

path integration. Through a process called self-supervised learning, the algorithm progressively improved its predictions, until it could, when presented with a view inside the learnt homing area that it had not seen before, make a good prediction of the home vector.

An advantage of this approach over a perfect memory of vector–view pairs is that the amount of time it takes the system to search through its memory remains constant, rather than increasing with the number of views, and it still performs well despite variations in the view. The authors showed, using simulations, that the neural network could navigate back home even when faced with unfamiliar views at distances of up to 2.5 times the radius of the learnt homing area. These neural networks were also very compact, requiring only a few thousand parameters; by contrast, billions are used in state-of-the-art image-recognition systems.

The effectiveness of this navigation scheme was thoroughly assessed first using realistic simulations, and then with a small flying robot. The robot had an omnidirectional camera, and various sensors that it used to perform path integration. The authors showed that, in indoor arenas, learning a homing area of only 5 × 5 metres around home could allow safe exploration and 100% successful returns across an area of up to 50 × 30 metres.

Testing the robot outdoors revealed some remaining challenges. Lighting variations made it more difficult for the algorithm to learn to associate views with vectors, and a larger, more sophisticated neural network was then needed for good performance. The flying robot was tilted by the wind, changing the camera angle and requiring further views to be learnt, which reduced the success rate. In a large, empty field, the views did not change enough as the robot flew for the algorithm to consistently associate particular views with unique vectors; however, adding some distinctive objects around the home location fixed this. Somehow, bees seem to have solved these problems.

Clearly, there is more to learn about bees, but does this work advance what scientists already know about them? The possibility that insects might associate views with vectors has often been proposed, but the available evidence provided more support for simple models in which the home-vector and view-memory systems operated more independently^{9,10}. By demonstrating, using real-world tests, the effectiveness of closely integrating these systems – while maintaining a plausible simplicity in the algorithm – Ou and colleagues' work invites reconsideration of these assumptions. Advances in understanding some key neural circuits underlying insect navigation¹¹ make this particularly intriguing to explore.

The work also provides an interesting

counterpoint to prevailing approaches to robot navigation, which typically try to build accurate 3D maps by combining multiple sources of information, including vision, depth-sensing, self-motion and external signals, such as GPS and wireless transmitters¹². Building such maps is necessary for some robot tasks, but for many use cases, such as monitoring crops or inspecting disaster sites, bee-like capabilities could be sufficient – and the low-power, low-compute solutions they inspire could be highly advantageous.

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1. Ou, D. *et al. Nature* **653**, 1039–1046 (2026).

Behavioural science

The constant repair of human cooperation

Jiabin Wu

Real-world data reveal that cooperation continually falls and rebounds. Motivation to cooperate must therefore be actively renewed rather than assumed to sustain itself. **See p.1110**

Why do humans cooperate with each other? This question has long been of interest to social and behavioural scientists because social dilemmas create a conflict between individual material incentives (such as financial gain) and collective efficiency. Cooperation produces socially desirable outcomes, but withdrawal from cooperation (known as defection) is often rational for people or groups acting in their own self-interest. Even so, human societies have repeatedly shown a striking capacity to sustain cooperation in practice – although achieving cooperation does not mean that it is permanent. On page 1110, Sabin *et al.*¹ show that cooperative behaviour can erode over time, even after it has been established successfully. Their findings suggest that cooperation might need to be renewed and defended continually, rather than be assumed to persist once it emerges.

Sabin and colleagues studied group lending in Sierra Leone over five years. In this setting, groups of small-business owners received loans as part of a joint-liability contract. If the group's loan was not fully repaid at the end of the loan cycle, all members bore the financial consequences and lost access to further loans. Each borrower would benefit if the group met the repayment requirement. However,

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they had an incentive to contribute as little as possible while hoping that the collective good would be maintained.

The authors found that cooperation – contributing to monthly repayments – declined over time, but not in a simple downward trend. Instead, it followed a pattern of punctuated decline: repayment fell within a loan cycle, then rebounded sharply when loans were restarted (Fig. 1). These rebounds occurred when staff members at the lending organization reminded borrowers of their cooperative responsibilities.

What explains this pattern? The authors make a convincing case that it reflects behavioural mechanisms rather than learning, strategic incentives or worsening economic conditions. Learning cannot explain why the number of repayments repeatedly increased again after loans restarted, even after borrowers had gained experience. Strategic explanations also fit poorly. Because there is no fixed limit on the number of loan cycles, the decline cannot be attributed to a standard end-game effect (in game theory, this is the breakdown of cooperation to maximize individual gain in the game's final round). There was also no clear reason to delay repayment within a cycle. Moreover, the authors found

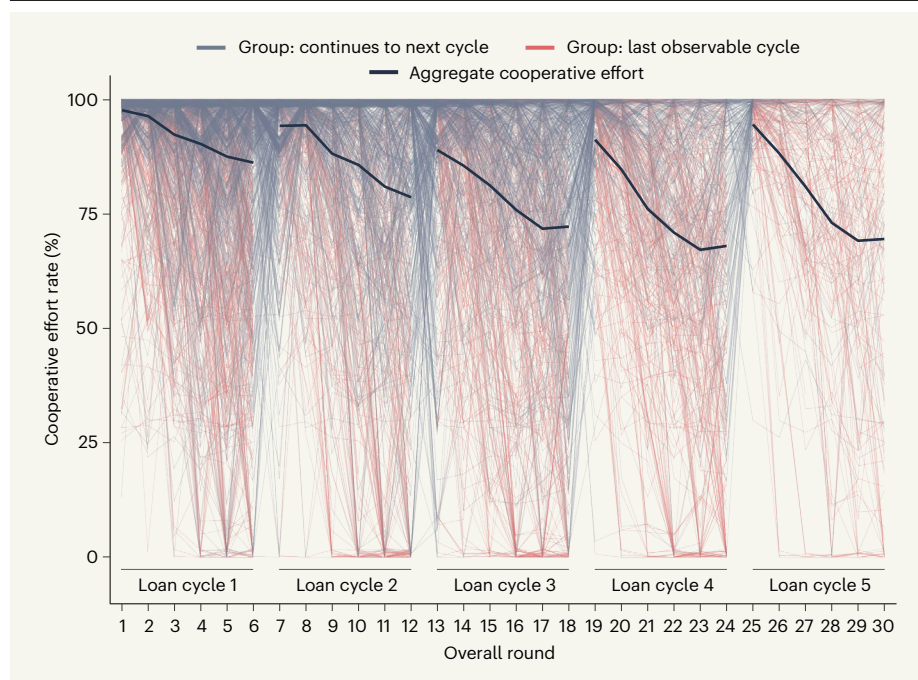


Figure 1 | The repeated fall and rise of human cooperation. Sabin *et al.*¹ investigated long-term changes in cooperation. They studied group lending in Sierra Leone. Groups of small-business owners participated in joint-liability contracts, in which the group received a loan and was collectively responsible for repaying it; failure to repay the loan would result in ineligibility for the next loan cycle. The authors show that cooperative effort (measured as the timeliness of repayment) exhibits a punctuated decline pattern, falling over the course of one loan cycle as motivation to cooperate declines, and rebounding at the beginning of the next loan cycle as borrowers are reminded of their cooperative responsibilities. Each thin line shows the cooperative effort of a single group over time (grey indicates groups that continued to the next loan cycle, orange indicates groups that did not). The thick black lines indicate the average cooperative effort across all groups. Each loan cycle lasted 6, 8, 10 or 12 months, and each round represents periodic repayments within that cycle. (Adapted from Fig. 1c of ref. 1.)

no evidence that worsening financial hardship drove the pattern.

Interviews with borrowers and staff members of lending organizations point to a behavioural explanation. Over time, some group members reported becoming “lethargic”, “relaxed” or simply “tired of paying”, suggesting a gradual erosion of their motivation to cooperate. This weakening of commitment increased the temptation to partially free-ride and it pushed groups towards collective failure, especially because the remaining members often behaved as ‘conditional cooperators’ – once they saw others failing to contribute, they, too, became unwilling to continue doing so.

This finding matters for two reasons. First, most laboratory studies in economics and behavioural science are too short-lived to capture this kind of slow-moving erosion. The paper therefore shows the value of field research for revealing dynamics that matter in real life but are hard to detect in the lab. Second, although the mechanism might sound intuitive, it points to something broader: cooperation often does not collapse all at once, but wears down over time. Very little in human society sustains itself automatically. At the interpersonal level, even a happy marriage

endures only if both partners continue to invest in it over many years. At a much larger scale, liberty is no different – it exists in a delicate balance between a strong state and an organized society, and its preservation is a constant struggle².

Two limitations of the study are worth noting. First, the behavioural mechanism can be inferred only indirectly. The authors do not have sufficient interview data from the defectors, and must instead rely mostly on the accounts of others in the group and staff members. As a result, the precise psychological processes that drive defection remain unclear. This is less a flaw of the study than a constraint of the setting: people who have already defected might have little incentive to cooperate with researchers. Still, it highlights a broader challenge for fieldwork. Because some of the most valuable data come from precisely those individuals who are least willing to provide them, researchers might need to invest extra effort in tracing and interviewing such participants. Second, the study does not yet yield a clear policy suggestion for addressing the long-term decline in cooperative motives. That is understandable, because the phenomenon it identified is still theoretically underdeveloped.

A task for the future is to account for the foundations of the behavioural mechanisms identified in this paper. The psychological or neuronal processes involved are not yet observed well enough, but evolutionary theory could help to frame the deeper question: why would evolution permit or sustain motives with this kind of built-in instability? Existing models on the evolution of motives^{3–6} usually assume that motivations such as altruism, reciprocity and moral concern remain stable during an individual’s lifetime and that it is only the distribution of such motives in the population that changes across generations. But perhaps this assumption should be reconsidered. Motives might need to be modelled not as traits that are fixed over the life course but as conditions marked by a built-in instability that allows them to change, and perhaps systematically decline, over time.

After recognizing that cooperative motives can deteriorate over time, how should policy respond? It has been argued⁷ that the effective design of institutions must take the heterogeneity of human motives seriously. Socially valuable outcomes are sustained not only by harnessing self-interest towards collective ends, but also by evoking, cultivating and empowering public-spirited motives. Researchers in the field of behavioural-mechanism design – which studies the development of rules for making decisions and allocating resources while accounting for realistic models of human behaviour – have begun to take that insight seriously^{8–10}. But Sabin and colleagues’ study suggests that one more requirement might need to be added. If cooperative motives are not stable, then it is perhaps not enough to evoke, cultivate and empower them once; policy might need to renew them repeatedly over time, too.

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