Biology | Amir Ayali & Gil Ariel

Collective-motion-state

What makes locust swarming so robust?

Swarming locusts are well-known for the destruction they can cause to vegetation and agriculture, yet our knowledge about the behaviour of locusts which enables the swarms to maintain their structure is far from complete. Amir Ayali from the School of Zoology, Tel Aviv University, Israel, and Gil Ariel from the Department of Mathematics of Bar-Ilan University, Israel, have led several studies on collective motion in locusts. Their recent work identifies a novel behavioural state that could hold the key to a more detailed understanding of swarming behaviour.

Collective motion – or the ability of animals to form groups that move collectively – is a key behavioural feature of many species including schooling fish, flocks of birds, crowds of humans and even artificial agents such as swarming robots. This behavioural feature, thought to increase the survival of the group, has attracted scientists from many disciplines, each aiming to understand more about how such mass interactions work. Previous research has shown that these interactions are influenced by the dynamic relationships between the individuals themselves and the co-ordinated activity of the group as a whole, as well as their wider interactions with the environment.

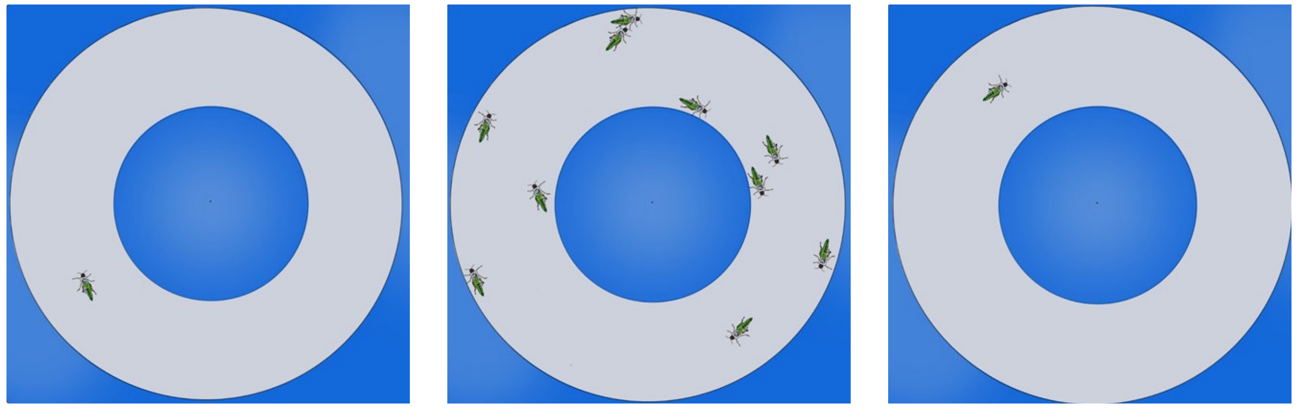
The coordinated migration of locusts is a model example of animal collective motion. Swarms of marching locusts have been known to have a devastating impact on agriculture as far back as human records reach, with descriptions of this remarkable natural phenomenon appearing in all the ancient scripts. These insects swarm in groups of millions and can migrate across large distances, leaving a wave of devastation in their path. How a swarm maintains its structure is a big puzzle. The swarm is based on local interactions between neighbouring individuals, yet it is extremely robust: millions of animals maintain their overall movement in the same direction for hours or days at a time.

Amir Ayali from the School of Zoology, Tel Aviv University, Israel, and Gil Ariel from the Department of Mathematics of Bar-Ilan University, Israel, have led several studies on collective motion in locusts. Their recent paper investigates the factors which enable locust swarms to maintain their integrity. The researchers have also used a simplified computer model to simulate the behavioural adaptation of individual locusts in different behavioural states, to understand which factors increase the stability of locust swarms and prevent the swarms from dispersing.

COLLECTIVE-MOTION-STATE

To understand the behavioural adaptations at the level of the individual locust and their effect on swarm formation and maintenance, the researchers monitored the specific walking characteristics of individual insects during collective motion while swarming. Collective-motion-state is a term coined by the researchers to explain the behavioural mode that was induced in the locusts taking part in collective movement. The locusts' kinematic behaviour – which can be explained as the quantitative parameters describing the walking behaviour, such as speed and walking bout duration – changes in this state and is different to that observed prior to experiencing collective motion. It is important to note that the collective-motion-state is a newly described, unique behavioural mode demonstrated by swarming locusts, and should not be confused with the 'locust density-dependant gregarious phase' that has been amply documented.

Locusts were monitored using a barcode tracking system.



An individual locust was monitored in isolation (left). It was then joined by other animals (middle) and in the final stage, the locust was isolated again (right). The researchers examined the locust's walking kinematics in all three stages – and found significant differences.

To monitor this behaviour, the researchers examined individual animals upon their joining and leaving a group of locusts. An individual was taken from a dense-rearing cage, introduced into a ring-shaped arena and monitored in isolation, before being joined by nine other animals. In the final stage, the same animal was again held in isolation. During these three stages (isolation, swarming, and re-isolation), the walking trajectories of the individual locust were tracked at high resolution which provided detailed statistics of its walking kinematics. Results showed that when in a group, the insects displayed a distinct behavioural mode that is statistically different than individuals that did not undergo collective motion.

The researchers found that there was large intergroup and small intragroup variability in behaviours.

Collective-motion-state was only adopted when the locusts took part in collective marching within the experimental arena. Furthermore, the researchers also found that the collective-motion-state is transient: if the locust does not experience collective motion for some time, it loses the unique walking behaviour that it previously adopted in response to the collective motion. While the dynamics behind this phenomenon were not examined in this study, it is thought that this loss of behaviour could be due to external factors such as the availability of food or the day-night cycle.

SWARMING BEHAVIOUR

In previous work from 2019, a research

The results from this study on locust swarms provide insights that could be applied to emerging technologies, such as drones and robots.

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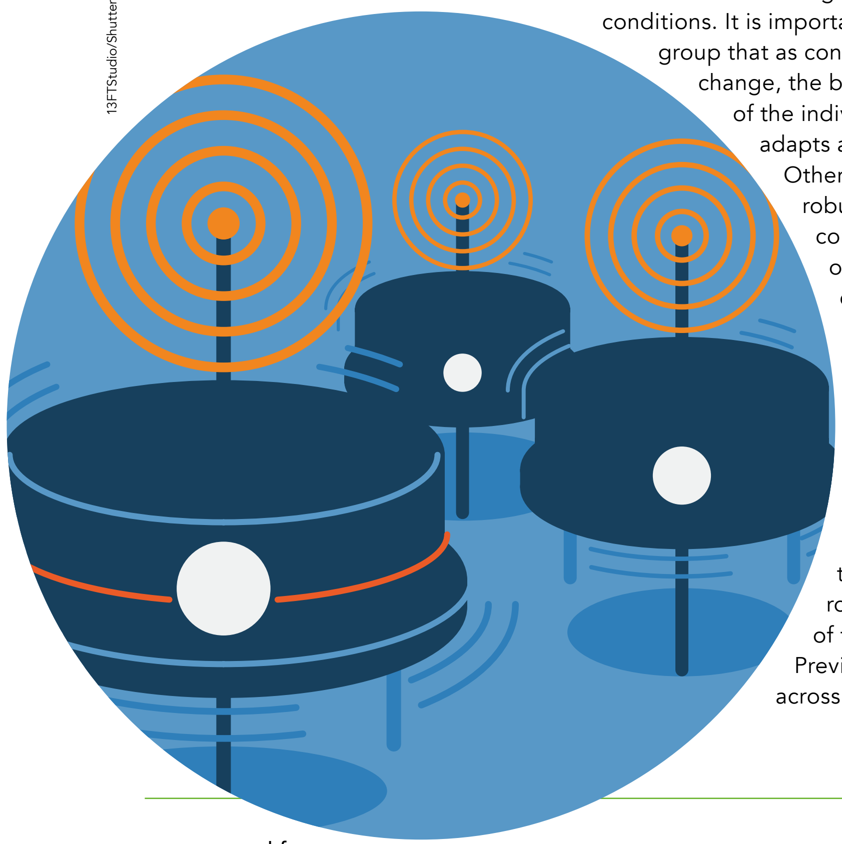
team led by Ayali and Ariel investigated intra- versus intergroup variance in collective behaviour. They found that there was large intergroup and small intragroup variability in behaviours. Behaviours that were consistent across the groups were considered essential for swarm formation. Their recent study confirmed these observations surrounding variability and further expanded on them to show that variability also exists in time, i.e. following collective motion. In addition to the variability of behaviour within a group, an individual's behaviour can also change over time, which allows it to adapt to changes it experiences, both in the environment and as a result of changes in social conditions. It is important for the group that as conditions change, the behaviour of the individual adapts accordingly. Otherwise, the robustness or consistency of the swarm could be negatively impacted. Hence, the collective-motion-state was found to be essential to the robustness of the swarm. Previous research across many species has demonstrated that variability among individual animals can have important consequences for the collective behaviour of the group.



TAKE-HOME MESSAGE

The findings from this study make an important contribution to the knowledge and understanding of the mechanisms underlying collective motion in nature. Locust swarms continue to have devastating impacts across the world, most recently in Africa and Asia, and understanding the swarming phenomenon is crucial for human well-being and survival. As a result, scientific attention has focused on understanding how collective behaviour in a swarm works and has largely focused on local interactions among individual locusts. This current study expands on this information by including the internal state of the individual locusts as an important factor in dictating its behaviour, demonstrating that the collective-motion-state has an important role in maintaining the integrity and consistency of the swarm.

As scientists continue to work on developing swarming robots for various real-world applications, such as search and rescue and for cleaning oil spills, the robustness of the swarm is proving to be a major challenge. The results from this study provide novel insights that could apply to this emerging field.

Behind the Research

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Research Objectives

Dr Amir Ayali and Dr Gil Ariel investigate how the behaviour of individual locusts contributes to the structure of the swarm.

Detail

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Bio

Amir Ayali received his PhD from the Hebrew University of Jerusalem in 1995. He went on to become a postdoctoral fellow at the Section of Neurobiology and Behavior, Cornell University. In 1999 started his group at the School of Zoology, Tel Aviv University, where he also served as Chair between 2010 and 2015.

Gil Ariel is an Associate professor at the department of mathematics of Bar-Ilan University, Israel. His research involves applied mathematics with emphasis on mathematical biology and collective motion. He received his PhD in mathematics from the Courant Institute of Mathematical Sciences at NYU.

Funding

This research has been supported by the Israel Science Foundation (research grant 2306/18)

Collaborators

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- Ciona Sha-ked
- Noa Agmon

References

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Personal Response

How may the results from this study be incorporated into future research that could be used to prevent the devastating impacts that swarms of locusts have on human communities?

"A major reason keeping us from successfully dealing with the devastating effects of locust outbreaks is our to date far from complete understanding of the complex dynamics associated with locust swarming and collective motion. The more we know about the mechanisms involved in the mass migration of locust swarms, the better we will be equipped in our efforts to prevent them. The collective-motion-state is a newly identified, individual-level, feature of the swarming locusts. Further research into physiological correlates and even the mechanisms underlying this unique behavioural state will open new avenues for locust control."

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