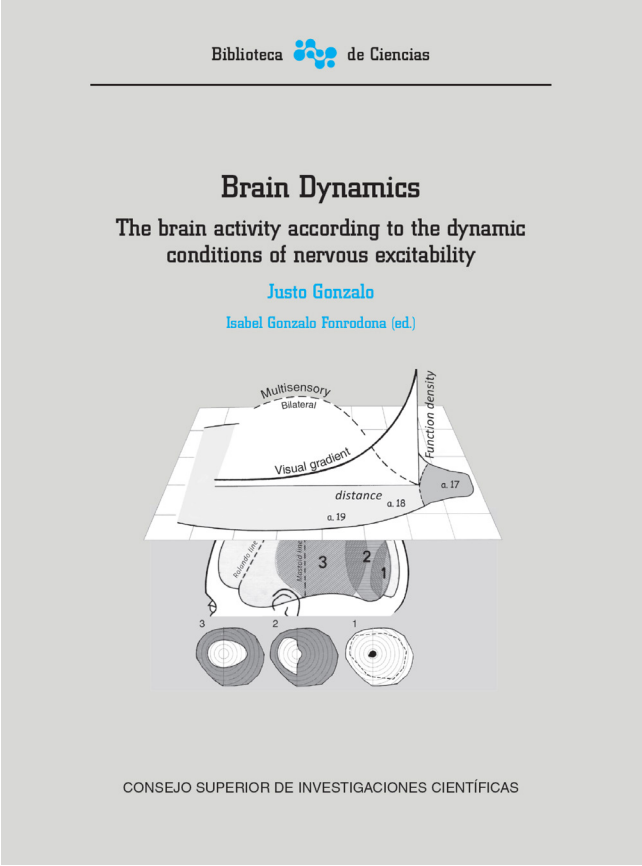

Brain dynamics: the brain activity according to the dynamic conditions of nervous excitability (Vols. 1 and 2, supplements I and II)

Justo Gonzalo
Isabel Gonzalo Fonrodona (ed.)

Editorial CSIC (Consejo Superior de Investigaciones Científicas). Madrid 2023. 648 pages and 214 figures
ISBN: 978-84-00-11232-5
e-ISBN: 978-84-00-11233-2

Open Access:
http://libros.csic.es/product_info.php?products_id=1762&language=en

After the Spanish Civil War (1936-39), Justo Gonzalo y Rodríguez-Leal (Barcelona, 1910-Madrid, 1986) published his groundbreaking, extensive research on the functional organization of the cerebral cortex in the monograph *Dinámica cerebral: la actividad cerebral en función de las condiciones dinámicas de la excitabilidad nerviosa*[1,2] (Brain dynamics: the brain activity according to the dynamic conditions of nervous excitability). The work reviewed here is the English translation of the book published in Spanish in 2010,[3] which includes a facsimile edition of volumes 1 and 2 of that monograph, as well as two supplements, also in Spanish. Volumes 1 and 2 were published by the Cajal Institute (part of the Consejo Superior de Investigaciones Científicas [CSIC; Spanish National Research Council]) in 1945 and 1950, respectively. Supplement I is an article published in 1952 in the journal *Trabajos del Instituto Cajal de Investigaciones Biológicas*,[4] and supplement II is a compilation of unpublished documents written from 1960 onwards. In a first, general, section, volume 1 addresses the new findings and the research approach, and subsequently turns to the experimental analysis of visual functions, whereas volume 2 focuses on tactile functions and expands on new concepts. Supplement I introduces the concept of "cortical functional gradient", and supplement II introduces the concepts of "dynamic similarity" and "allometry". This book is edited by Isabel Gonzalo Fonrodona, whose perseverance and dedication have made possible the translation and dissemination of this research.

The book is not only of considerable historical interest, but also of theoretical and experimental significance: despite the time that has passed since its publication in the mid-20th century, its content remains innovative in many aspects, and its relevance persists today. This research is pioneering in its application of the laws of nervous excitability to the functioning of the human cerebral cortex, as well as in its dynamic conception of the cortex. The book is rich in experimental data, singular phenomena, and concepts. Some of the phenomena were rediscovered years later, and others remain unknown. Certain concepts are far removed from the traditional, rigid localizationist conceptions adopted during much

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Received: 9 March 2024 / Accepted: 27 March 2024

of the 20th century,[5,6] and are directly related to current theories about the functioning of the cerebral cortex. Throughout the book, the author demonstrates a profound understanding of brain physiology and anatomy, which is also reflected in the abundant and accurate bibliographic references. The author's introduction to volumes 1 and 2 provides a general overview of the physiological basis of the research, and a brief chronology of the research from 1938 to 1950. It is worth highlighting, as stated in the preface by the editor of this English edition, the excellent reception that the volumes received in their time from eminent authors from other countries, such as Wolfgang Köhler, Robert Bing, Morris Bender, Hans-Lukas Teuber, Julián de Ajuriaguerra, and Henry Hécaen, to name just a few.

Volume 1 begins with a long, essential section (General aspects) that provides an excellent summary of the physiological and functional approach of the research, the fundamental findings that constitute the starting point of the author's physiological and dynamic conception, the methods followed, and the new concepts. A qualitative description is given of the phenomena found in two patients (called M and T) with brain injuries sustained in the Spanish Civil War, who each presented a unilateral lesion located in the left parieto-occipital cortex, of greater magnitude in M than in T. These patients are the initial prototypes of the so-called "central syndrome of the cerebral cortex." At first sight, these patients presented minor symptoms (loss of vision, particularly in patient M, and a degree of visual and tactile agnosia) that did not seem to cause great difficulties in their daily lives. The meticulous examination of patient M (the more severe case) led the author to the discovery, in 1939, of what he called "dynamic action phenomena" ("asynchrony," "facilitation," and "repercussion"). These phenomena were later confirmed in patient T, and characterize the previously mentioned central syndrome, which is the focus of the entire study. As the author points out, the peculiar characteristics of this syndrome allow exploration of the functioning of sensory structures, giving rise to new concepts.

Asynchrony results in the disaggregation of functions (which in a normal situation operate in an "all-or-nothing" manner) into partial reactions depending on nervous excitability (intensity and duration of the stimulus). These partial reactions result in some unusual effects, including inverted or partially tilted vision and tactile inversion, phenomena which are studied in detail by the author. The sensory functions are thus "reduced" (the higher ones are lost), depending on the magnitude of the lesion (neuronal mass lost) and the degree of physiological demand of each one. This functional disaggregation demonstrates the existence of a continuity between the simplest sensation and the higher function ("gnosis") of an entire sensory system.

Facilitation is a phenomenon that improves perception by nervous summation, compensating for deficient excitability, either by increasing in the intensity of the stimulus, or by the presence of other stimuli of the same or a different modality (multisensory), and especially by muscular effort, as well as by iteration of the stimulus. Adequate facilitation enables near-normal perception.

Repercussion consists in impairment involving all sensory functions (visual, tactile, auditory), in all their manifestations, with bilateral symmetry, despite the lesion being unilateral and equidistant from the visual, tactile and auditory projection areas (hence the name central syndrome). This phenomenon confirms the dynamic unity of the cerebral cortex proposed by the author, and is the aspect that, at first sight, most conflicts with the prevailing ideas of the day.

The author introduces the concept of "physiological level," distinguishing between the inactive state of the patient, free of any facilitation, and states facilitated by other stimuli. In this context, the author interprets the much-discussed case of the patient Schneider reported by Goldstein and Gelb[7,8] as a case of central syndrome. He also notes that a lesion closer to the projection areas results in asymmetric repercussion, with dynamic effects ("paracentral syndrome"). However, if the lesion occurs within a projection area, the disturbance only affects a sensory system contralateral to the lesion, with hardly any dynamic effects ("peripheral or marginal syndrome"). The effects are thus dependent on the magnitude and position of the lesion.

Following this extensive overview, the author moves on to the quantitative analysis, describing the extensive, meticulous experimental research conducted over several years on patients M and T. This experimentation produced objective data on very remarkable phenomena.

The remainder of Volume 1 focuses on visual functions (electrical and mechanical excitability, color, shape, image orientation, and schema). Deficits in excitability were particularly relevant, with a considerable increase

in reaction time and great permeability to iteration, especially in patient M in the inactive state; also noteworthy are the partial reactions appearing in the perception of colors, according to their different excitability: the blue-yellow pair was the most altered in the case of patient M. A certain inversion of color isopters (less accentuated in T and in M under facilitation) is also noticeable. The section devoted to visual forms includes the study of the visual field, which was found to be concentrically reduced to a few degrees in M in the inactive state, but increased markedly, reaching the periphery, under intense illumination or facilitation. Thus, there is not total blindness in the affected field, but rather a dynamic reduction ("functional depression"). A similar phenomenon is described in visual acuity. Another singular fact is the spatial delocalization of color with respect to objects, generating a kind of irradiation (referred to by Gelb[9] as "flat color vision"), to a different degree for each color. Another rare disorder is triplopia (monocular triple vision of an object). This part of volume 1 also includes a detailed analysis of the loss of visual perception of motion and its different phases of perception, passing through the phase of reversal of motion with a shorter and faster trajectory, until movement is correctly perceived under high stimulation or facilitation. Patient M's visual perception of shapes and figures in the inactive state is unstable, with a tendency to simplification, and successive rather than comprehensive perception. Regarding image orientation, as the luminous intensity of the test object decreases, the image undergoes a rotation in the frontal plane, reaching 170° in the most affected eye of patient M and only 25° in the worst eye of patient T. Simultaneously, the image loses sharpness and colors (in a certain order), and decreases in size and brightness. Image is corrected with increasing illumination, or with facilitation by muscular effort or other stimuli. Finally, dissolution of schema function occurs, manifesting with changes in vision and constructional deficit. An extraordinary disorder described by the author is that such figures as writing and portraits are recognized with the same ease whether they are oriented normally or upside down, with patients not noticing the change in orientation. There was also a change in the reference system, which instead of being allocentric is egocentric.

Volume 2 of the monograph presents a quantitative analysis of tactile functions (electrical and mechanical excitability, pressure, pain, temperature, tactile space, orientation, and schema), analogous to the analysis of visual functions. The anomalies were found to be of the same quantitative order as those affecting vision. Excitability showed increased chronaxia and rheobase, as in vision, weights were underestimated, patients presented iterative capacity, and vibration showed loss of high frequencies and overestimation of rhythm. The author observed a pathological interval between simple sensation and pain, and between simple sensation and temperature.

The section on tactile space, which is of particular importance, as noted by the author, deals with the dynamic effect of asynchrony in the localization of tactile stimuli. For example, the localization of a point stimulus in the hand goes through different phases (up to five can be distinguished) as the intensity of the stimulus increases, from irradiated sensation with no localization to normal localization, passing through a phase of contralateral localization with some irradiation. The author analyzes in detail the dynamics of localization, as well as spatial discrimination, and the perception of motion and figures on the skin, advancing aspects of the reduction of the body schema. Regarding orientation, the peculiar phenomenon of tactile inversion is also studied in detail, being explored by means of various types of stimuli: punctiform, rectilinear, movement over the skin, and joint movements of the limbs and head. In the contralateral phase, the movement is perceived in the opposite direction, and appears smaller and faster. The study of the orientation of one's own body is also addressed. The complex process of walking presents special characteristics because of the iteration that can occur. In this case, the first step is not perceived, the second is perceived as inverted, very short and fast; the third, transversal, etc, until the steps are perceived almost correctly.

The author describes how the process of tactile and visual inversion, occurring together with proximal deviation (in touch) and decreased image size (in vision), follows a spiral-like process associated with a reduction of the tactile or visual field. Having verified the process of inversion in the auditory system, with similar characteristics, he establishes general concepts such as the "sensory field" and its "spiral development" in "sensory growth," determined by the "dimensions of the field" (intensity, space, and time), valid for all sensory systems of a spatial nature. Thus, the central syndrome is the expression of a reduced field that can grow by intensification of the stimulus or by facilitation.

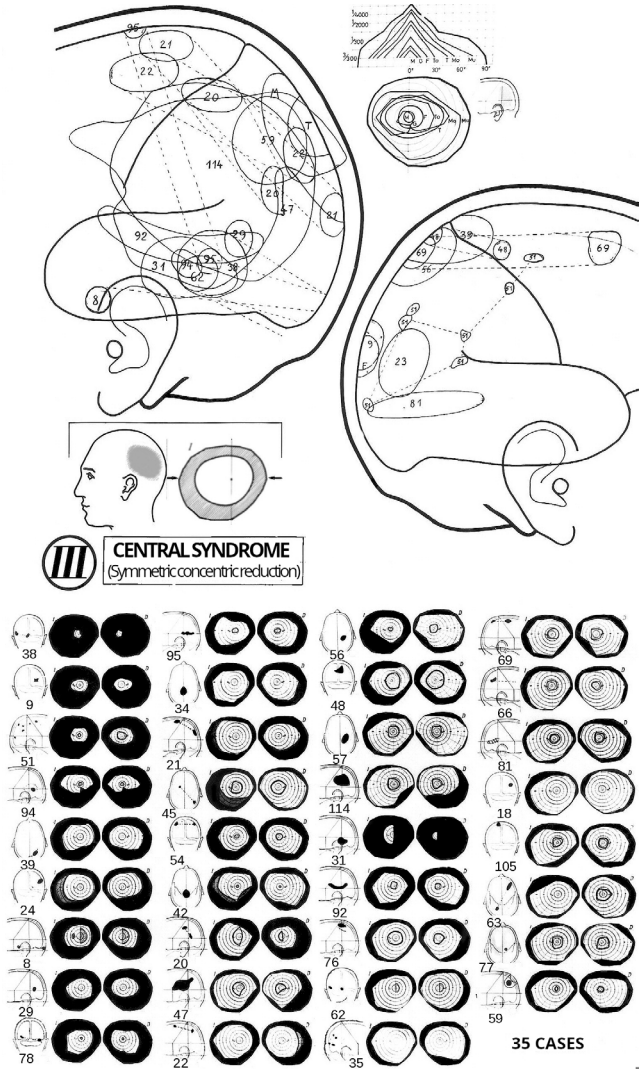

Figure 1. Series III of cases studied by J. Gonzalo. The image shows 35 cases of central syndrome (multisensorial and symmetrical) of varying intensity, with concentric reduction of the visual fields. Cases are labeled with numbers. Image reproduced from Figure 3 of supplement II (p. 610), courtesy of Editorial CSIC.

Finally, the author addresses the tactile schema, on the basis that there are different degrees, as the result of a progressive differentiation of the tactile sensory field, with continuity between them. These degrees of increasing complexity in tactile spatial organization are the somatic, postural, and praxis models. The author analyzes several of his own observations, such as the inversion and the previously mentioned egocentric (rather than allocentric) reference, as well as cases from other authors (including patients with Gerstmann syndrome). The section ends with an analysis of the schema in manual touch (tactile gnosis) and an extensive review of tactile agnosia.

In supplement I (the 1952 article), the author summarizes volumes 1 and 2; further stresses the importance of the magnitude of the lesion; discusses once more the spiral development of the sensory field, relating the inversion process to the secondary areas; contributes new cases of central syndrome, among others; and introduces the concept of "cortical functional gradient." He gives the example of the visual and tactile gradients, as an arrangement of the syndromes observed and the transitions between them. In contrast to other authors, who divide the cerebral cortex into a mosaic of interconnected static centers, the author proposes that the cortex is a dynamic unit, with the various gradients representing "functional continuity." He also presents the correlation he found between visual image tilt and visual field width in 24 cases of central and paracentral visual syndrome. Of special interest are some remarks on auditory functions in central syndrome. The author concludes with a concise, essential exposition of the most characteristic aspects of brain dynamics and their significance in a general context.

Supplement II compiles several later unpublished manuscripts in which the author presents the concepts of "dynamic similarity" and "allometry," applied to the central syndrome, and establishes that this syndrome is the result of a change of scale in nervous excitability with respect to the normal brain. The organization is maintained, and the disaggregation of functions (due to asynchrony) is governed by allometric laws. Dynamic similarity and allometry, together with cortical gradients, form the backbone of the final version of the author's functional dynamic theory of the human cerebral cortex. In his words:

> The brain dynamics developed in these studies lead to a neolocalism of allometric gradients. It constitutes a neurophysics of the cerebral cortex. The cortex would be a system organized in gradients, which changes its metric scale in lesions, preserving the same functional plan (functional similarity), and whose multiple particular functions change allometrically according to their respective allometric coefficients. (Supplement II, p. 604)

This supplement includes 30 illustrations made between 1960 and 1975. Among these, we find series of cases

studied by the author (eg, 35 cases of central syndrome in Figure 1), and diagrams illustrating some of the phenomena and concepts introduced, also applied to the language system.

The book compiles much of Gonzalo's research on brain dynamics, beginning in 1938 in the midst of the Spanish Civil War (1936-39), when he was working as a neurologist at a military hospital near Valencia, and continued in Madrid, where he continued studying patients M and T, among others, for several years.[10,11] Before the outbreak of the Civil War, he trained in Austria and Germany (1933-35), and then worked as a clinical neurologist in Madrid, where he conducted anatomical-clinical research at the Cajal Institute. In 1942, he joined that Institute (which was now part of the CSIC) as head of the Laboratory of Cerebral Pathophysiology, located in the Faculty of Medicine of the University of Madrid. Between 1952 and 1954, he examined a multitude of individuals with brain injuries, most of whom were wounded during the Civil War. From 1945 to 1966, he gave doctoral courses in which he presented his research. In the 1960s and 1970s, he continued with his research, addressing various topics. Part of his research remained unpublished; supplement II gives a brief idea of this work.

The publication of this book contributes to the dissemination of the author's work beyond the Spanish-speaking community. Since the mid-1940s, English has been the lingua franca of most scientific journals and books. Any work written in another language, regardless of its potential relevance, is usually overlooked. In this sense, the Spanish monograph *Dinámica cerebral* is no exception. Its translation into English enables any reader to access the remarkable contributions of the neuroscientist Gonzalo. In addition, the digital version is available through open access.

The book has the dual purpose of: *1)* vindicating the author's unknown contributions to the study of the functional organization of the cerebral cortex, and *2)* showing that some of the concepts and methodologies presented remain valid today. In fact, despite the decades that have elapsed since the author's initial publications, his contributions provide a view of brain physiology that is in line with current research attempting to explain the functioning of the cerebral cortex. The concepts of brain gradient and multisensory facilitation are two clear examples.

Gonzalo's cortical functional gradient was not understood in its full magnitude at a historical moment in which the notion of modularity, which was more accessible and conceptually straightforward, was the paradigm of reference to understand and explain the functioning of the cerebral cortex. Except for occasional contributions such as those of Teuber (1972)[12] and Goldberg (1989),[13] it was not until the present century that several authors considered the concept of gradients as one of the essential principles of cortical organization.[14-18] The latter authors base their conclusions on neuroimaging studies, whereas Gonzalo's conclusions were based on detailed clinical observations of different syndromes (central, paracentral, and involving projection areas). The multisensory facilitation described by the author, which is related to multisensory integration, was addressed in detail in the late 20th century, and is currently an extraordinarily active line of research.[19-23]

Conflicts of interest

The author has no conflicts of interest to declare.

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