The Brain-Behavior Continuum

The Subtle Transition between Sanity and Insanity

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PREFACE

Since time immemorial, the myriad of efforts to understand the nature of mental life epitomize what is one of the most fundamental quests for knowledge. The research field of mental illness abounds with models reflecting the reality of troubled minds with various degrees of accuracy, ranging from unrestrained presumptions to the hard facts of neuroscience. Perhaps one of the most posed questions in philosophy and the natural sciences is the construction of a model about the relationship between mind and body. Are they separate or parallel? Or is there a sequence? And if so, which one is in charge? Does our brain orchestrate our behavior with the inevitability of an epileptic seizure or a migraine? Is there a controlling mind that does the conducting? This uncertainty contributes to the state of confusion that the study of the brain seems to cause, because compared with other organs in the human body, the brain seems to be regarded in a very different manner. Few people question the need for insulin once their pancreas is diseased and diabetes diagnosed. Yet, it normally takes a few relapses for the mental illness sufferer to finally surrender to the idea of taking regular medications. Why do we have this peculiar attitude toward the brain, apparently disregarding the fact that its pathologies are just as valid and real as those of the pancreas? This position, perhaps, is not entirely unfounded, for there is a fundamental difference between brains and other human organs: brains determine behaviors and possess the power of logical thinking and self-referentiality that no other organ does. Brains can monitor themselves, can correct any peculiar style of behavior, if only endowed with enough logical competence and will … or so we think.

Ever since the times of Hippocrates, who was one of the first to recognize epilepsy as a "disease caused by the brain's disharmony," we have come to accept that we cannot control epileptic seizures by the power of our minds. Seizures are behaviors (indeed, the definition of epilepsy is based on the behavioral manifestation of seizures) produced by the brain activity resulting from some pathological

process. On the other hand, we are fast to judge criminal psychopaths for their reckless behaviors, ample evidence linking antisocial behaviors with brain abnormalities notwithstanding. We assume that social predators must, and, in fact, can "easily" control their vicious habits by the use of proper thinking, acceptable logic, and the power of self-control. Yet, how much of a choice do they have in reality? Maybe, little more than when trying to stop an epileptic seizure? After all, seizures and antisocial behaviors are both fabrications of "diseased" brains, by-products of deviations from the considered normal neurophysiology.

The purpose of this monograph is to explore the perspective of a smooth continuum between distinct brain activities resulting in different behaviors, from seizures to mental illnesses and personality disorders. Many books have appeared on the topics of brain, mind, and behavior. So, why devote more words that may be lost in the already vast sea of words dedicated to these matters? This book is not proposing new theories of brain and behavior, its main purpose is to integrate different levels of description using frameworks that have been advanced and are well established in the natural sciences. In this sense, this volume describes, and integrates, what is already known, and endeavors to guide researchers in several neuroscientific areas to achieve a more fundamental comprehension and appreciation, absolutely needed in these days of massive data gathering, of an integrative approach to understanding brain function and behavior. The realization of a global understanding of brain function and behavior requires a flexible switching between levels of description, today more than ever. The current trend in the neurosciences and brain research is to develop sophisticated studies that benefit from an impressive arsenal of cellular and molecular methodologies. Thus, we have at our disposal an overabundance of empirical data generated under experimental conditions that, most commonly, try to isolate the phenomenon under scrutiny in supposedly controlled laboratory settings: reductionism at its best. In general in the biological sciences, the comprehensive understanding of high-level laws lags considerably behind the understanding of elementary processes, and the choice of the level of description determines to a large degree the nature of the understanding that is finally achieved. This book introduces a high-level perspective, searching for simplification among the structural and functional complexity of nervous systems by consideration of the distributed interactions that underlie the collective behavior of the system. Thus, the focus is on the nature of the interactions among the components of nervous systems: the dynamics of coordinated cellular activities that, of course, result from underlying neurophysiological events. We will see that, by focusing on the perspective of the dynamics of organized activities, with the added advantage that it can be made independent from the material particles that constitute a system, apparently diverse phenomena become conceptually closer.

The term "continuum" is used both with the connotation utilized in continuum theory (a branch of topology), and with that used in physics. The mathematical aspect denotes anything that goes through a gradual transition from one condition to another, without abrupt changes. In physics, theory of relativity for instance, the space–time continuum model explains space and time as part of the same reality rather than as separate entities. Our understanding of "brain–behavior continuum" denotes, first, the gradual transitions that most of the times occur in brain activities and behaviors, the progression from heath to disease. We illustrate with some examples how subtle alterations at the level of the analysis of electrophysiological recordings may gradually transition into robust changes in brain activities that sometimes are translated into a distinct pathological state. Second, it denotes, in the physics sense, that brain activity and behavioral actions are not separate and independent entities. Rather, it is a continuous transition between the microscopic (molecular), mesoscopic (cellular/network), and macroscopic (collective behavior, coordinated activity patterns) levels which constitute the brain and its activity that ultimately manifests itself into perceptions, emotions, and actions; which can, in their turn, alter the brain in a sort of feedback loop, affecting not only patterns of synchrony, but also the very molecular structures that have produced them (phenomena generally known as "neuroplasticity"). We argue that, due to the plastic nature of the brain and the fact that behaviors can alter brain structure and function, the boundaries between brain and behavior are rendered artificial, at least as it is seen at a certain level of description.

Our monograph is then a comprehensive study (overview) of the main current concepts in brain activity at the global, collective (or network) level, and an attempt to explain how normal neurophysiology can develop into brain pathological states, always concentrating at the network or collective level but paying attention too to the underlying molecular and cellular aspects that result in the specific pathologies here described. The emphasis is on a few crucial aspects that, we think, need to be understood and considered by a wide variety of medical practitioners and neuroscientists, for a global understanding of brain and behavior in these days of massive data gathering. Of particular importance, which is still underestimated by a vast majority of neuroscientists, is the notion of "small changes, large effect" and the determinism of brain activity resulting in specific behaviors. In this regard, the concept of free will has to be addressed, or at least how much freedom there is in that "will." This is discussed in the context of the possibility of control of some brain networks using other networks in various physiological and pathological states.

This book, if needs to be classified into some field, we would tend to place it into the neurophysics category: it is a neurophysics book about some clinical aspects, rather than a clinical treatise with neurophysical aspects. It is intended for

an audience composed of neuroscientists (experimentalists as well as theoreticians and computational neuroscientists), psychiatrists, neurologists, neurosurgeons, biophysicists, and those interested in the workings of the brain and its relation to behavior. The main concepts can be understood by educated readers in general. Some very technical particulars are included for those interested in specific details because of the need for precision in these days when concepts from other disciplines are permeating neuroscience, particularly analysis methods and frameworks from dynamic system theory. The intuitive appeal of many of these theoretical constructs has attracted much attention from neuroscientists, psychologists, and clinicians, which has resulted in a metaphorical language that, while very useful, sometimes lack accuracy thus making these metaphors become extended a bit too far. Hence, for the sake of accuracy, sections in some chapters present detailed analyses that try to go beyond the metaphors, to demonstrate that a relatively rigorous application of dynamical frameworks can indeed be accomplished in brain science. Because of the interrelatedness of many of the aspects discussed in various chapters, no chapter stands alone, and, at least, it is recommended to go over the main concepts presented in Chapters 1 and 2 before reading any other section.

A general underlying uncertainty in most of the neuroscientific studies here considered is whether mental states, that determine behavioral outputs, can be reduced to neurophysiological phenomena. Many words have been devoted to this query, but this is not the place to address it. Perhaps better to be content with the formulation of some correlations between neurophysiological phenomena at several levels of description and behavioral manifestations. It is not without interest noting the fact that it is the brain that is trying to comprehend itself, as well as the nature of reality as perceived by the constraints of neural information processing. Francis Bacon (1561–1626) decreed that "Human understanding is like an irregular mirror, which distorts and discolors the nature of things by mingling its own nature with it" (Novum Organum, 1620). Physicists know quite well that the laws of nature deal more with our perception and knowledge of phenomena rather than with phenomena themselves. The contents of the brain, whether molecules or ideas, cannot be separated from the rest. The continuum proceeds at many levels. It is hoped that the careful consideration of the brain–behavior continuum will reveal that the pathological brain exists only in terms of degree, exposing the artificiality and fuzziness of the created boundaries between normal neurophysiology and neuropathologies. We apologize beforehand if some of the many works, empirical and theoretical, that have been commented throughout this monograph have been misrepresented, and if such a thing has occurred, a feedback form the original authors would be appreciated so that future editions can be amended.

QUOTES

"Science will teach man that he never has really had any caprice or will of his own, and that he himself is something in the nature of a piano key … and that there are, besides, things called the laws of nature; so that everything he does is not done by his willing it, but is done of itself, by the laws of nature. Consequently, we have only to discover these laws of nature, and man will no longer have to answer for his actions, and life will become exceedingly easy for him."

F. Dostoyevski, *Notes from the Underground* (1864)

"If we ask whether we are free, the kind of answer we want may not be possible. A better question to ask is: do we make choices? The answer is certainly yes… Are our choices constrained? Yes."

Schall, J.D. (2001) *Nature Reviews Neuroscience* 2, 33–42

"Further conceive, I beg, that a stone, while continuing in motion, should be capable of thinking and knowing, that it is endeavouring, as far as it can, to continue to move. Such a stone, being conscious merely of its own endeavour and not at all indifferent, would believe itself to be completely free, and would think that it continued in motion solely because of its own wish. This is that human freedom, which all boast that they possess, and which consists solely in the fact, that men are conscious of their own desire, but are ignorant of the causes whereby that desire has been determined. Thus an infant believes that it desires milk freely; an angry child thinks he wishes freely for vengeance, a timid child thinks he wishes freely to run away. Again, a drunken man thinks, that from the free decision of his mind he speaks words, which afterwards, when sober, he would like to have left unsaid. So the delirious, the garrulous, and others of the same sort think that they act from the free decision of their mind, not that they are carried away by impulse.

As this misconception is innate in all men, it is not easily conquered. For, although experience abundantly shows, that men can do anything rather than check their desires, and that very often, when a prey to conflicting emotions, they see the better course and follow the worse, they yet believe themselves to be free."

Spinoza, *Letter to G.H. Schaller* (October 1674)

"El triunfo supremo de la razón… es poner en duda su propia validez."
(The supreme triumph of reason… is to cast doubt on its own validity.)

Miguel de Unamuno, *Del Sentimiento Trágico de la Vida* (1954)

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