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Beyond Boundaries Expanded Edition: Neuroscience, Brains and Machines

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The review of the book "Beyong Boundaries: the new neuroscience of connecting brains with machines - and how it will change our lives" (2nd edition) is justified by the relevance of the study that discusses the relationship between body and mind, as well as inquiring about the distinct strands that formulated investigations and experiments since the beginning of neuroscience. Another highlight stems from its position among a significant number of investigations aimed at understanding the probable connections between human thought and behavior. Objectively, the research presents the human brain and the new discoveries made possible by what was developed between Duke University (USA) and the Edmond and Lily Safra International Institute of Neurosciences, located in Northeastern Brazil, in the city of Natal, state of Rio Grande do Norte. Experiments have shown significant results including rodent and primate studies through the brain-to-brain interface (BBI) that resulted in the BrainNet paradigm (network of connected brains).

The book was first released in Brazil in 2011, authored by physician Miguel Nicolelis, a Brazilian scientist and professor at Duke University (USA). At the time, the experimental predictions presented in the current version had not yet been published. This updated second edition incorporates 13 chapters, which indicate, with accessible language, the historical processes of brain research.

The first chapter highlights the 1980s and its relevance to the recognition of studies on brain activity, besides indicating the precursors in the investigation of the functional structure of the visual cortex. In this sense, the author analyzes neuroscience is in the twentieth century, criticizing its reductionist and individual approach to the different neurons present in each brain structure. At the time, there was no sophisticated electronic equipment capable of processing the analysis of simultaneously generated electrical activities.

Reductionism has induced neuroscientists to devote their research to descriptions of anatomical and biochemical properties, for example, of specific neurons and the main components of their structures. However, the human brain represents a complex system with simultaneous electrical signals produced by groups of individual neurons and distributed in various brain regions. In this logic, the individual neuron does not reach the possibility of generating behavior or thought.

Scientific and clinical advances have proved the insufficiency of the reductionist application. The proposal is for the reader to reflect on the neuroscientific objectives based on the populations of neurons, reporting a complex computational experiment conducted at the FMUSP Medical Informatics Laboratory in the 1980s, which already indicated parameters for current studies.

The second chapter presents a timeline with relevant scientists in this field of research who have made contributions since the 1700s, such as physician Luigi Galvani [1737-1798] and physicist Alessandro Volta [1745-1827], as they discovered electrophysiology and enabled scientific advances in the eighteenth century. Researcher Thomas Young [1773-1829] also stands out, the first computational neuroscientist in history, whose theories were experimentally confirmed in the twentieth century.

Chapter 3 portrays cytoarchitecture, a field of study that began in the twentieth century and demarcates as a research area, with methods of staining brain tissue, being Nissl method relevant in studies on the distribution of neuron groups. Between the 19th and 20th centuries, studies indicated the cortex with a possible division into six neuronal layers, numbered between the outermost and innermost. In this perspective, it was up to neurologist Korbinian Brodmann [1868-1918] the most widely accepted cytoarchitectonic classification of the cortex. Another aspect of impact was the studies on phantom limbs, from which the first reports about the phenomenon date back to the Middle Ages, from limbs amputated in soldiers. In the sixteenth century there are records of medical treatises with techniques that improved the survival of victims of amputations following armed conflict in Europe. Despite intense research into the causes, debate persists about the neurophysiological mechanisms that cause this syndrome.

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Current research indicates that the brain's direct interaction with artificial tools allows the central nervous system to incorporate them as a part of it.

Chapter 4 reports the first record of electroencephalogram (EEG), made possible by physician Hans Berger [1873-1941], who investigated ways to measure brain electrical activity. This activity started to be registered in patients of different clinical conditions. Today, EEG is an essential tool used for diagnosis and research. Another prominent instrument in the twentieth century was the microelectrode, as it recorded the action potentials produced individually by neurons. It currently consists of a metal cylinder that is progressively inserted into brain tissue surgeries.

The fifth chapter highlights the creation of an experimental apparatus that tests the ability of mice to use their facial whiskers to differentiate the diameter of an opening in the dark. This is a planned experiment that addresses a basic issue related to the potential physiological interaction of these neural pathways. The task of tactile discrimination aims to quantify the interactions of both neural pathways. Over the past 25 years, the techniques of the electrophysiological field have expanded, as has the recording of multiple neuron activity. The book introduces the uncertainty principle of neurophysiology, which describes how the relativistic brain produces thoughts from its own point of view.

Chapter 6 defines the theory that when populations of neurons work together and are inserted into a broad neuronal circuit, they can use specific patterns of electrical activity to maintain complex motor behavior. However, it was necessary to create an experimental paradigm to investigate the motor cortex of awakened animals, an idea known as brain-machine interface (BMI). When a rhesus monkey controls the movements of a robotic arm using its thinking alone, it would directly benefit thousands of humans.

Chapter 7 presents research and auxiliary techniques in biofeedback or feedback studies. Studies such as that of neurophysiologist Eberhard Fetz, still in the 1960s, registered the technical norm to investigate the physiological behavior of individual neurons of the primary motor cortex of awakened rhesus monkeys. Experiments of this kind made possible the principle of BMI after 30 years.

Chapter 8 deals with the new technological generation: neural prostheses, which generated new theoretical discussions about the methods to be used. In 2014, the international "Walk Again" research consortium was part of a group of paraplegic patients who learned to directly control the movements of a robotic lower limb exoskeleton. The new concept was launched worldwide at the opening of the World Cup with a kick from a Brazilian para-athlete on a soccer ball.

Chapter 9 presents the morphological and physiological transformations about new mental processes of the Homo genus, with growth of frontal and parietal lobes and parallel neuronal pathways. The oral language identified in this evolutionary brain process is an evolutionary aspect of the human race. The skill needed to make tools also fits into the evolution of the civilizing process.

Chapter 10 highlights the initial process of building the brain-brain interface (BBI) as a legitimate experimental strategy. In 2013, the experiments were published with records of the brain connection of an explorer rat and a decoder rat. In 2015, the new BrainNet paradigm presented studies with groups of monkeys and rats.

In Chapter 11, we present brain studies on the recognition of neuroscientist action. The implementation of the brain-machine interface is an attempt to verify the physiological principles that determine the dynamic operation of neural populations in free animals to express their behaviors. Chapter 12 reports a 2-decade work in a neuroscientific laboratory, which proposes to modify the way neurophysiologists approach the brain by implementing new measures of the behavior of neuron populations.

Finally, the 13th and last chapter describes the Walk Again Project, developed in Brazil since 2013, based on assistive technologies that allowed partial neurological recovery of paraplegic patients through voluntary movements and tactile sensations of paralyzed limbs. Among the experiments conducted in the project, stands out the robotic exoskeleton, controlled by the brain electrical activity of each participating patient. Throughout each chapter, the illustrations are linked to the research presented. It is a suitable reference work for students and professionals with interest in the neuroscientific field.

References

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