Society for Neuroscience

194 A FORMAL THEORY FOR CEREBELLAR FUNCTION: THE PREDICTIVE DISTRIBUTED PROPERTY OF THE CORTICO-NUCLEAR CEREBELLAR SYSTEM AS DESCRIBED BY TENSOR NETWORK THEORY AND COMPUTER SIMULATION.

A. Pellionisz and R. Llinás, Dept. Physiology & Biophysics, New York Univ. Med. Ctr., 550 First Ave., New York 10016.

It is difficult to describe in abstract terms the properties of a neuronal network in which inputs are distributed over a large cortical area, carrying information in a parallel manner. Generally these networks are treated as "loops" of a few individual neurons, or the system is simply deemed redundant. This spatially distributed parallel organization, being characteristic for the brain in general and for the cerebellum in particular, has compelled us to devise a new set of premises for the analysis of such systems. Using computer simulation methods, two features of a new theory of cerebellar function (Pellionisz and Llinás, *Neuroscience*: in press) will be demonstrated. At the single cell level the theory identifies the function of individual Purkinje cells as taking different order time-derivatives of the parallel fiber input. *The first tenet of the theory holds that the activity of individual cells over a cortical area may be represented by a spatially distributed, finite, series expansion of a time-function, which is then reconstructed on a set of nuclear neurons.* For the cerebellum, given a proper ratio of Purkinje cells taking 0,1,2,3.... order derivatives, these cellular activities can be treated as a Taylor expansion such that the reconstruction of the time function on the nuclear neurons can provide a running tally which predicts (by extrapolation from the past neuronal activities) a future value at a delta look-ahead time. While it is intuitively obvious that prediction is essential for coordination of time functions, our theory embeds the above assumption into a second tenet in order to formulate a general theory for the cerebellar coordination. *Neuronal networks are considered as tensors (in full generality), each identifying a scalar valued function of a number of vector variables which is linear in each variable.* Rather than conceptually oversimplifying neuronal networks into "loops" or "reflexes", we regard these entities as tensors; thus the function of the cerebellum may be explained by the available tensor theory. For example, the Purkinje cell network becomes a tensor of rank two, which assigns to a given mossy fiber vector (curve-point in m-space at t) a Purkinje cell vector (curve-point in n-space at time t + delta) by virtue of the connectivity matrix. The application of these principles will be demonstrated by computer simulation. In addition to providing a theory for cerebellar coordination, the model demonstrates the principle of distributed organization of a system which is, by its nature, quite impervious to diffuse lesions. (Supported by USPHS grant NS-13742 from NINCDS)

8th Annual Meeting
St. Louis, Missouri
November 5–9, 1978

Published by
Society for Neuroscience
Bethesda, Maryland

194 A FORMAL THEORY FOR CEREBELLAR FUNCTION: THE PREDICTIVE DISTRIBUTED PROPERTY OF THE CORTICO-NUCLEAR CEREBELLAR SYSTEM AS DESCRIBED BY TENSOR NETWORK THEORY AND COMPUTER SIMULATION.

A. Pellionisz and R. Llinás, Dept. Physiology & Biophysics, New York Univ. Med. Ctr., 550 First Ave., New York 10016.

It is difficult to describe in abstract terms the properties of a neuronal network in which inputs are distributed over a large cortical area, carrying information in a parallel manner. Generally these networks are treated as "loops" of a few individual neurons, or the system is simply deemed redundant. This spatially distributed parallel organization, being characteristic for the brain in general and for the cerebellum in particular, has compelled us to devise a new set of premises for the analysis of such systems. Using computer simulation methods, two features of a new theory of cerebellar function (Pellionisz and Llinás, *Neuroscience*: in press) will be demonstrated. At the single cell level the theory identifies the function of individual Purkinje cells as taking different order time-derivatives of the parallel fiber input. *The first tenet of the theory holds that the activity of individual cells over a cortical area may be represented by a spatially distributed, finite, series expansion of a time-function, which is then reconstructed on a set of nuclear neurons.* For the cerebellum, given a proper ratio of Purkinje cells taking 0,1,2,3.... order derivatives, these cellular activities can be treated as a Taylor expansion such that the reconstruction of the time function on the nuclear neurons can provide a running tally which predicts (by extrapolation from the past neuronal activities) a future value at a delta look-ahead time. While it is intuitively obvious that prediction is essential for coordination of time functions, our theory embeds the above assumption into a second tenet in order to formulate a general theory for the cerebellar coordination. *Neuronal networks are considered as tensors (in full generality), each identifying a scalar valued function of a number of vector variables which is linear in each variable.* Rather than conceptually oversimplifying neuronal networks into "loops" or "reflexes", we regard these entities as tensors; thus the function of the cerebellum may be explained by the available tensor theory. For example, the Purkinje cell network becomes a tensor of rank two, which assigns to a given mossy fiber vector (curve-point in $\underline{m}$-space at $\underline{t}$) a Purkinje cell vector (curve-point in $\underline{n}$-space at time t + delta) by virtue of the connectivity matrix. The application of these principles will be demonstrated by computer simulation. In addition to providing a theory for cerebellar coordination, the model demonstrates the principle of distributed organization of a system which is, by its nature, quite impervious to diffuse lesions. (Supported by USPHS grant NS-13742 from NINCDS)