Feedback Loop

A relationship between variables in a system where the consequences of an event feed back into the system as input, modifying the event in the future.

Every action creates an equal and opposite reaction. When reactions loop back to affect themselves, a feedback loop is created. All real-world systems are compose of many such interacting feedback loops—animals, machines, businesses, and ecosystems, to name a few. There are two types of feedback loops: positive and negative. Positive feedback amplifies system output, resulting in growth or decline. Negative feedback dampens output, stabilizing the system around an equilibrium point.[1]

Positive feedback loops are effective for creating change, but generally result in negative consequences if not moderated by negative feedback loops. For example, in response to head and neck injuries in football in the 1950s, designers created plastic football helmets with internal padding to replace leather helmets. The helmets provided more protection, but induced players to take increasingly greater risks when tackling. More head and neck injuries occurred than before. By concentrating on the problem in isolation (e.g., not considering changes in player behavior) designers inadvertently created a positive feedback loop in which players used their head and neck in increasingly risky ways. This resulted in more injuries, which resulted in additional redesigns that made the helmet shells harder and more padded, and so on.[2]

Negative feedback loops are effective for resisting change. For example, the Segway Human Transporter uses negative feedback loops to maintain equilibrium. As a rider leans forward or backward, the Segway accelerates or decelerates to keep the system in equilibrium. To achieve this smoothly, the Segway makes one hundred adjustments every second. Given the high adjustment rate, the oscillations around the point of equilibrium are so small as to not be detectable. However, if fewer adjustments were made per second, the oscillations would increase in size and the ride would become increasingly jerky.

A key lesson of feedback loops is that things are connected—changing one variable in a system will affect other variables in that system and other systems. This is important because it means that designers must not only consider particular elements of a design, but also their relation to the design as a whole and the greater environment. Consider positive feedback loops to perturb systems to change, but include negative feedback loops to prevent runaway behaviors that lead to system failure. Consider negative feedback loops to stabilize systems, but be cautious in that too much negative feedback in a system can lead to stagnation.[3]

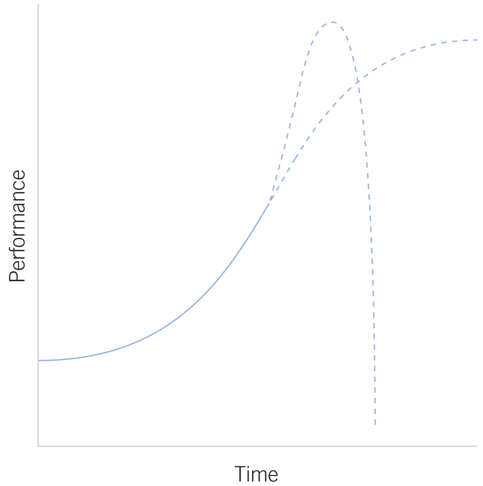
See also Convergence, Errors, and Shaping.

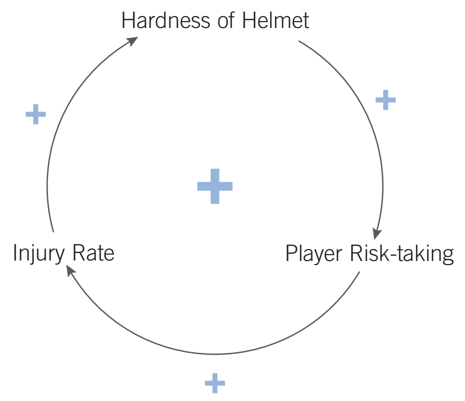
[1] In terms of practical application, the seminal works on systems and feedback loops include *Industrial Dynamics*, MIT Press, 1961; *Urban Dynamics*, MIT Press, 1969; and *World Dynamics*, MIT Press, 1970, by Jay W. Forrester.

[2] See, for example, *Why Things Bite Back: Technology and the Revenge of Unintended Consequences* by Edward Tenner, Vintage Books, 1997.

[3] See, for example, *Macroscope: A New World Scientific System* by Joel De Rosnay, translated by Robert Edwards, Harper & Row Publishers, 1979.

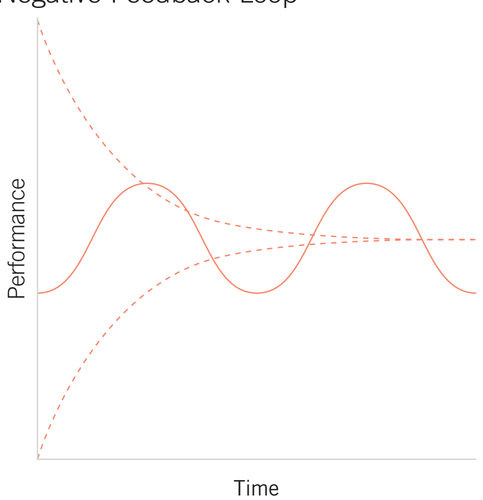
Positive Feedback Loop

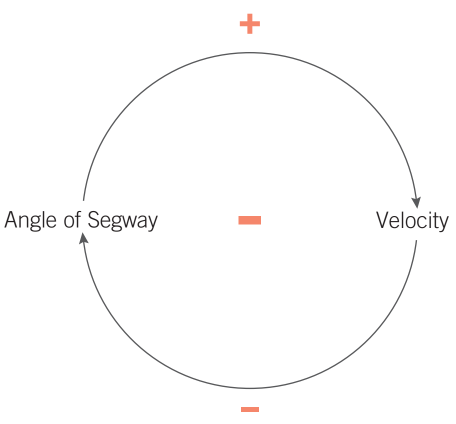




The design history of the football helmet is a classic example of positive feedback. Positive feedback loops will eventually collapse, or taper to an S-shaped curve if limited by some other factor, such as new rules penalizing the use of helmets in tackling.

Negative Feedback Loop





Negative feedback loops are used to stabilize systems—in this case, to balance the Segway and its rider. Negative feedback loops are applied similarly in thermostatic systems and fly-by- wire controls in aircraft. Negative feedback loops assume a goal state, or oscillate around a goal state if there are delays between the variables in the loop.