# REPRESENTING PATTERNS OF PARKINSONIAN MOVEMENTS USING SEQUENTIAL NEURONAL NETWORKS

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## ABSTRACT

Our study is about a method of representing different states of central motor control in movement disorders using recursive neuronal networks with biological structure. Torques of limb movements computed from kinematic measurements, which were obtained from a 3-D TV based movement analysis system, were used as learning curves for a neuronal network with sequential structure (Jordan). Movements in Parkinsonian patients with ("on") and without ("off") medication led to different connections between the neuronal layers. Graphic representations of neuronal connections can be used to categorize Parkinsonian movements and they allow an insight into the motor control mechanisms of Parkinson's disease.

## INTRODUCTION

In Parkinson's disease neuronal loss of dopamine producing neurons in the substantia nigra of the midbrain leads to a severe impairment of movements. The diagnosis of this common disease is usually made according to clinical criteria, which are mainly based on the typical patterns of motors symptoms. Therapy with L-DOPA, a precursor of dopamine, improves motor impairments, particularly in the early stages of the disease. Abnormal motor patterns (hyperkinesia, dystonia) can reduce the therapeutic effects of the L-DOPA therapy in advanced stages of the disease. The measurements and the characterization of these motor patterns and, in a higher degree, the understanding of the motor control mechanisms are difficult tasks. This is due to the individual symptoms of the disease and to the complexity of the biomechanical analysis required to describe and analyse the pathological movements. To this purpose we have investigated the role of sequential recursive neuronal networks with an implementation related to the structure of the motor control system.

## METHODS

3-D kinematic parameters of aiming movements in the working space of the arm were measured with a TV based system (ELITE). Patients with Parkinson's disease in early and advanced stages (Hoehn&Yahr stage II-IV) performed aiming movements of the hand in a two-dimensional working space by flexion and extension of the forearm in a vertical plane (Fig. 1).

Figure 1. *Stick representation of the forearm for an aiming movement of 60 degrees in a Parkinsonian patient with optimal L-DOPA therapy ("on" state). Positions of the right arm at 0.1 sec intervalls as obtained by the TV motion analyser are shown.*

Meaningful values of the kinematic parameters of the trajectories were obtained by averaging 8 aiming movements for a fixed target. Measurements were obtained for each patient in states without L-DOPA medication ("off", worst motor performances) and with L-DOPA medication ("on", best motor performances).

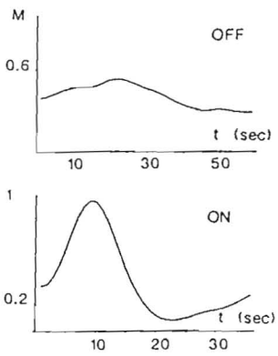


Figure 2. *Average torques for an aiming movement involving a 45 deg. flexion of the forearm in a Parkinsonian patient without ("off" state) and with drug therapy ("on" state).*

Torques for three target points (flexion of 30, 45, 60 degrees) were used as learning curves for a neuronal network with sequential recursive structure (Fig. 3) as described by Jordan(1). For this purpose the values of the torques at 9 discrete sampling times were learned by a neuronal network with 54 neurons arranged in 3 interconnected layers.


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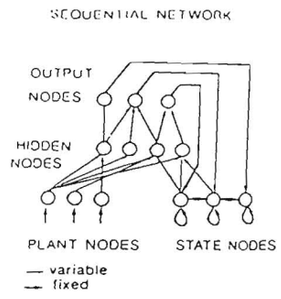


**Figure 3.** *Structure of the sequential neuronal network of Jordan(1). Thin arrows represent neuronal interconnections with variable strength, thick arrows show interconnections with fixed strength.*

## RESULTS

The strength of the interconnections between the neurons of the different neuronal layers for the averaged torques of a typical Parkinsonian patient are illustrated in the neuronal interconnection maps of Fig. 4. The sizes of the squares are proportional to the absolute values of the weights. Moreover positive values are reproduced as black squares, negative values as white ones.

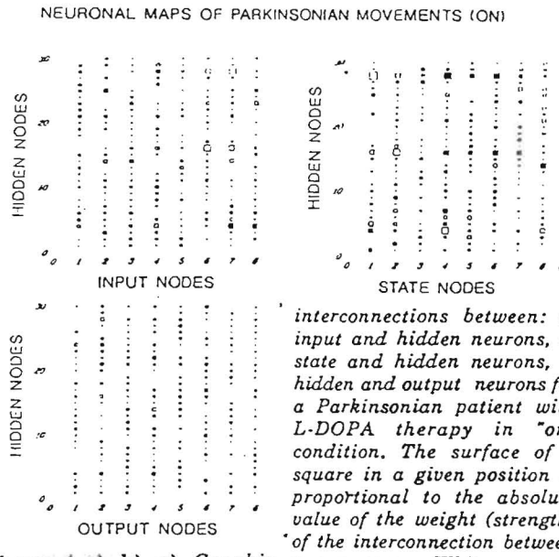


**Figure 4 a), b), c).** *Graphic maps of the weights (strengths) of the neuronal interconnections between: a) input and hidden neurons, b) state and hidden neurons, c) hidden and output neurons for a Parkinsonian patient with L-DOPA therapy in "on" condition. The surface of a square in a given position is proportional to the absolute value of the weight (strength) of the interconnection between two neurons. White squares represent negative values, black squares positive.*

Similar maps were obtained for Parkinsonian patients in "off" states with different degrees of impairment (bradykinesia). The major differences between maps about "on" and "off" states were usually seen in the maps depicting the interconnections between neurons in the state layer and neurons in the hidden layer, while the interconnections between input and hidden neurons and hidden and output neurons were less affected by changes in motor performances induced by the pharmacological action of L-DOPA. This therapeutic effect can be best observed in Fig. 5, where the differences between corresponding neuronal maps in "off" and "on" states are represented.

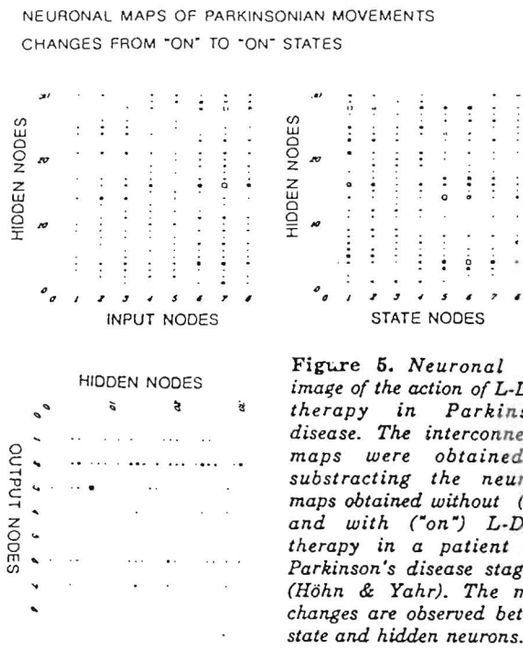


**Figure 5.** *Neuronal map image of the action of L-DOPA therapy in Parkinson's disease. The interconnection maps were obtained by substracting the neuronal maps obtained without ("off") and with ("on") L-DOPA therapy in a patient with Parkinson's disease stage III (Höhn & Yahr). The major changes are observed between state and hidden neurons.*

## DISCUSSION

Neuronal networks can be used to describe complex nonlinear dynamic systems such as limb movements in neurological disease without detailed biomechanical analysis involving differential calculus.

To understand the mechanism of motor control neuronal networks with biological structure are particularly interesting.

The structure of the neuronal network proposed by Jordan has a particular relevance in the study of motor control. The analysis of Parkinsonian movements reveals that L-DOPA causes a major change in the interconnections between state and hidden layer. Since in Parkinson's disease the therapeutical action of L-DOPA affects the neuronal interconnections in the basal ganglia, an anlogy can be drawn between the neuronal layers in Jordan's network and the brain structures responsible for the motor symptoms of Parkinson's disease. Our analysis suggests a major role of the basal ganglia in coordinating sensory feedback and cortical motor commands.

## REFERENCES

Jordan, M.I., Attractor dynamics and parallelism in connectionist sequential machines. In Proceedings of the 8th Annual Conference of the Cognitive Science Society, pp. 531-546 (1986).

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