A random world is a fair world

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A preference for fairness or equity in the distribution of resources influences many human decisions (1). The origin of this preference is a topic that has consumed philosophers (2), social scientists (3), and biologists (4) for centuries. However, although we feel a sense of fairness deeply and intuitively, it has so far been difficult to explain from first principles how such a feeling might have evolved. How could natural selection allow for the survival of "fair" individuals who sometimes give things away to equalize resources when they must compete with self-interested individuals who keep everything for themselves? In PNAS, Rand et al. (5) provide a unique and compelling solution to this puzzle: it's all because of dumb luck.

To study fairness, authors use the so-called "ultimatum game" (6). In this game, one person (the proposer) offers a specific division of a sum of money, and the other (the responder) decides whether to accept this offer. If the responder accepts, they each receive the amount of money as proposed. If the responder rejects the offer, they each receive nothing. If both players are rational and self-interested and they play the game only once, then the responder should accept any nonzero offer (something is better than nothing!). Knowing that, the proposer should offer slightly more than zero to the responder and keep the rest for himself.

However, this result is not what we observe, anywhere. Dozens of studies in both large (7) and small-scale (8) societies show that proposers tend to make "fair" offers, in the range of 30–50% for the responder. Furthermore, responders tend to demand such behavior, rejecting offers when they fall below 20–35%.

Past efforts to explain the origin of these preferences have used deterministic game theory, which assumes that individuals with higher expected payoffs will always come to dominate the population (9). These models cannot explain fair offers or rejection of nonzero offers without making additional assumptions. For example, if we assume individuals have information about others' past behavior, then they can make strategies contingent on the reputation of their opponents, and this will benefit individuals with a reputation for rejecting low offers. However, how did the individuals get this information? And how do they avoid being exploited by individuals who can fake such a reputation? The additional assumptions are complex and hard to justify.

Instead, Rand et al. (5) return to first principles and use a different approach. Rather than assuming that evolution is deterministic, they assume it is stochastic. In reality, evolution sometimes favors the lucky, especially when the relationship between payoffs and survival is weak. This theory means a variety of strategies can endure and the winning strategy must do well in such an environment. Intuitively, if some of the responders are rejecting nonzero offers—not because it is the best strategy but because it happens to survive sometimes—then proposers need to make fairer offers.

Proximate selfish behavior can be bad for you, and under evolutionary pressure may not even survive.

Remarkably, when Rand et al. (5) apply stochastic evolutionary game theory in this way, they find that offers exceed demands and demands are greater than zero, just as they are in the empirical data. This result is true under a very wide range of possible scenarios when they vary selection (the relationship between payoffs and survival) and mutation (the likelihood that an individual chooses a random strategy). In fact, in some of these scenarios, they can exactly reproduce the average offer and the average demand from experiments in behavioral economics.

If the article ended there it would already be impressive for the way this work explains the observed data with the most parsimonious model to date. However, Rand et al. (5) also use the model to make two unique predictions, both of which are confirmed by careful measurement in a sample of 140 subjects.

First, as selection becomes weaker, it increases the likelihood of survival for both proposers and responders who try alternative strategies. Therefore, people living in circumstances where it is harder to assess the success of others' strategies should make both higher offers and higher demands. Second, as the rate of mutation increases, it directly increases the average offer because the average without mutation is less than one-half. However, the effect of mutation on demands is more ambiguous. Random demands will tend to increase the average because they are also below one-half, but there is more to lose from rejection because the offers tend to be higher, and this favors lower demands. Therefore, people living in circumstances where others are inconsistent in their behavior should make higher offers but not necessarily have higher demands.

Why Randomness Matters

It may seem remarkable that randomness is what drives "fair" behavior in this model, but it is consistent with what we know about other human behaviors that apparently defy rational explanation: uncertainty is key.

For example, it is well known that humans tend to exhibit overconfidence. When making interpersonal comparisons on a wide variety of traits, most people think they are above average. Such a bias might cause individuals to engage in contests they are sure to lose. However, uncertainty about capabilities means that the overconfident are also more likely to win other contests because less-confident individuals may decide not to enter the contest in the first place. As a consequence, evolutionary models show that, counterintuitively, overconfidence maximizes individual fitness and populations tend to become overconfident under a wide variety of conditions (10). Similar behavior in the face of uncertainty is observed in physician prognostication (11).

Author contributions: J.H.F. and N.A.C. wrote the paper.

The authors declare no conflict of interest.

See companion article 10.1073/pnas.1214167110.

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Stochastic evolutionary game theory has not yet been widely used, but it is already yielding a variety of promising results, fitting empirical data on human behavior better than deterministic models (12, 13). An important conceptual innovation in the stochastic theory is that selection is not the only important factor in evolution. Mutation is also important, and it is the balance between mutation and selection that ultimately matters for determining evolutionary outcomes. Although this may seem to complicate deterministic models, many basic models yield elegant closed-form solutions (14) and the analogs to agent-based evolutionary models are direct and easy to interpret.

For example, Nowak, Tarnita, and Wilson (15) recently applied stochastic evolutionary game theory to the problem of eusociality and showed that it could help to explain group-level evolutionary outcomes without any extra assumptions about "inclusive fitness." Although dozens of other scholars wrote rebuttals (16) to this work (primarily to defend their use of more approximate models), these responses did not counter an important point: inclusive fitness theory is a special case of a more general model that is simply based on individual selection under mutation and a precise elaboration of the set of interactions among individuals in the population. Thus, a random world is also one in which we can better understand how individual selection can drive group behavior.

Next Steps

An important challenge for stochastic game theory is whether or not it can be used to predict individual-level behavior. The model elaborated by Rand et al. (5) does an excellent job in matching population averages but, as they show in their supplementary information, there is wider variance in individual strategies than is normally present in empirical data. For example, their model yields too many individuals who make and demand offers above 50%.

Stochastic learning theory has faced similar challenges. Simple rules based on reinforcement learning (17) were used successfully to explain aggregate behavior in pigeons, goldfish, and, in some situations, in humans, but they were abandoned by psychologists in the 1970s in part for their inability to predict individual-level behavior (7). However, this disconnect between group and individual results may be easy to fix simply by adjusting a functional form in the model. For example, a simple model of voter behavior generates more realistic individual-level results when reinforcement yields fixed percentage changes in behavior rather than changes that become smaller near-extreme values (18). Similarly, in the Rand et al. (5) model, it may be the case that local mutation yields less variance in individual behavior than global mutation, and in fact this may be a way to test what kinds of exploration strategies are most likely.

Given that the Rand et al. (5) model can be interpreted as either a learning or natural-selection model, it suggests a wide variety of possible mechanisms. Some of these mechanisms could be cultural, such as those advanced by Henrich et al. in their study of ultimatum game play in several small-scale societies (8). It would be interesting to conduct the same experiment used by Rand et al. in each of these societies to see if variation in expectations about successful opponents and the mutability of their game play could explain variation in mean offers and demands. Other work suggests that variation in ultimatum game play is heritable; in other words, genetic variation is, in part, driving the different strategies that people use when they play the ultimatum game (19). In addition, functional MRI studies of other behavioral games suggests that the ventromedial prefrontal cortex and the insula may play a mediating role between genes and a sense of fairness (20). Although the insula result has been interpreted in the context of its association with social decision-making, it would be interesting to see if the ventromedial prefrontal cortex activation is driven by processing expectations about others strategies.

Finally, although Rand et al. (5) generate their results with a model that is based on individual natural selection, it is fascinating that it yields behavior that may otherwise appear to be based on something else. Rand et al. call the process "self-interested natural selection" but later note that "myopic self-interest is vanquished whereas fairness triumphs." This is a nice turn of concept. Proximate selfish behavior can be bad for you, and under evolutionary pressure may not even survive because fairness maximizes individual fitness. It may not be fair to be selfish, but it is certainly selfish to be fair.

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