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The mechanisms behind synchronized hunts in spiders

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Spiders are known for their aggressive behavior, but some species are social. This is the case for Anelosimus eximius, a social species that forms colonies with hundreds of spiders living in a common web. When hunting, these spiders synchronize their movements: they start and stop quickly, all at the same time. Analyses explain how this impressive ballet could emerge from simple behavioral rules.

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In nature, entities like cells or organisms like spiders and humans, can interact to generate collective behavior. Among these fascinating behaviors, synchronization is found at all scales of life, from heart tissue where cells beat regularly to assemblies of fireflies that flash in rhythm. Within these groups, termed biological systems, no single entity assumes the role of leader and the emergence of synchronization relies on multiple interactions between group members who each obey simple behavioral rules.

Two broad classes of models can explain how synchrony occurs in biological systems. The first category assumes that each individual has an intrinsic rhythmicity, and that synchronization relies on individuals adjusting their phases to each other. In flashing fireflies, for example, an individual emits flashes of light at regular intervals, even if that individual is isolated. When in a group, all individuals emit flashes synchronously. In the second category, synchronization relies on the ability of individuals in the group to activate other individuals without any of them having an intrinsic rhythmicity. This is the case in the formation of the Mexican wave in stadiums, whose propagation occurs because individuals standing up incite the seated spectators to stand up in their turn. Coordination of the activity requires some kind of communication – electric in cardiac cells, visual in fireflies or humans at the stadium – so that each entity is informed of the state of the other members of the group. In general, communication is established between close neighbors, which implies that the signal does not propagate immediately to the whole system.

Within the 50,000 known species of spider, about 20 have developed a permanent social life and some display amazing forms of cooperation. In the rainforests of South

America is found the species Anelosimus eximius which forms colonies that can contain thousands of spiders occupying a web covering the vegetation on several square meters. Collectively, these spiders can catch prey tens of times larger than a single spider. When a prey falls into the web, nearby spiders rush towards it by synchronizing their movements: they all move together, then pause their movement and resume it in unison.

To unravel the mysteries of this phenomenon, our team conducted a field experiment in French Guiana. We used a vibrating device that mimicked the vibrations of a prey to trigger hunts and videotaped groups of spiders in action. The transitions between immobile and mobile states occur in less than a second and, on the web, it is then possible to observe waves of several tens of spiders moving all together and in rhythm towards the prey. Back in the lab, we analyzed spider movements frame by frame and recorded the position and behavior of each spider. We used this data to identify the behavioral rules underlying synchronization. First, we found that the duration of each move is constant and does not depend on the behavior of other individuals. Where it gets interesting is when the spiders are stopped. The decision to move depends on the relative intensity of the vibrations on the web: the spiders remain motionless until they can distinguish the vibrations caused by the other moving spiders from those of the prey. Only when this condition is met can they start moving again, and this is where social amplification comes in: one spider will start moving spontaneously, which will produce vibrations that will incite the other spiders to start moving and so on until all the hunters are on the move. With this strategy, the spiders can locate the prey despite the vibrations they are producing when moving.

These simple behavioral rules allow the spiders to adapt almost instantly to any change during the hunt. For example, when the intensity of the vibrations by the prey varies according to whether it is struggling more or less in the web. This also allows them to adapt to any type of prey falling into the web without an individual coordinating the activity of the group members. Since it is not possible to experimentally manipulate spider behavior, we also developed a computer model to explore the benefits associated with synchronization. We found that, even if the spiders lose time when they stop during the hunt, these pauses benefit the group; they improve the accuracy of individual spiders to detect prey and the efficiency of hunting.

In addition to explaining a fascinating phenomenon, this research represents a source of bio-inspiration for people who aim to rapidly coordinate the actions of numerous agents, for instance to facilitate the displacements of swarms of drones.