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Research Article

Autonomic Function Assessment in Parkinson's Patients with Yoga Practice Using Kernel Method and Entrainment Techniques

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Abstract

The experimental procedure of lowering and raising a leg while the subject in supine position is considered to stimulate and entrain the autonomic nervous system of fifteen patients with Parkinson's disease practicing Yoga and fifteen age and sex matched control Parkinson's disease non Yoga practicing patients . The assessment of autonomic function for each group is achieved using an algorithm based on Volterra kernel estimation. By applying this algorithm and considering the process of lowering and raising a leg as stimulus input and the Heart Rate Variability signal (HRV) as output for system identification, a mathematical model is expressed as integral equations. The integral equations are considered and fixed for Parkinson's Patients without Yoga practicing and Parkinson's Yoga practicing patients so that the identification method reduced to the determination of the values within the integral called kernels, resulting in integral equations, whose input-output behavior is nearly identical to that of the system in both Control Parkinson's without yoga practicing patients and Parkinson's Yoga practicing patients. The model for each group contains the linear part (first order kernel) and quadratic part (second order kernel). A difference equation model was employed to represent the system for both control Parkinson's patients without Yoga practicing and Parkinson's Yoga practicing patients. The results show significant difference in first order kernel (impulse response) and second order kernel (mesh diagram) for each group. Using first order kernel and second order kernel, it is possible to assess autonomic function qualitatively and quantitatively in both groups.

Keywords: Autonomic function, Volterra kernel, Entrainment, System identification

Introduction

Impaired autonomic function has been associated with an increased risk of mortality in Parkinson's patients [1-8]. Autonomic dysfunction involving both sympathetic and parasympathetic systems has also been demonstrated in Parkinson's using cardiovascular reflex tests based on heart rate to various stimuli [1-6]. However, the clinical significance and pathophysiology of these findings in Parkinson's are poorly understood. Conventional time and frequency domain analysis techniques based on the linear fluctuation of heart rate insufficient in outline the changes in heart rate dynamics [7,8], therefore, new methods based on nonlinear dynamics have been introduced to quantify complex heart rate dynamics and complement conventional measures of its variability [9-14].

One aim of this study is to propose another approach using Volterra kernel for system identification of nonlinear relationship between input stimulus (lowering and raising leg) and the output (HRV signals) to assess the autonomic function of control Parkinson patients without Yoga practicing and Yoga practicing Parkinson patients . Also, in this study, we propose simple experimental procedure to stimulate the autonomic nervous system by subjecting both groups to stimulus based on lowering and raising a leg as shown in figure 1 [15]. This study may help in screening the autonomic neuropathy noninvasively specially in Parkinson patients in qualitative and quantitative way.

Patients and Methods

Patients

Fifteen consecutive Parkinson Yoga Practicing Patients fulfilling disease society Brain Bank (9) clinical criteria were included in the study from patients that were referred to the department of Neurology in Johns Hopkins University. The patients were independent in their daily activities. The control group consisted of 15 healthy age

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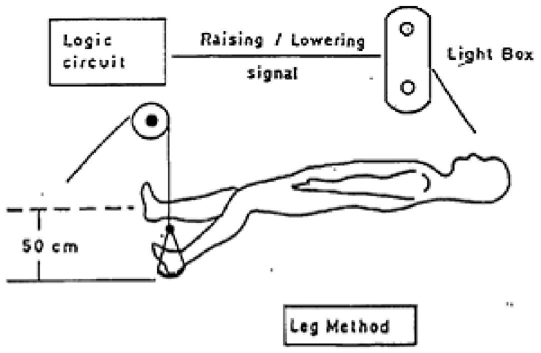

Figure 1: The leg method experiment.

matched subjects selected from Parkinson patients who did not practice Yoga. They all underwent complete physical examination and has no disease or medication affecting autonomic nervous system (ANS) in their history. All subjects agreed to participate in the research prior to their inclusion in the study and the consent of ethical committee was obtained and approved the study protocol.

Experimental Procedure and Methods

The experiments were carried out noninvasively as shown in Figure 1 for fifteen Parkinson's patients Practicing for at least 9 months (mean age 49.6 years) and fifteen Parkinson's patients without Practicing Yoga (mean age 53.3 years). The patient was placed on a bed with room temperature of 22 °C and rested for 10 minutes then he was requested in this supine position to raise and lower his leg according to 7 periods of time(frequencies) namely :5 s, 10s,15 s ,20 s ,25 s , 35 s and 40 s. These periods covered the frequency response of the system for exact identification for exact identification of the system using algorithm by Fakhouri [14]. This algorithm proposed another approach using system identification of the input-output relationship of ant physical or physiological system. This is performed by means of a mathematical model which can be expressed either by a set of differential equations (parameters and static estimation) where the topology of the system is assumed known or by integral equations (non-parametric, weighting function, kernel or functional) which needs little or no prior assumptions about the system. This provides a powerful tool for identification of system whose underlying processes are not well understood. So, by using the algorithm [14], it is possible to identify HRV signal-Raising and lowering leg -system in terms of the functional Volterra series in which the form of integral equation is fixed and the identification method reduces to the determination of the values within the integral, called kernel. Further details will be found in [14].The subjects' signals were recorded for 10 minutes for every period of time mentioned above. These signals include Electrocardiogram (ECG) measured in Lead II sampled at rate of 1000 Hz, HRV (derived from ECG) and stimulus input pulse measured using strain gage mounted on the leg so that electrical pulse produced with the period of time matching to the time of raising and lowering of leg as shown in Figure 1. HRV signals and stimulus input signals were processed through digital filter with bandwidth in the range of 0-1.5 Hz which covered the spectrum of HRV signal stimulated by the periods of lowering and raising a leg and sampled at 3.8 Hz with 1024 points stored for each signal. Figure 2 illustrated the derivation of HRV signal from ECG. The technique used in this study to produce HRV signals based on the hardware described by Cohen et al. [15] and developed by the author for interfacing to laptop computer. This technique based on hardware device to detect R-R intervals using threshold circuit and interfaced the R-R intervals to software program to reconstruct the heart rate variability signals which is now suitable for sampling and processing as shown in Figure 2 [16].

Results

Following Fakhouri's algorithm [14], it is possible to compute the first kernel (impulse response) and second order kernel (mesh diagram) for both groups. Figures 3 and 4 show the first

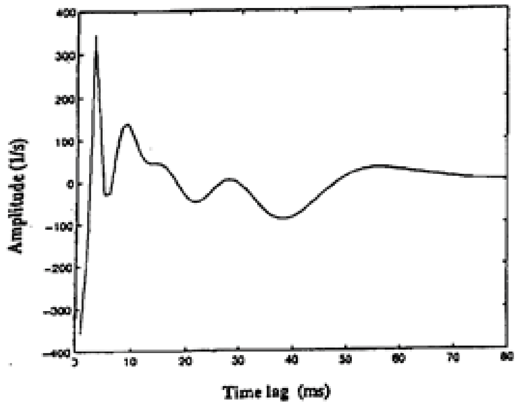

Figure 2: Derivation of heart rate variability (HRV) signal from Electrocardiogram (ECG).
(a) ECG (b) Detection of R-R interval (c) Construction of HRV signal (d) Smoothed Derivation HRV signal

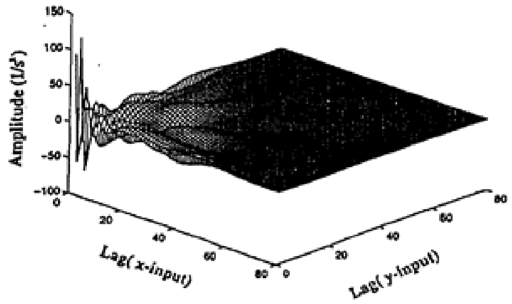

Figure 3: A Typical First Kernel (Impulse Response) for Parkinson's Yoga Practicing patient.

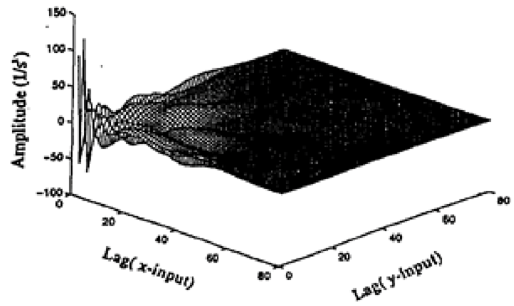

Figure 4: A Typical First Kernel (impulse response) for Parkinson's Non-Yoga practicing patient

order kernel for A typical Parkinson's Yoga practicing patient and a typical Parkinson's patient without Non Yoga practicing patient respectively. While Figure 5 illustrates A typical second order kernel of Parkinson yoga practicing and Figure 6 shows A typical second order kernel of Parkinson patient without Yoga practicing. Table 1 shows comparison of averaged Normalized Mean Square Errors of HRV variability (NMSE) Standard Deviation (in %) of first order and second order rejection as well as test of significance (p values) for both two groups. Full information about the derivation and statistical analysis of NMSE can be found in [16].

Discussion

Figures 3 and 4 demonstrate a typical response of the linear part of the system(first order kernel) for both Parkinson patient Yoga practicing and Parkinson patient without Yoga practicing respectively. This response exhibits the oscillatory and underdamped nature of the system for Parkinson practicing Yoga and less oscillatory amplitudes for Parkinson patient without practicing Yoga. Also, for mesh diagram as shown in figures 5 and 6, the amplitudes of figures 6 belong to typical Parkinson's patient without practicing Yoga is greatly reduced compared with figure 5 of typical Parkinson's practicing Yoga . This may be attributed

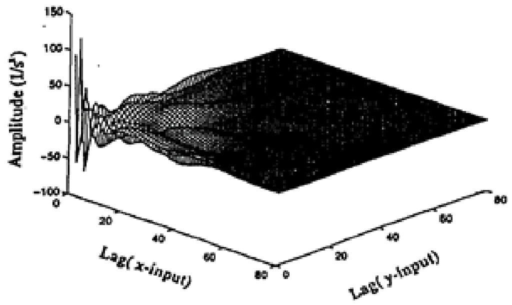

Figure 5: A Typical second kernel (mesh diagram) for Parkinson's Yoga practicing patients.

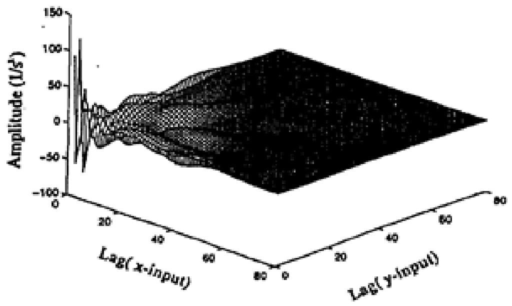

Figure 6: A Typical second kernel (mesh diagram) for control Non- Yoga practicing Parkinson's patient.

Table 1: Comparison of averaged Normalized Mean Square Errors(NMSE) of first order and second order kernel prediction of both groups.

	Model order			
	First order (NMSE)		Second order (NMSE)	P value
Parkinson Non Yoga	(15)	36.50 ± 6.43	23.46 ± 4.34	< 0.05
Parkinson Yoga Patients	(15)	21.43 ± 12.45	15.75 ± 7.76	0.001

to the nature of the system being sensitive to stimulus [11] i.e., the lowering and raising the leg causes variations in heart rate reflected in high response in Yoga practicing Parkinson's patient as illustrated in figures 3 and 5.

While this process is not happened for Parkinson's patients without Yoga practicing due to malfunction of autonomic nervous system and well-illustrated in low amplitude in figures 4 and 6 respectively. The appearance of low amplitudes of second order kernel of figure 6 (mesh diagram) for a typical Parkinson's patient without Yoga practicing suggests correlation between autonomic function and this diagram which may be used as indicator of the dysfunction of autonomic nervous system in Parkinson patients. The significance of Mesh figure (Figure 5) as illustrated for Yoga practicing Parkinson's patients is to give insight the dynamics of the effect of Yoga in autonomic nervous system in this group with high amplitude with respect to the other group without Yoga practicing as illustrated figure 6 and table 1 summarizes the average NMSE of the model prediction for 15 Parkinson patient practicing Yoga and 15 Parkinson patients without Yoga practicing. It is apparent that NMSE of the first order model is about 8-12 % higher than NMSE of the second order model for both groups. This indicated the significance of second order model of the system in describing the nonlinearity and complexity of relationship between stimulus and HRV. Referring to table 1, The NMSE for first order and second order for Parkinson's patients without Yoga practicing is greater than Parkinson's patients Yoga practicing ($p<0.05$ and 0.001 respectively).The results indicated in this paper shows the improvement of autonomic function of Parkinson's patients practicing Yoga as shown in figures 3 and 5 as well as table 1. Another methods of analysis based on entropy method and posture entrainment can be used for detecting the performance of autonomic function of Parkinsons patients practicing Yoga .However, These results given this research may give model quantitative indices to assess the autonomic nervous system in health and disease.

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