Perception, movement, emotion, and cognition are irreducibly intertwined, argues a neuroscientist.

NEUROSCIENCE

Transcending reductionism in neuroscience

The brain is a relational organ that is not just the sum of its parts

By **Alex Gomez-Marin**

In his new book, *The Entangled Brain: How Perception, Cognition, and Emotion Are Woven Together*, Brazilian neuroscientist Luiz Pessoa offers a way to construe the brain as a fully integrated organ, a framework that "while not rare, is also *not* mainstream among neuroscientists." A "divide-and-conquer strategy" has produced ever more refined brain maps, he argues, and subsequent leaps from structure to function. However, not only are anatomical brain areas far from simply located units of cognition but, as the subtitle of the book makes explicit, perception, cognition, and emotion are also interweaved.

To stress the networked nature of the brain, Pessoa has chosen a timely adjective: "entangled." He seeks a portrait of the brain beyond the high-resolution caricature of cognitive functions placed inside cerebral boxes.

The first chapters of the book build the case for the problem to be solved: "Our understanding of the role of a specific region needs to be gradually bootstrapped." Pessoa initially dives into brain anatomy because, no matter how dry, it is a must. In turn, proper anatomy calls for embryology. And, as tackled later in the book, evolution also informs brain organization. Disciplines, we learn, are entangled too.

So, what is the remedy for reductionism? Pessoa goes for large-scale distributed circuits within a network perspective—a complex systems approach where "many relatively simple interacting parts" exhibit "emergent" behaviors. Emergence can be invoked as a free miracle, and the misuse of networks lends itself to hairball graphs. However, Pessoa's amalgamation of systems theory, cybernetics, and network science is a necessary step.

Pessoa claims that "biology does not work like physics, and even less so like engineering." He challenges linchpin assumptions in the life and mind sciences—the reducibility of organisms and their brains, ceteris paribus, and the belief that truth is to be found in simplicity. The obviously nontrivial requires restating: We cannot explain "all biology in terms of physics and chemistry."

Pessoa devotes many pages to his own research on emotion. The reader is then introduced to the role of the hypothalamus, the amygdala, the insula, and other brain areas such as the cingulate and prefrontal cortex. Wondering about neural modularity, Pessoa discusses the logic of dissociations. One can learn tremendously from lesions and manipulations, and yet brain regions can carry out tasks previously performed by other parts now gone.

Pessoa then challenges the "*billiard ball* model of causation" with a more dynamic view. However, he wonders whether neural trajectories, as signatures of cognitive tasks, do explanatory or descriptive work. He subscribes to the current renaissance of process philosophy in biology, whereby organisms are conceived of as processes rather than things.

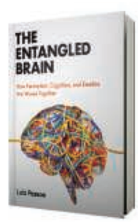
Much like classical physicists chiseling atoms, the irrepressible desire of neuroscientists to literally observe the mind leads to paradox, if not fallacy. Visualization and naming engross us. The fanfare provoked by a brain region lighting up in blue under a scan upon the presentation of a blue stimulus borders on a Monty Python sketch. And the lesson goes beyond brain areas: There is no such thing as the "gene of jealousy" or the "hormone of hate," for example.

Despite explicitly mentioning the pioneering work of theoretical biologists Ludwig von Bertalanffy and Robert May, Pessoa hints at the sterility of "idle armchair musing." Should we tend toward frenzied benchwork productions instead? The former without the latter is barren; the latter devoid of the former is bovine.

The book says little about the bodies, minds, and reciprocal interactions between organisms and their environments. Certainly, "a brain can be thought of as an entire circuit 'in between' sensory and motor cells." Perception, nevertheless, is virtual action.

The Entangled Brain often reads more like a manifesto than an argument. Indeed, mantras such as "circuit X produces behavior Y" betray a can of misconceptions. However, there is room for both separation and connection, as the synapse metaphorically symbolizes and literally enables. The disputes between lumpers and splitters are half-truths.

Given Pessoa's wink at a processual view of life, one wonders whether his postreductionism also calls for a postmaterialist neuroscience. Paraphrasing Erwin Schrödinger, if *verschränkung* (entanglement) is the defining characteristic of brains and minds, it enforces an entire departure from classical lines of thought. In this sense, *The Entangled Brain* instantiates yet another conservative revolution in current neuroscience. ■



The Entangled Brain
Luiz Pessoa
MIT Press, 2022.
280 pp.

The reviewer is at the Instituto de Neurociencias, Consejo Superior de Investigaciones Científicas–Universidad Miguel Hernández de Elche, Alicante, Spain. Email: agomezmarin@gmail.com

10.1126/science.ade8689

PHOTO: SIMON RITZMANN/GETTY IMAGES