Order From Rhythmic Entrainment and the Origin of Levels Through Dissipation

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Rhythmic entrainment is the formation of regular, predictable patterns in time and/or space through interactions within or between systems that manifest potential symmetries. We contend that this process is a major source of symmetries in specific systems, whether passive physical systems or active adaptive and/or voluntary/intentional systems, except that active systems have more control over accepting or avoiding rhythmic entrainment. The result of rhythmic entrainment is a simplification of the entrained system, in the sense that the information required to describe it is reduced. Entrainment can be communicated, passing information from one system to another. The paradigm is a group of jazz percussionists agreeing on a complex musical progression.

Some symmetry is relic from either earlier undifferentiated conditions and/or deep universal principles, but individual systems are usually individuated through the production of information that distinguishes them from other systems (Collier 1996). Rhythmic entrainment is a counterpoint to the production of information by symmetry breaking, though similar principles are involved.

Rhythmic entrainment can either be forced (driven) or spontaneous (self-organising). Forced entrainment can be either high power or low power. In high power entrainment, one powerful system drives another through immediate force, e.g., a boat's movements on storm waves at sea. Low power forced entrainment is of interest because it depends more on persistence and careful application of force than on immediate power. An example would be driving a large oscillator (say a swing) with small applications of force just off a node ("pumping" the swing). Forced cases always transfer pre-existing order.

Spontaneous entrainment creates *new* symmetries via the dissipation of energy and/or information. Systems tend towards minimal energy and tend to organise themselves so as to minimise dissipation. This increases higher level order, or symmetry. Examples can be found in resonances in the solar system resulting from tidal dissipation. Resonance tends to reduce dissipation and lower the energy of the system. We argue that similar processes are widespread.

Physics

Some of the most interesting spontaneous symmetries are in the Solar System. One obvious one is the 1:1 correspondence between the Moon's rotation and revolution times. This is typically attributed to tidal torques lagging behind the direct line between the Moon and the Earth that create dissipation of gravitational energy. The torques are minimised if there is a 1:1 correspondence, since then there is no lag. There are some other much more complex resonances, however. Mercury's rotation period is in a 3:2 relation to its revolution period around the Sun; i.e., Mercury turns three times on its axis for each time it goes around the Sun. This can also be accounted for in terms of tidal torques, since they are less in a 3:2 resonance than in any nearby relation (though greater than they would be for a 1:1 relation, in which there would be no tidal torque). Therefore, Mercury is effectively caught in the 3:2 resonance. How did it arrive in this resonance, rather than some other? Basically, the answer is chance. In the total Sun-Mercury phase space with tidal dissipation there are a number of attractors representing resonances, with fractal boundaries between the resonance basins. With no other information, there is a bout a 30% of 3:2 resonance, 50% for 1:1, and the other rest cover the other probabilities. Further resonances are a near 5:2 between the rotation period of Venus relative to its passing the Earth, and a resonance between Pluto and Neptune such that although Pluto crosses the orbit of Neptune, it will never hit Neptune (this may be partially a relic of Pluto having been a moon of Neptune at one time).

Physics also provides good examples of forced resonances, as when a force drives an oscillator towards its natural oscillatory frequency (nearby frequencies are damped by dissipation, so not any frequency can be driven unless there is considerable power and lots of energy to waste). Even chaotic oscillators can be put into resonance; the resonance itself is harmonic, but the motion of each oscillator is chaotic. This shows the possibility of forcing a resonance in an otherwise unpredictable system.

There are many other cases of spontaneous entrainment in physics. One especially simple case is the formation of dissipative structures through the promotion of noise. Bénard convection cells are the simplest of these, since they are so closely controlled. Nonetheless, the cells form spontaneously when the conditions are right. Other forms of entrainment are seen in the formation of eddies, standing waves in streams and waves in the atmosphere. In each case the entrainment creates a macroscopic structure that contains symmetries not present in the original microscopic structure. Although it is possible to create circumstances that will produce a certain resonance, in systems with multiple attractors this can be done only probabilistically, undermining controllability (large applications of power and dissipation of energy are required to overcome this lack of uncontrollability). In systems like the climate and weather, with many attractors, control is virtually impossible, since very small effects can move the system from one attractor to another (the so called "butterfly effect").

Several lessons can be learned from the physical cases. First, for the forced case, there are natural resonances in certain systems that can be driven by forces that contain the relevant frequency. The oscillator will resonate at its natural frequency because other frequencies will be damped by dissipative forces. To drive a system at an unnatural resonance requires a great deal of power, and wastes a lot of energy to overcome dissipation. We believe that the same principles apply across all systems, including social systems for forced resonance. In the case of spontaneous resonance, the properties of the system imply attractors to which the system can be led by dissipation. Systems with multiple attractors are hard to control, and like forced oscillation, require considerable power to drive them to a desired attractor, or else very subtle applications of force in regions near the chaotic zone between attractors.

Measurement

Measurement is a special form of entrainment in which the measured property drives a special device into a resonance that correlates in a theoretically predictable way with the driving property. We give a couple of examples from geophysics, and then argue that sensation is the most fundamental form of measurement, working on the same principles.

Micro-gravity surveys are often done with a gravimeter, a device that responds to the local force of gravity by moving a delicate spring holding a weight. Absolute measurements are impossible with this device, but the relative force a gravity at different locations can measured very accurately. Basically, the gravitational force twists the spring, the twisting being proportionate to the change in gravitational field strength. This is an example of directly forced entrainment. Magnetic surveys, on the other hand, are done with a device that has an ability to resonate at various frequencies when driven by a force. The magnetic field, much stronger than the energies required to drive the meter into resonance, drives the meter into one of its many possible resonances, designed to be very close together to permit a high degree of accuracy in measurement. In this case, the forcing is indirect, since the meter has its own resonances, one of which is selected by the force of the magnetic field.

Sensing is similar to measurement with geophysical instruments, but has some additional interesting properties, both in operation and origin. In operation, energy is passed from the thing sensed that has a form that stimulates the nervous system so as to entrain the form in a way that we can use to form expectations, predictions, and guide actions (though this process is fallible, partly because of possible failings in the sensory system, but more likely at other points in the process. Possible, most sensation is more like the gravity meter, directly forced, but in hearing and smell the sensory system has a number of natural resonances, and the forcing is indirect. I has been suggested that both smell and hearing systems are kept normally in a chaotic state, and that the sensation drives the system into one of the infinity of oscillatory states that make up the chaotic state. Although this mechanism is not universally accepted, it would allow very fast sensation, because all the sensory states are already present in the sensory apparatus. A sensory system near to chaos would be almost as effective in response, but would allow only a predetermined set of responses that might be slightly different than the driving sensory impulse. Possibly more subtle phenomena are grasped in the same way, even across sensory modes.

Sensory systems, as we have described them, already contain all the possible responses, but they had to originate in some way. This origin was not designed. The most likely explanation is that the underlying structure was malleable, and gradually responded spontaneously to sensory inputs, whose increasing effectiveness was guided by interaction with the environment and by selection. These guiding processes are a sort of forcing that tune the sensory system as it evolves, but the original formation of sensory attractors must have been spontaneous, with information dissipative in the interactive and reproductive and selection processes. Similar mechanisms might be involved in the formation of learned higher order perceptions as well as learned ideas and practices.

One of the more vexing problems of measurement of our day is what happens in Quantum Mechanical system when they interact with measurement (macroscopic devices). In this case the energies involved are very subtle, and we cannot rely on forcing. We speculate a pro-Bohmian approach in which the guiding wave entrains the measurement device. Since the energy in the wave can be extracted only a half wave length at a time, there are natural limits on this sort of measurement, relative to the size of the properties to be measured. Conjugate values, like momentum and position, which together make up action, the units of the Planck's constant, cannot be measured entirely independently, since they are entangled in the single wave, and can only be entrained together.

Memes

The communication of memes is one of the most interesting forms of entrainment. Memes can be ideas, practices, ideologies and paradigms, among other things, though they are most often thought of as ideas. In some cases, when the basic primitives are already there, memes are passed by simple resonance, causing an appropriate combination of preexisting memes. In other cases, new primitives must be created, as when an apprentice learns from a master. This involves some simple forcing through recombination, but largely involves the spontaneous generation of memes through the generation of new primitives in the apprentice in the presence of the master's memes, which aid in the entrainment through reward and punishment, but also through copying and practice directed in an appropriate way. This latter form of learning can be carried out independently, and is probably a major factor in the transmission of memes.

The original metaphor for entrainment from music is a social case, and we believe that entrainment is common at the social level. This can help to create social order and function, but it can also be wasteful and counterproductive if done poorly. In some cases practices, ideas and ideologies form spontaneously and unpredictably when the right conditions occur, resulting in very rapid change. Fashion and art change, and the fall of the Berlin Wall probably contain large elements of this sort of entrainment. The population affected need not be prepared for the eventuality, but there must exist a social attractor (perhaps one of many), that random variations allow to become expressed throughout the population. If there are many attractors, the change will be essentially unpredictable, and in that sense random. This suggests that there will never be a fully predictive social science, especially in the case of history.

Authoritarian and totalitarian states put a premium on control. To some extent, they must rely on predispositions in their populations, but largely they rule by terrorist methods and fear. This requires a large concentration of both political, economic and political power, since driving a system artificially a requires a lot of power and waste of energy. This suggests that such states will be unstable. Unfortunately, whenever there are large concentrations of political, economic or physical power, there will be a tendency to use forced entrainment of ideology, however inefficient. A more efficient but less reliable method is propaganda and advertising, which attempt to drive or create resonances through subtle forcing. This method still requires a concentration of power to exclude competitors.

We believe that a stable social system is best founded on spontaneous entrainment. This is both more stable and more efficient than forced coordination and obedience. Its main problem is that it may lead to arbitrary and unproductive entrainments, basically pathological, so some control is mandatory except in the most advanced social systems, in which stability is already well entrained, and mechanisms for the dissipation of concentrations of power already entrenched in the structure of the system. Great variety can be tolerated in such a system, with minimal control, and it allows both the greatest freedom and flexibility.

Reference

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