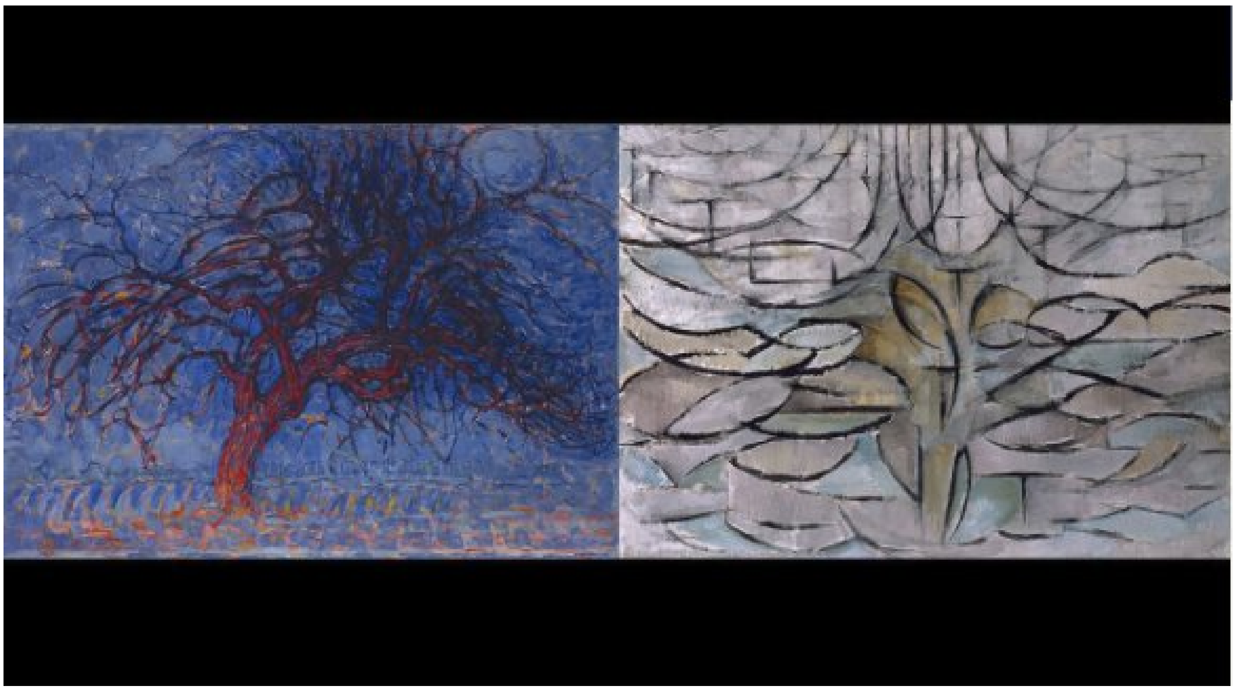
PHYS.ORG

New paper answers causation conundrum

November 17 2017



Red Tree #1, #3 by Piet Mondrian. The compression of information from one version to the next illustrates the concept of coarse-graining. Credit: Santa Fe Institute

In a new paper published in a special issue of the *Philosophical Transactions of the Royal Society A*, SFI Professor Jessica Flack offers a practical answer to one of the most significant, and most confused questions in evolutionary biology—can higher levels of organization drive the behavior of lower-level components?

Called downward causation, an example of this idea would be a high level human social system, such as a government, making laws that more or less force individuals at a lower level to act in certain ways—stopping at a stop sign, for example. There are many similar colloquial examples to be found in the biological and social sciences, from cells to societies. However, as soon as one spends a little time considering how this causality works, trouble arises.

To summarize a long and convoluted debate, downward causation suffers from the criticism that higher levels of organization are 'just' temporal and spatial patterns that are the outcome of dynamics at a lower level. As patterns, they have no agency and hence cannot be considered causes.

In the new paper, Flack suggests that in order to get traction on this problem we need to step back and consider what makes adaptive systems different than physical systems.

Physics is dominated by concepts like pressure, temperature, and entropy. These emerge through simple collective interactions and provide deep insights into the behavior of the physical universe.

Biology and social science, which deal with adaptive systems, make use of comparable collective concepts including metabolism, conflict management, and robustness, but in contrast to physics, these are "functional" properties. Where physics produces order through the minimization of energy, adaptive systems produce order and novel function through the addition of information processing.

"Why adaptive systems have this extra step and whether it makes them fundamentally subjective are big, open questions," Flack explains. She says that fundamental subjectivity could mean that adaptive systems would be intractable to scientific attempts to predict their behavior, or characterize it through universal laws.

In order to make progress on these questions, Flack argues that we must first understand how adaptive systems find workable solutions to challenges posed by the environment, which would require them to overcome subjectivity.

"Consider that every individual body, every brain, is composed of multiple noisy components—cells, neurons, etc, processing noisy data," she says. "When we see the world this way, from the bottom up, the question becomes how all of the component decisions combine to produce a functional output, or solution to a problem. We can think of this process as a collective computation."

Flack, David Krakauer, and their colleagues have discovered in their work on neural and social systems that collective computation can produce "layers" or levels that emerge through a process of collective coarse-graining by the system components, in which inessential information is discarded from one layer to the next. Behavioral variation at the microscopic level or in the environment gets compressed or coarse-grained to produce the next level up, and then these regularities "feedback" to the layer below to reduce variance or inform decision making at the lower level. The consolidation or strengthening of the layers essentially creates what Flack calls in the Phil Trans paper "effective downward causation"—making it seem like the higher level solution is the cause of the lower level behavior when really what is happening is the lower level components are using the coarse-grained variables that constitute the higher level to guide decision-making.

"This iterative coarse-graining and variance reduction appears to allow the system components to collectively converge or agree on what the regularities are in the world, which reduces uncertainty and allows them to better adapt and better extract energy to do work," writes Flack.

"Sometimes this process captures a ground truth about the world and sometimes it results in the components collective computing—essentially creating—their macroscopic worlds. The broader impacts of this way of thinking have the potential to be enormous. If this view is correct laws operating on universal quantities derived from microscopic processes might also govern biological systems. But in contrast to physical systems identifying these laws in living systems will require a theory of collective computation—an understanding of the algorithms adaptive systems use to compute and how error and imperfect information can be overcome through coarse-graining and compression to produce slowly changing, predictive, and therefore, functionally useful, aggregate-level properties."

More information: Jessica C. Flack. Coarse-graining as a downward causation mechanism, *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* (2017). DOI: 10.1098/rsta.2016.0338

Provided by Santa Fe Institute