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Rachel Carson Center for Environment and Society
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Benedikt Berninger

Causality and the Brain

History, while shaped by a variety of non-human factors, is ultimately made by humans, whose actions, in terms of motivations and their capability of understanding different situations, are intricably bound to the design (through biological evolution) of their brains. Since antiquity, historians have faced the problem of explaining historic events, such as the Peloponnesian War or the Second World War, by identifying the *causes* that have led to them. Just as in the natural sciences, the concept of causality is of fundamental importance to the science of history.

Yet it may be argued that the very concept of causality, rather than being a brain-independent reality, may itself derive from the way the human brain encodes and structures experience, that is, by changing the strength of the functional connectivity between neurons according to inbuilt algorithms that themselves depend on the precise temporal order of neural activity (Berninger and Bi 2002). Immanuel Kant ([1765] 1965), in an attempt to solve a problem originally formulated most articulately by David Hume ([1739] 1888), concluded that the notion of causality, rather than being derived from experience, is an *a priori* condition of experience. He agrees with Hume that the idea that a certain cause is followed by a certain effect with necessity cannot be derived from experience: repeating the same experiment a hundred times does not prove that the next time the result would be the same; rather, the notion of necessity is a categorical condition for the notion of causality.

Needless to say, scientists are a long way from having a neurobiological explanation of how our brain "computes" a kind of more categorical causality. We have proposed that, at an elementary level, it may be related to the phenomenon of spike timing dependent plasticity (STDP) of synapses (Berninger and Bi 2002). STDP is a phenomenon occurring at many central synapses, for instance the so-called Schaffer collaterals in the hippocampus, which play a crucial role in the formation of episodic memories (Bi and Poo 2001). A synapse between a neuron *A* and a neuron *B* becomes strengthened when the firing of *A* precedes the firing of *B* within a narrow time window of few milliseconds. If the temporal order is reversed, i.e., neuron *B* fires before it receives input from neuron *A*, then the synapse becomes weakened. Anthropomorphically expressed, the synapse

A to *B* becomes strengthened when it contributed to the firing of *B* and weakened when it did not contribute. Thus, the synaptic modification rule appears to serve on a very elementary level as a causation detection mechanism.

Why would considering the neurobiological basis of the cognitive category of causality be relevant to the idea of neurohistory? Despite the fact that it obviously arose in adaptation to a real world, we cannot assume that a biologically implemented mechanism is limitlessly applicable to all phenomena. In fact, there are examples of situations where an appropriate description of the phenomena contradicts our commonsense understanding of causality. The unpredictability of the exact moment of decay for a single radioactive atom may be taken as an example *par excellence* of the failure of a strict causality in which every subsequent moment is entirely determined by the previous one. Likewise, our mind struggles with the view of physicists like Prigogone in the field of nonintegrable dynamical systems who suggests: "Insofar as we are unable, not only in practice, but as a matter of principle, to describe the system by a trajectory, and are forced to use a distribution function corresponding to a finite (even arbitrarily small) region, we can only predict the statistical fate of the system" (quoted in Balescu 2007, 27).

One might ask whether such reasoning can also be applied to the science of historical processes: to consider historical processes as transitions between *attractor* states, seemingly stable, but constantly destabilized by mutually interacting and interdependent factors. In a similar analogy, historical processes may be compared to the transition between brain states: they are stable within short temporal windows, but are necessarily transient and eventually result in persistent (but not necessarily permanent) modifications of the circuitry, thereby modifying the attractor landscape itself, sometimes irreversibly. If, then, we consider history to share certain structural features with nonintegrable dynamical systems, thus allowing the possibility for the emergence of complex or chaotic behaviors, it would strongly suggest that we attribute an erroneous degree of predictability to history when we try to isolate individual causal relationships between single historical *momenta* of political and ideological nature.

These considerations serve to illustrate that our thinking is often restricted by commonsense understanding, which is itself, not unsurprisingly, the result of the faculties and limitations created by the design of our brain. One important task of neurohistory may be to incorporate an awareness of these faculties and limitations into the way we think about humankind and history.

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