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Mimicry helps sheep solve a dilemma

Imitation behaviors play a key role in many collective phenomena seen in animals. An analysis of the collective movements of grazing sheep has revealed that sheep alternate slow dispersion phases with very fast regrouping, in which they imitate the behavior of their neighbors. This study, conducted by researchers from the CNRS, CEA, and the Universities of Aberdeen, Nice Sophia Antipolis and Toulouse III – Paul Sabatier[1], was published on September 28, 2015 in the journal *PNAS*. It shows that the intensity with which the sheep mimic one another plays a crucial role in the ability of a herd to maximize the grazing area explored while minimizing the time needed to regroup when faced with potential dangers.

Many animal species live in groups, such as shoals of fish and herds of animals. This lifestyle offers many benefits to individuals by increasing protection against predator attacks. It can also sometimes vastly improve the efficiency of foraging for food. In these groups of animals, imitation behaviors are the cornerstone of many collective phenomena. However, individuals do not imitate one another constantly or at the same intensity over time, which has the effect of increasing the complexity of collective behaviors. Group behaviors are determined by the importance with which each animal treats the behavior of its neighbors relative to its own motivations. Knowing how these two types of influences combine to determine the decisions of each individual within a group is crucial for understanding the complex dynamics of many collective phenomena, not only in animals but also in humans.

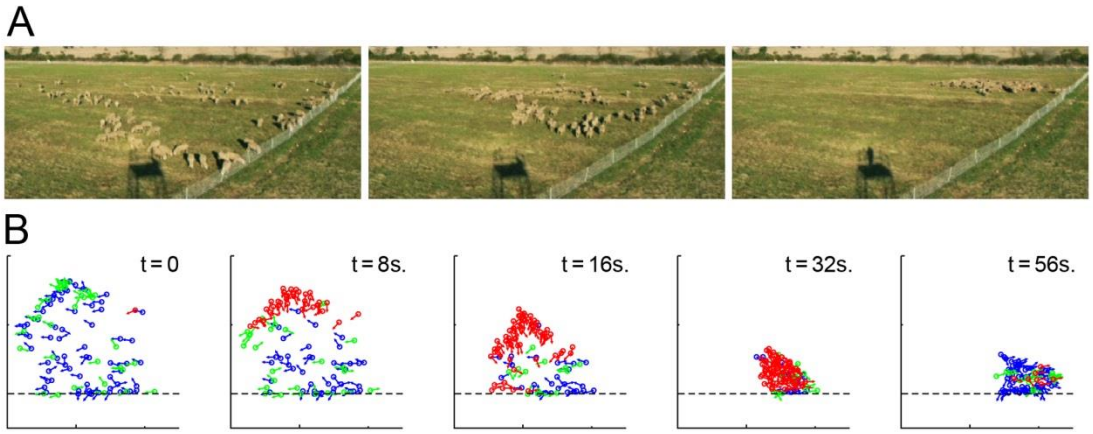
To study these phenomena, the researchers analyzed the collective movement of flocks of a hundred Merino sheep grazing under controlled conditions on the *Domaine du Merle* at Salon-de-Provence. They demonstrated that these movements have intermittent dynamics: slow dispersion phases alternating with phases of consolidation and very fast movement during which sheep mimic the group already in motion. The analysis of these regroupings, and therefore of the mimicry phase, reveals that they are similar to avalanches: their amplitudes are random and distributed over a range with a very large scale. At the scale of the group, this system appears similar to what is called a "critical" condition.

In addition, by using a mathematical model to reproduce the interactions between sheep and their effect on spontaneous behavior, scientists have shown that the intensity of mimicry plays a critical role in the ability of a herd to maximize the area foraged for grazing while minimizing the time needed to regroup. These studies demonstrate that the intermittent dynamics observed in sheep stem from the need for each

[1] The following French laboratories were involved: *Centre de recherches sur la cognition animale* (CNRS/*Université Toulouse III – Paul Sabatier)*, *Service de physique de l'état condensé* (CNRS/CEA) and *Laboratoire Jean-Alexandre Dieudonné* (CNRS/*Université Nice Sophia Antipolis*).

individual to balance two conflicting motivations: to explore enough new grazing area to find food but also to stay in contact with other herd members so as to benefit from the protection offered by a compact group.

These results also offer new elements for the current debate on the issue of "criticality" of living systems. Being neither in too much disorder nor too rigidly organized – one of the signatures of critical phenomena in statistical physics – sheep would be able to respond effectively to external disturbances, an advantage that could have been selected by evolution. This study suggests that such behavior could be vital when sheep sense the presence of a predator. It would allow the group to develop a form of "collective intelligence" and circulate information.



A. An example of a spontaneous regrouping phase resulting from mimetic behavior of a flock of Merino sheep
B. Sheep position and movement speed reconstructed from image analysis. Colors indicate the speed of movement of each individual (blue: immobile, green: walking, red: running). © CRCA-CNRS, Toulouse.

Bibliography

Intermittent collective dynamics emerge from conflicting imperatives in sheep herds. Ginelli, F, Peruani, F., Pillot, M.H., Chaté, H., Theraulaz, G. & Bon, R. *Proceedings of the National Academy of Sciences USA*. September 28 2015.

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