases as an adaptive way to manage errors in decision-making suggests why this is the case [4]. Bayesian decision-making may be ideal, but it is not the only way to achieve optimal behavior and is unlikely in nature. In evolution, and perhaps especially in decision-making mechanisms, simplicity can trump complexity.

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