MEDITATION: ITS TREMENDOUS IMPACT ON HEART RATE VARIABILITY

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ABSTRACT

The heart is connected through the nervous system directly to major organs and is able to sense their need. The heart also responds to adrenaline in the blood flowing through it. With these inputs the heart is able to adjust its rate to accommodate the needs of the whole body. By its heartbeat, it is able to broadcast a common signal to every cell. One measure of heart health is Heart Rate Variability (HRV). HRV is defined in terms of how different the lengths of time between each heart beat is. The greater the difference in times between heart beats, the healthier is the heart thought to be. Individuals may be able to learn to increase their own HRV and become healthier by a daily meditation practice. This paper uses Heart Variability as the base signal for studying the impact of meditation on it. The paper brings out the difference between pre and post meditation conditions in terms qualitative measure of Power Spectral Density (PSD) variations using Smoothed Pseudo Wigner Ville (SPWVD) distribution method. The simulations highlight the meditation effects overtime period in PSDs.

KEYWORDS

HRV, SPWVD, STFT, WVD

1. INTRODUCTION

Because the heart is continually adjusting its heart rate, the heartbeat is not a constant signal. Internal and external stimuli, including thoughts, emotional reactions, and changes in the environment trigger immediate changes in heart rate so that a beat will come slightly early or late; this creates HRV, a part of normal cardiac function. In a non-meditative state, there is no discernible pattern to the heart rate variability. If charted on a graph, the pattern of the heart rate would appear chaotic, with several jagged peaks[1]. The study of HRV signals is very much essential as the cardiovascular system is influenced by various factors during meditation. It has been suggested that HRV can provide non-invasive prognosis and diagnosis tools for a number of pathological conditions [2]. Most importantly, it was demonstrated that heart rate variability exhibits various features that can be used to distinguish between heart rate under healthy and life-threatening conditions [3]. Furthermore, it has been shown that the study of HRV can lead to a better understanding of the dynamics of the underlying physiological mechanisms [4] in a variety of different conditions, such as apnea, sleep [5] etc. It is widely accepted that neuroautonomic

Natarajan Meghanathan, et al. (Eds): SIPM, FCST, ITCA, WSE, ACSIT, CS & IT 06, pp. 545–552, 2012.

DOI : 10.5121/csit.2012.2353

control results in modulation of HRV [6] through the antagonistic action of the two branches of the autonomic system, namely the sympathetic (SNS) and parasympathetic (PNS). The paper is organized as follows. Section 2 deals with the importance of meditation. Section 3 deals with the analysis of HRV. Section 4 deals with the results and discussions. The paper is concluded in Section 5.

2. WHY MEDITATION?

Practicing meditation has been shown to induce some changes in the body. By learning more about what goes on in the body during meditation, researchers hope to be able to identify diseases or conditions for which meditation might be useful.There has been an explosion of popular and scientific interest in the potential health benefits of various types of meditative protocols. However, the comparative physiologic effects of different forms of meditation remain incompletely explored.

Some types of meditation might work by affecting the autonomic (involuntary) nervous system. This system regulates many organs and muscles, controlling functions such as heartbeat, sweating, breathing, and digestion. It has two major parts:

- The sympathetic nervous system helps mobilize the body for action. When a person is under stress, it produces the "fight-or-flight response": the heart rate and breathing rate go up and blood vessels narrow (restricting the flow of blood).
- The parasympathetic nervous system causes the heart rate and breathing rate to slow down, the blood vessels to dilate (improving blood flow), and the flow of digestive juices increases [7].

Meditation trains our mind to regulate itself, leads us beyond the outer activity into the inner silence of our hearts, where we find ourselves connected to our divine essence. The regulated mind and connection with our inner divinity develops in us a balanced state which is unaffected by the ups and downs of everyday life [8]. Meditation, especially slow breathing, is known to influence the Heart Rate Variability (HRV). Researchers in Taiwan studied the effect of inward attention during meditation on HRV (Wu and Lo, 2008). Inward attention is an important process to enter into transcendental consciousness in Zen-meditation [9].

3. ANALYSIS OF HRV

HRV represents one of the most promising marker for measuring activity of the autonomic nervous system — the system that is responsible for cardiovascular mortality [6]. It is a product of the dynamic interplay of many of the body's systems. Short-term (beat-to-beat) changes in heart rate are largely generated and amplified by the interaction between the heart and brain. This interaction is mediated by the flow of neural signals through the efferent and afferent pathways of the sympathetic and parasympathetic branches of the Autonomic Nervous System (ANS). HRV is thus considered a measure of neurocardiac function that reflects heart–brain interactions and ANS dynamics. HRV data is usually analyzed in terms of its PSD. The PSD reveals the relative strengths of the frequency components of the signal [10]. Frequencies in the range 0.0033 to 0.04 Hz (VLF) are associated with parasympathetic activity; frequencies from 0.15 to 0.4 Hz (HF) are associated with sympathetic activity. The intervening band (LF) is a mixture of the two influences [5]. The analysis of HRV has become a tool for noninvasively detecting the cardiovascular modulation of ANS. Traditional analysis in frequency-domain mainly includes calculating the power and the peak frequency of each physiological frequency component. Whether employing the non-parametric or parametric method to estimate the Power Spectrum Density (PSD), the approximate stationary of HRV is presupposed. However, only in short-term analysis can data meet this condition. With the increase of the record time, the nonstationarity of HRV notably appears. Figure 1 shows the components of a human system responsible for HRV variation.

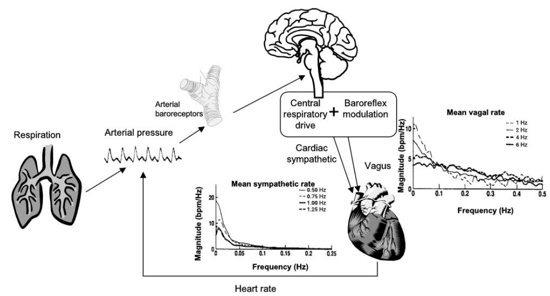


Figure 1. Schematic figure representing components section responsible for heart rate

It shows the frequency response characteristics to vagal and sympathetic activity with regard to the heart rate [11]. Recent results in research on HRV analysis show that its dynamic behavior gives the scope for nonlinear components involved which contribute substantially in nervous system regulation. Traditional power spectral analysis of HRV data, irrespective of employing either parametric or non parametric approaches implies the signal to be stationary. But as HRV signal is non-stationary the limitations of these techniques have been eliminated by Time Frequency Representations (TFRs).They include among others Short Time Fourier Transform(STFT) and Quadratic Wigner- Ville Distribution (WVD) [12].

3.1 Wigner- Ville Distribution (WVD)

The WVD belongs to the Cohen's class which in continuous domain can be expressed in the following general form [13].

$$P(t,w)=\frac{1}{2\pi}\int\int\int e^{-jvt-j\tau w+jvu}\ (\varphi(v,\tau)x(u+\tfrac{\tau}{2})x^{*}(u+\tfrac{\tau}{2}))dud\tau dv \qquad (1)$$

It provides a representation of the signal x(t) in the joint time-frequency domain. The WVD for a deterministic, complex valued signal x(t) can be easily derived from the above equation, by setting the kernal φ as shown in equ. 2.

$$WD(n,w)=2\sum_{k=-\infty}^{\infty} e^{-2jwk}h_N^{\,2}(k)x(n+k)x^{*}(n-k) \qquad (2)$$

If x(t) is band limited, the WVD in the discrete case is given by

$$WD(n,w)=2\sum_{k=-\infty}^{\infty} e^{-2jwk}h_N^{\,2}(k)x(n+k)x^{*}(n-k) \qquad (3)$$

Where we have assumed T=1. The $h_N(k)$ window is superimposed on to the data in order to limit the summation. The implementation and the properties of the discrete WVD have been widely investigated. The zero order local moment in the time variable of the equation (3) is equal to the PSD of the signal and is given by

$$\int W(t,w)dt=\left|X(w)^{2}\right| \qquad (4)$$

At any given time n, the product $x(n+k)x^*(n-k)$ makes the past and the future overlap, so that a finite duration component beginning at time n_0 is not detected unless n>. If n is > n_0, then the product $x(n+k)x^*(n-k)$ is not zero and subsequent Fourier transform detects the frequency component. This property provides the WVD with an excellent time resolution, which is adequate for the study of transient in variability signals.

The interference terms in WVD can be dramatically reduced by smoothing in time and frequency. The result is the smoothed-pseudo Wigner-Ville distribution (SPWVD) which is defined as follows.If one chooses a separable kernel function $f(\xi,\tau)=G(\xi)h(\tau)$, where $G(\xi)$ represents function of interest and $h(\tau)$ represents truncation window length, with a Fourier transform of the form:

$$F(t,v)=FT[f(\xi,\tau)]=g(t)H(v) \quad (5)$$

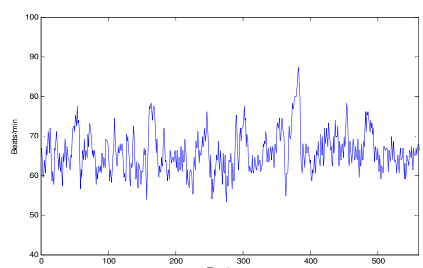
We obtain the Smoothed Pseudo Wigner-Ville Distribution (SPWVD) as:

$$SPWVD_{(t,v)}=\int h(\tau)[\int g(s-t)x(s+\frac{\tau}{2})x^*(s-\frac{\tau}{2})ds]e^{-j2\pi vt}d\tau \quad (6)$$

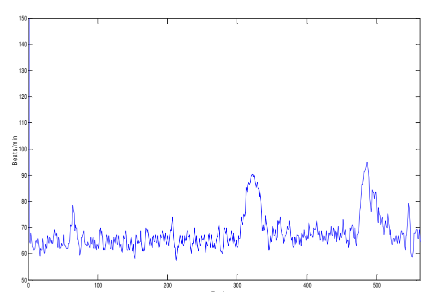
As HRV signal is non stationary in nature, the usage of SPWVD is extended to study the spectral density of the signal and hence to identify the effect of meditation on the PSD of the HRV signal.

4. Results and Discussions

The simulation is carried out using the HRV records of Physiobank [14]. The HRV record consists of pre and post meditation data. Four such records were collected and their PSDs were obtained using SPWVD-TFR technique. Figure 2 and 3 show the HRV time series of pre and post meditation data. It can be seen that the post meditation HRV data is a smooth variation compared to that of pre meditation data.



(a)



(b)

Figure 2(a). HRV before meditation for a duration of 1.5 minutes (b) HRV before meditation for a duration of 1 minute

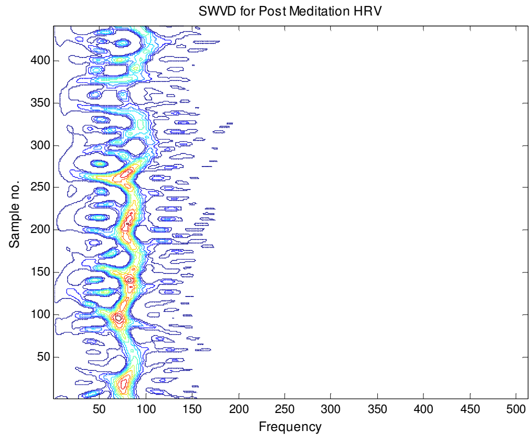


Figure5. SPWVD for the post meditation data shown in Fig.3(a)

The post meditation time frequency plot is shown in Fig. 5. The plot is for the same subject shown in Fig.4 but after meditation. There is a continuity of the spectral content in the time axis indicating a narrow region of variation in frequency. The frequency variation is only in the range of samples from 50 to 100. This indicates the variation in frequency is less and the consistent after meditation. The Fig. 6 and Fig. 7 also indicate the time frequency plots of pre and post meditation data for the same subject.

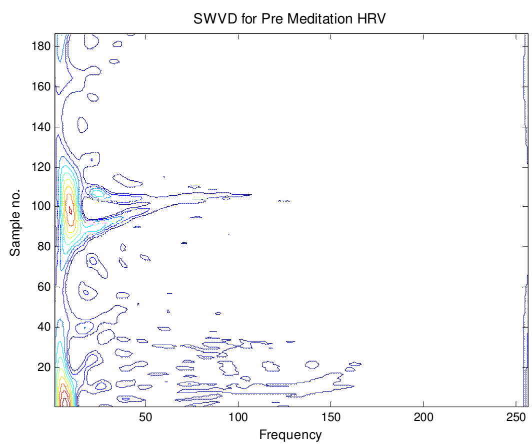


Figure 6. SPWVD for the pre meditation data shown in Fig.2(b)

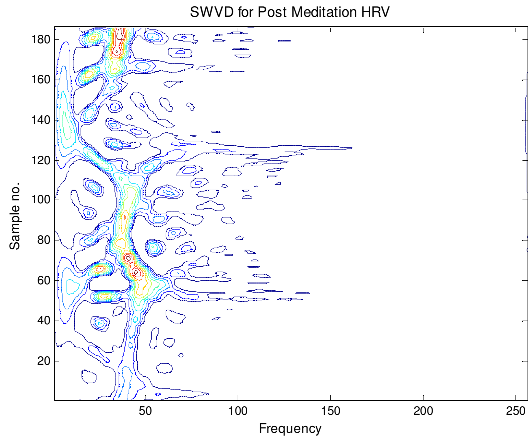


Figure7. SPWVD for the post meditation data shown in Fig. 3(b)

5. CONCLUSION

In this paper, we have studied the PSDs of HRV qualitatively, obtained before and after meditation. The statistical and spectral measures of HRV indicate that meditation may have different effects on health depending on frequency of the resonant peak that each meditator can achieve.

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