# University of Brasília

**Electrical Engineering Department**


# Topics in Biomedical Engineering

## Task 2


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# 1 Questions about the scientific article:

## 1.1 Question 1

Por que o artigo afirma que um coração saudável não é um metrônomo?

According to the article [1], healthy biological systems exhibit complex patterns of variability that can be described by mathematical caos, and the heart rate variability (HRV) is characterized for changes in the time intervals between consecutive heartbeats (IBIs).

Thus, a healthy heart is not a metronome because the oscillations of a healthy heart are complex and constantly changing. In other words, the heartbearts are not regular like a musical metronome which controls the rithm of a orchestra. The article also assert that the variability of non-linear systems, like the heart-beating, provides flexibility to rapidly cope with an uncertain and changing enviroment.

## 1.2 Question 2

O que é o sinal de variabilidade da frequência cardíaca (heart rate variability, ou HRV na sigla em inglês)? Procure a internet em busca de figuras que mostram (b.1) como obter o sinal de HRV a partir do ECG e (b.2) um gráfico do sinal de HRV x tempo e explique, no texto, o que estas figuras estão mostrando. Lembre-se de citar a fonte das imagens encontradas e das referências consultadas.

According to the article [1], the heart rate variability (HRV) is the fluctuation in the time intervals between adjacent heartbeats. It is an emergent property of interdependent regulatory systems which operate on different time scales to help us adapt to environmental and psychological challenges. HRV reflects regulation of autonomic balance, blood pressure (BP), gas exchange, gut, heart, and vascular tone, which refers to the diameter of the blood vessels that regulate BP, and possibly facial muscles.

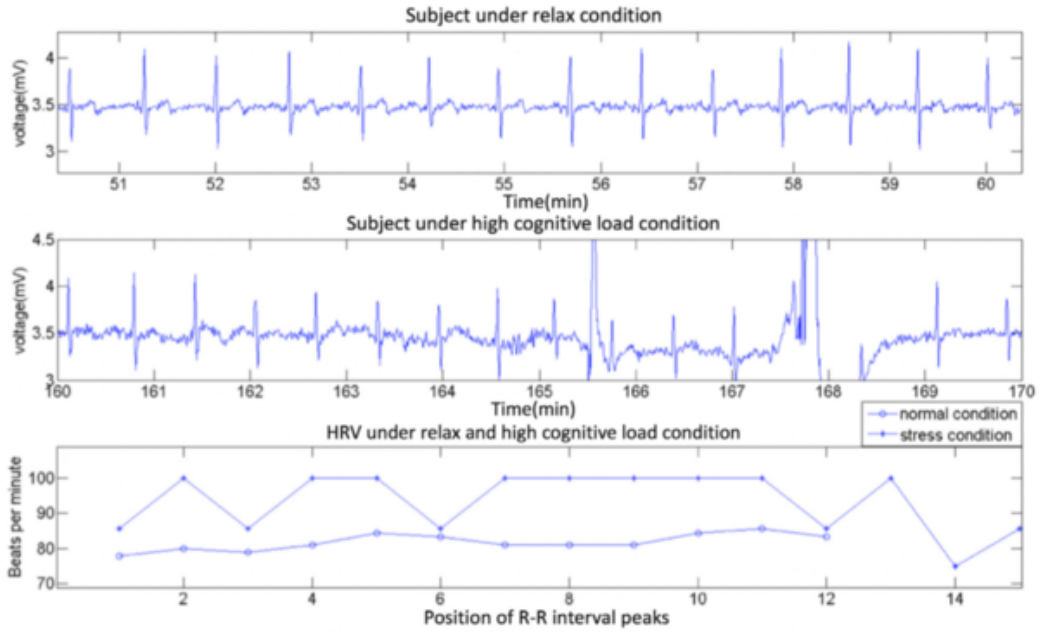


Figure 1: Changes in HRV caused by stress in environment [Fig extracted from [6]]

The HRV signal is obtained by measuring the interval of time between consecutive heart beats, seen on the ECG, that is not constant, but something that varies from beat to beat. This is the reason why a HRV signal is never just a straight horizontal line.

The image above shows the ECG of a person under relaxed conditions, another ECG when under high cognitive load condition and a HRV of both cases.

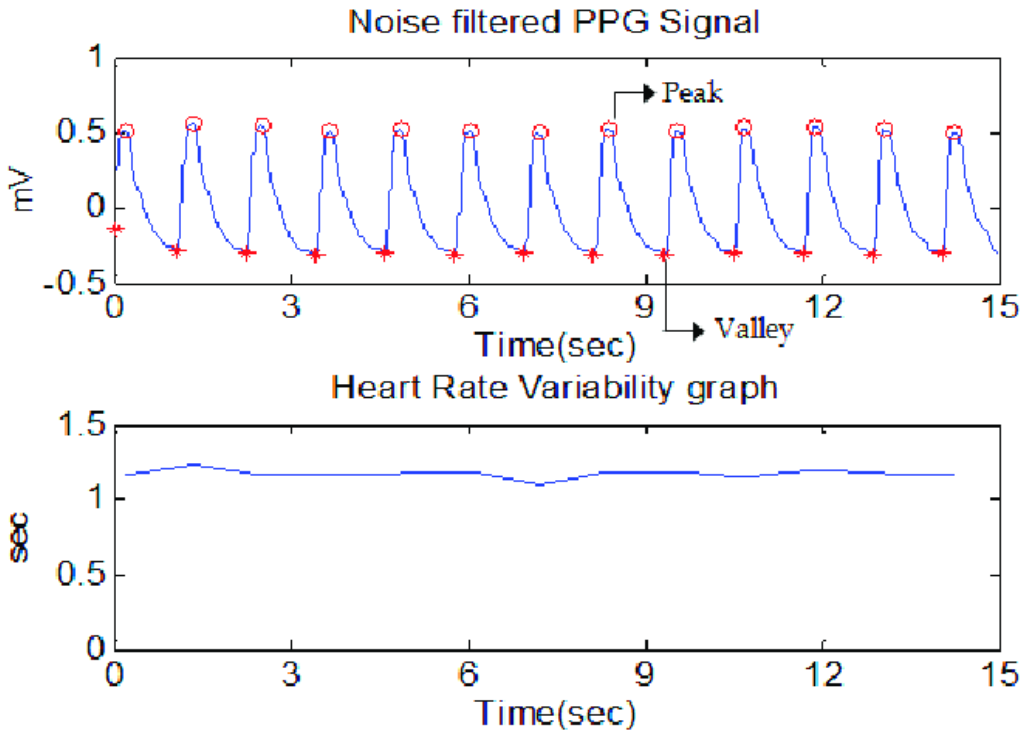


Figure 2: HRV plotted in function of time. [Fig extracted from [6]]

The image above shows a PPG signal and a HRV signal plotted in function of time obtained from the PPG signal, not an ECG one.

## 1.3 Question 3

Quando o artigo fala em medidas de curto-prazo de HRV, durante quanto tempo o sinal de HRV deve ser analisado? Neste outro artigo do Task Force (força tarefa) of The European Society of Cardiology and The North American Society of Pacing and Electrophysiology, durante quanto tempo recomendam que se deve analisar o sinal de HRV para se determinar medidas de curto prazo ("short term recordings", pg. 358)?

According to the article [1], page 2, short term measurements are recorded over **5 minutes**.

According to [7], page 358, minimum **2-5 minutes** are required for short term recordings, although **5 minutes** are recommended.

We can conclude that the recommendation of both articles are based on the same standards.

## 1.4 Question 4

Voltando ao artigo de Shaffer et. al., qual o intervalo de frequência definido como a banda de baixa frequência (low frequency band ou LF band) e qual o tempo mínimo da gravação necessário para a determinação desta banda, segundo o artigo? E para a banda de alta frequência (high frequency band ou HF band)?

According to the article [1], the LF or baroreceptor range has the range of frequencies defined around (**0.04 - 0.15 Hz**), and is typically recorded over a minimum **2 minutes** period.

Furthermore, the HF band or respiratory band has the range of frequencies defined around (**0.15 - 0.40 Hz**), and is conventionally recorder over a minimum **1 minute** period.

In a comparison between LF band and HF band, is logical the the first need a larger time period of recorded than the second one because the LF band has less oscillations in a period - the definition of frequency - of the HF band, and, in consequence, has less information if the same period of time were adopted for both.

## 1.5 Question 5

Observe que 0,04 Hz corresponde a um período de 25 segundos (T = 1/f). Assim, quantos períodos de uma onda de 0,04 Hz ocorrem em 1 e em 2 minutos de gravação? Da mesma forma, f = 0,15 Hz corresponde a um período de 6,6 segundos. Quantos períodos de uma onda de 0,15 Hz ocorrem em 1 e em 2 minutos de gravação? O artigo do Task Force citado no item (c) recomenda um tempo de gravação de 5 minutos para medidas de curto-prazo de HRV. Neste intervalo de tempo, quantos períodos existem em uma onda de 0,04 e de 0,15 Hz, respectivamente?

A 0.04 Hz signal will have 2.4 cycles in one minute and 4.8 cycles in two minutes. A 0.15 Hz signal will have 9.091 cycles in one minute and 18.182 in two minutes.

For a 5 minutes time, a 0.04 Hz signal will have 12 cycles and a 0.15 Hz signal will have 45.45 cycles.

## 1.6 Question 6

Para se realizar a análise espectral do sinal de HRV neste curso, é necessário escolher um trecho em que o sinal é estacionário. No capítulo 2, “Method-

ological Aspects of Heart Rate Variability Analysis", de Tom Kuusela, do livro "Heart Rate Variability (HRV) Signal Analysis: Clinical Applications", editado por Markad V. Kamath, Mari Watanabe e Adrian Upton, como o autor define um sinal estacionário (item 2.2.4)? Neste mesmo capítulo, como o autor explica a relação entre estacionariedade de um sinal e a duração da gravação deste mesmo sinal?

The aforementioned chapter defines a stationary signal as the lack of shift in many parameters of the signal. Therefore the base level of the signal, the amplitude distribution, the spectrum and auto correlation should remain constant in order to have a stationary signal.

Biological signal are mostly non-stationary, because external stimuli trigger physiological responses that significantly alter the parameters of many body systems. As it is preferable to analyse stationary signals, so that you can use a broader class of methods, there are some strategies that can be used to approximate linear and invariant systems. This chapter states that the longer is the recording of the signal, the less stationary it is, what implies that taking shorter segments is a good option.

## 1.7 Question 7

Voltando ao artigo de Shaffer et. al., os autores comentam que há dois processos responsáveis pela geração das variabilidades de curto prazo do sinal de HRV (short term HRV). Quais são estas duas fontes de variabilidade do sinal de HRV que os autores citam?

The article [1] cites that two distinct but overlapping processes are responsible for short-term HRV measurements. The first process is a complex and dynamic relationship between the sympathetic (**SNS**) and the parasympathetic (**PNS**) branches. Equally important, the second process includes the regulatory mechanisms that control heart-rate (HR) via respiratory sinus arrhythmia (**RSA**), the baroreceptor reflex (negative-feedback control of blood pressure (**BP**)) and rhythmic changes in **vascular tone**.

## 1.8 Question 8

Explique o que os autores querem dizer com uma relação dinâmica (dynamic autonomic relationship) entre o sistema nervoso parassimpático (PNS) e o sistema nervoso simpático (SNS) em um coração saudável. Há mais informações sobre isso no capítulo 2 desta dissertação de mestrado (em português).

Using the articles [1] and [2] as references, the *dynamic autonomic relationship* between the sympathetic nervous system and parasympathetic nervous system concerns in a complex (both linear and non-linear) association that varies all the time due multifatorial reasons imposed by the fisiological processes. Exemplifying, the SNS is one of the agents which can increase the heart-rate, while the PNS can decrease, the resultant heart-rate is determined as a result of this associative relationship, which explains the dynamic nature.

The autonomic nature comes from the autonomic or autonomous term that means the non-voluntary activity of the Autonomic Nervous System, which is responsible for the control of non-voluntary process of human's body, like heart-beating and respiration, and is divided in two main parts: Sympathetic Nervous System and Parasympathetic Nervous System.

## 1.9 Question 9

No item "Frequency-domain measures" do artigo de Shaffer et. al., qual o tempo mínimo necessário (em minutos) para se obter medidas confiáveis da região de baixa frequência (low frequency ou LF band)?

The article [1] asserts that the necessary minimum period of time recorded to have reliable measureaments in the LF band **0.04 - 0.15 Hz** is **2 minutes**.

## 1.10 Question 10

Neste outro artigo de Shaffer et. al. (A healthy heart is not a metronome: an integrative review of the heart's anatomy and heart rate variability), no item "Low frequency band" (pg. 9 da versão em pdf do artigo - há um link para o pdf no link do artigo), os autores explicam o reflexo do barorreceptor (ilustrado na figura 9). O que são os barorreceptores e como eles atuam para manter a pressão arterial constante, segundo os autores?

According to the article, the baroreceptors are stretch-sensitive mechanoreceptors located in the chambers of the heart and vena cava, carotid sinuses. They maintain the blood pressure at a relatively constant level by activating a response when the carotid and aortic tissues are distended, which happens when the blood pressure rises.

The activation of the baroreceptors triggers a chain reaction that, as an end-result, activates the parasympathetic response and inhibits the sympathetic one, reducing the blood pressure. In opposition, when the blood pres-

sure is low, the baroreceptors will not activate and the sympathetic system will engage to rise the blood pressure.

## 1.11 Question 11

Segundo informações constantes no projeto de final de curso do prof. João Luiz, do ENE, o que são batimentos ectópicos ou extra-sístole e porque eles precisam ser removidos/editados quando o objetivo do estudo é a análise da variabilidade da frequência cardíaca? Procure na internet figuras que mostram o que são batimentos ectópicos (normalmente são seguidos por uma pausa compensatória) e outras informações acerca de como lidar com estes batimentos para se realizar a análise da variabilidade da frequência cardíaca.

According to the final graduation project of the *Prof. João Luiz Azevedo de Carvalho, Ph.D* [3], the ectopic beats or extrasystole are premature beats of high amplitude normally with a compensatory pause. Therefore, as shown in the Figure 3, there is a short R-R interval, in a row of a long interval.

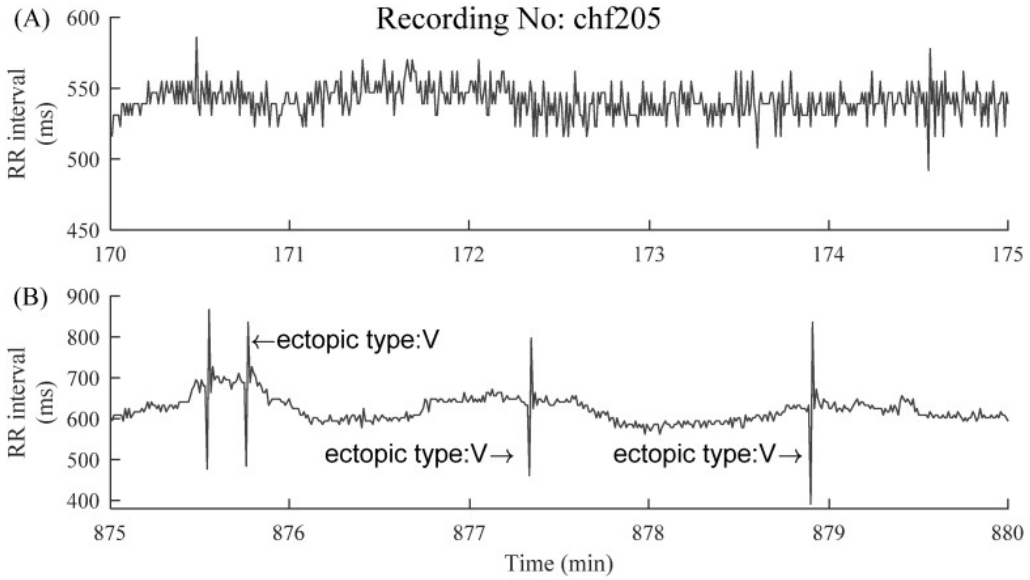


Figure 3: Ectopic beat with a compensatory pause in sequence [Extrated from: [4]]

The ectopic beats does not originate in sino-atrial node, but in others regions of the heart, thus this extrasystoles have no relation with nervous system performance, but only with the heart fisiology. As the object of analysis is the nervous system and is not specifically the entire heart, these

ectopic beats have to be removed, because they change drastically the length of R-R intervals and the analysis, which ends up rendering the signal.

Furthermore, an important information is that these ectopic beats not always appear like a high amplitude wave and also not always are in the R-R intervals. Therefore, is recommended that the marking of the extrasystoles be done first in the ECG, and not in the R-R interval.

Regarding to the ectopic beats dealing to analyze the heart reate variability (HRV), the Article [5] presents a new algorithm to detect ectopic beats and how to deal with them. The method concerns in a trend correlation of the heart timing signal, basically a predictor o R-R interval (RRI) at ectopic beat time is constructed by the weight calculation and the slope estimation of preceding normal RRI. Finally, the type of ectopic beat was detected and replaced by the preditor of RRI. This is a general view about the algorithm and more information about the metrics and the mathematical construction can be found in the reference [5]. Furthermore, in the literature, is also widely accepted the interpolation method and the use o Berger Algorithm in the ectopic beats treatment.

## 1.12 Question 12

No artigo Spectral Analysis of Heart Rate Variability: Time Window Matters, de Li et. al., os autores comentam vários passos necessários relativos ao pré-processamento do sinal de ECG para gerar o sinal de RRI (R-to-R interval, ou intervalo R-R). Enumere os diversos passos de pré-processamento citados e explicados pelos autores.

The steps of preprocessing are enumerated below:

1. Sampling and digitalizing: The sampling rate should be high enough to obtain the interval between R peaks (RR interval). The article suggests that 200Hz is the minimum frequency resolution and 250 Hz are recommended.

2. RR data editing: potential artifacts, ectopic beats and arrhythmic events should be identified, as they are non-sinus events. Ideally for short term HRV, a segment without those should be chosen.

3. Interpolation: When choosing segments without disturbances is not possible, interpolation can be used on the neighbourhood of the RR interval. Missed beats are more straightforward to handle than ectopic beats. Depending on the type of the ectopic beat different approaches of interpolation can be chosen.

4. NN data sequence: The Fast Fourier algorithm requires equally spaced RR intervals. Interpolation is also necessary to ensure the equal distance, with the negative effect of introducing biases. Practical experimentations show that this procedure usually works on a stable ECG of at least 5 min.

# References


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