# Desert Locusts Follow Unexpected Motion Rules

**New experiments with virtual reality suggest that locusts do not follow traditional rules of collective behavior.**

By Katherine Wright

About once per decade, millions of juvenile locusts collect in the deserts of East Africa and begin marching across the continent. The rules of how these insects move in swarms were mostly wrapped up, or so Iain Couzin of the Max Planck Institute of Animal Behavior, Germany, and his colleagues thought. In new experiments with locusts immersed in a virtual-reality (VR) environment, the team found that the classical models of collective behavior could not account for the locust marching behavior [1]. Instead, another model was needed. “We had no idea we would blow apart our understanding of these systems,” Couzin says. “We thought we’d replicate the old result and maybe find something new on top of that.”

The traditional model of collective behavior is the Vicsek model, which marks its 30th anniversary this year. In this model, individuals are treated as point particles that have some preferred direction of motion. A key assumption is that each individual interacts with its nearest neighbors—somehow sensing their directions—and then uses that “direction sampling” to choose which way to move. The alignment between individuals increases as the density of the group increases. Based on the Vicsek model, a swarm of locusts should exist in one of two states—a low-density disordered state and a high-density ordered one. And Couzin had seen this play out in locust lab experiments, or so he thought.

Experiments with real and virtual locusts indicate that traditional models of collective motion need a rethink.
**Credit: Vladimir Wrangel/stock.adobe.com**

Placing locusts in a circular racetrack for insects, he and his colleagues thought they observed a transition from disorder to order transpire as they increased the density of locusts in the system. Looking back now at the data, Couzin has his doubts. “Things we thought we saw weren’t there,” he says. A reanalysis of the data indicates no evidence of the density transition that they thought they had seen.

As part of their new study, Couzin and his team followed locusts marching across the deserts of Kenya. In these field experiments, the team modified the senses of some of the locusts, so that they either couldn’t smell or couldn’t see correctly. These modified locusts were marked with identifiable colors and were then returned to the marching swarms.

Locusts with no sense of smell marched in the same direction as the unmodified locusts, but completely blinded locusts moved in random directions. This random motion caused the locusts to bump into their neighbors, but in most cases those collisions provided no directional guidance to the blinded locusts, even when the density of the swarm was high. The results motivated

Researchers used a VR setup to study the factors that determine the direction that a locust moves relative to a group of "virtual" locusts. **Credit: S. Sayin/University of Konstanz**

the team to look more closely at the visual cues that affect locust motion.

Following the field experiments, Couzin and his colleagues set up a VR environment in the lab with a single real locust marching in a crowd of virtual locusts whose density ranged from 1 to 64 locusts per $m^2$. In one test, the team presented the real locust with two separate groups of virtual locusts both marching in the same direction. Rather than align with this uniform motion—as predicted in the Vicsek model—the real locust moved orthogonal to the flow until it had immersed itself in one swarm or the other. This non-Vicsek response showed no dependence on the density.

Despite these discrepancies, other researchers are not ready to throw out the traditional framework. "Nobody would expect the Vicsek model to describe such situations accurately," says Alexandre Solon, who studies active matter at Sorbonne University, France. He says the Vicsek model is based on simplified assumptions and only describes universal properties, but it can predict the transition to collective motion in many cases. Solon isn't surprised that the behavior of one locust facing complex stimuli would require a more detailed model, as is the case for birds and other animals.

Suraj Shankar, who studies active matter at the University of Michigan, agrees that the Vicsek model is meant to describe generic phenomena, not specific behaviors. But that doesn't take away from the new findings. "It's a beautiful demonstration of the additional complexities that can arise when interactions are behavioral, social, and cognitive, necessitating a revision of our simple models of flocking," he says. "Here by learning how a simple model is wrong, we can perhaps do better now to make it useful.

To explain their observations, Couzin and his colleagues considered a cognitive framework in which neurons in a locust's brain are represented as a ring of spins. When information comes in—such as the position of another individual—it excites the spins. For example, if the locust sees another locust to its right, the spins on the right side of its brain will get excited. If a third locust appears up ahead, the corresponding spins at the front of the brain will also get excited.

To decide its course of action, the locust basically adds up nearby spins and moves in the direction of the strongest excitation. "There is no information about alignment and no information about movement, it's just the positions of the others at any given moment and the electrical activity that is produced in the brain." As observed in the lab, the model predicts that coordinated motion can occur even at low densities.

Now that the researchers have a model that fits the data, they hope to be able to make better predictions about where and when swarms of locusts will move. They plan to scale up experiments in the lab to 10,000 individuals and to perform further experiments in the field.

And there may be more to learn from virtual environments. "Having VR tools that allow carefully testing interactions can, as this study has demonstrated, be very powerful and provide new insights that are difficult (if not impossible) to obtain in field experiments," says Christina Kurzthaler an active-matter researcher at the Max Planck Institute for the Physics of Complex Systems in Germany. She adds that including decision-making processes into active-matter models, as Couzin and colleagues have done, is a promising approach that "may lead to rich new physics and patterns of collective motion."

Katherine Wright is the Deputy Editor of ***Physics Magazine***.

**REFERENCES**

1. S. Sayin *et al.*, “The behavioral mechanisms governing collective motion in swarming locusts,” **Science 387 (2025).**