# Does Music affect HRV impulse? -A time domain study.

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*Abstract*— **The 2D Poincare′ plot of HRV signal reflects the effect of different external stimuli on ANS. The classification is generally done by fitting an 'ellipse' on the dense region of the constructed Poincare′ plot of HRV signal. However 2D Poincare′ plot sometimes fails to describe the proper behavior of the system. One such example is 2D Poincare′ plot of HRV signal in pre-music and on-music condition. In fact 2D Poincare′ plots in pre and on-music condition look almost similar for few subjects. So a proper classification tool is sought for. In this article, an improved technique called "3D Poincare′ plot with proper delay" has been applied to properly distinguish the pre-music and on-music state of some normal healthy subjects. The whole experiment is carried out at School of Bio-Science and Engineering, Jadavpur University, Kolkata, India.**

***Keywords—Average Mutual Information, Ellipse fit, Ellipsoid fit, HRV Signal, 2D and 3D Poincare' plot.***

## I. INTRODUCTION

Now a days, stress and anxiety have a large negative impact on our society and most of our diseases originate from psycho-somatic disorder. Therefore reduction of stress is necessary for the well-being of our society. Since music has a direct connection with human feeling and mood, it can be used for the reduction of stress of human being. An essential question that may arise at this point is how does music affect human physiological condition and what are the important parameters needed to classify the pattern? During the last two decades, the effect of different types of music to promote relaxation has been studied throughout the globe [8, 11]. The primary focus of those researches was to relate to the subjective responses of the subject, such as pleasure and changes in mood [9] rather than objective physiological responses. However, the results regarding the effect of music were found to be very much conflicting and confusing in relating to the exact circumstances and variables that affect the body's response to music, such as the type of music [10] and the subject's involvement in the music [9]. In some literature, it was found that music decreases the sympathetic nervous system (SNS) and increase parasympathetic nervous system (PNS) activity as measured by heart rate (HR), blood pressure (BP), and heart rate variability (HRV), indicating physiological relaxation [9], while in some other literature it was found that music increases SNS activity and it also increases the HR in subjects who listened to some preferred music after exercise [8]. In fact, it was also found that two other factors – respiratory rhythm [8, 12] and gender [8] affect the human physiological response to music.

HRV [1-4] is a popular non-invasive tool to assess different heart conditions. Due to its non-invasive character HRV has become an attractive tool for using it in the study of human physiological response to different stimuli [5-6]. HRV is the variation of time between two consecutive heartbeats. It is a useful tool to know the overall cardiac health and the status of the autonomic nervous system (ANS). There are two branches of the ANS—the sympathetic and the parasympathetic. The sympathetic branch increases heart rate and the parasympathetic branch decreases it. Thus at any instant, the observed HRV is an indicator of the dynamic interaction and balance between these two nervous systems. In the resting condition, both the sympathetic and parasympathetic systems are active with parasympathetic dominance. The balance between them is constantly changing to optimize the effect of all internal and external stimuli [13]. Although the effects of music on mind are mostly realized in brain through Central Nervous system (CNS), music also affects the conditions of heart through the dominance of Para-sympathetic nerves of Autonomic Nervous system (ANS). So it is no less important to study the effect of music through analysis of HRV data extracted from the corresponding ECG signals of the heart in the time domain, when we listen to music. In this article, for the purpose of analyzing the effect of music on HRV signals under pre-music and on-music state a very simple method has been proposed, which clearly analyze the effect of music on HRV signals. In fact traditional 2D Poincaré plot with proper delay is applied for the analysis of the effect of music on HRV signals. But no such distinction between the pre-music and on-music states can be

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978-1-4799-3163-7/13/$31.00 ©2013 IEEE

made visually or even by fitting an ellipse in the cloud region of the Poincare′ plot of HRV signals [6]. Hence 3D Poincaré plot with proper delay is applied, which gives satisfactory result in this context.

## II. METHOD

### *A. Acquisition of HRV data*

At first ECG data are collected from different subjects (age between 20 to 30 years male and female.) All subjects are basically students and academicians. The digitized form of ECG data are collected from those subjects and recorded by 'HRV data logger' machine (made by School of BioScience and Engg., Jadavpur University). All signals are taken at School of BioScience and Engg., Jadavpur University under normal room temperature and least noisy environment. Signals have been collected in two stages. In the first stage ECG are taken at normal condition. Then in the second stage ECG signals are taken when subjects are listening to music .All signals are taken in ten minutes duration. Then recorded signals are processed by MATLABR2010a software using moving window integration of a digital filter and converted into HRV signals.

### *B. 2D Poincaré plot , Average Mutual Information, 3D Poincaré plot*

To explore the HRV dynamics on 'beat-to-beat' basis, the original idea of 2D Poincaré plot included a delay/lag of one beat only [14]. Later on, 2D Poincaré plot with non-unit lag was developed [15][18]. But there was no specific basis of choosing this non unit lag, the choice was purely arbitrary. Possibly the reason was to get comparatively better form of 2D Poincaré plot. If, however, proper quantification of the 2D Poincaré plot is required for the purpose of interpretation of the behavior of the data, then best form of Poincaré plot is to be obtained in any way. For example, when quantification of 2D Poincaré Plot is made [16-17] by the process of 'ellipse fit' then for this ellipse, independent coordinates are to be sought for from the data itself. Naturally, for quantification by this method the Poincaré plot itself should have some form, which should not be of much irregular shape. Hence, there is a necessity for selecting proper lag for constructing best 2D Poincaré plot. In this case, the standard methods available for obtaining the proper lag are the method of minimum auto-correlation, a linear measure and the method of Average Mutual Information.

Mutual information function can be used to determine the "optimal" value of the time delay for the state space reconstruction.

Suppose $\{x(t)\}_{t=1}^{N}$ is given time series. A good choice for the delay $\tau$ is one that, given the state of the system $x(t)$, provides maximum new information with measurement at $x(t+\tau)$.

$$I(\tau) = \sum_{t=1}^{N-\tau} P\left[x(t), x(t+\tau)\right] \log\left(\frac{P\left[x(t), x(t+\tau)\right]}{P\left[x(t)\right] P\left[x(t+\tau)\right]}\right)$$

It was suggested in [7] that the value of delay, where $I(\tau)$ reaches its first minimum be used for the 2D Poincaré reconstruction.

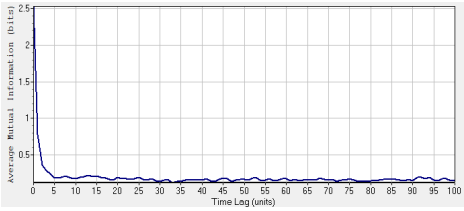


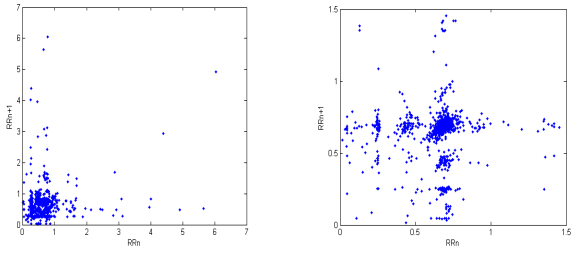

Fig.1: $I(\tau)$ vs $\tau$

2D Poincaré plot is constructed with the independent coordinates $(x(t), x(t+\tau))$ and 3D Poincaré plot is plotted with the independent coordinates $(x(t), x(t+\tau), x(t+2\tau))$.

## III.RESULT AND DISCUSSION

### *A.2D Poincaré Plot with proper delay of HRV signal in pre-music and on-music state*

Fig.2 shows the 2D Poincaré Plot with proper delay of HRV signals in pre-music and on-music state.




**Pre-music sate** **on-music state**

Fig 2. 2D Poincaré Plot with proper delay of HRV signals in pre-music and on-music state.

It is observed that both the Poincaré plots are dense in some area with some outliers. Actually, there is no known canonical way to eliminate these outliers of the plots except manual supervision and visual inspection. However, these things are not at all important here.

Rather, it is necessary to focus on the main cluster because the important, relevant and necessary information in this context is hidden within the orientation of the main cluster. We have tried to quantify these plots by fitting an ellipse to their main cluster. So, we have computed the lengths of the major axis and minor axis in each case and finally taken the ratio of two axes as a quantifying parameter, which is given in table.1 and 2.

TABLE1

| subject | SD1 | SD2 | SD2/SD1 |
|---|---|---|---|
| a1 | 0.445502 | 0.518924 | 1.164807 |
| a2 | 0.14233 | 0.1527 | 1.072858 |
| a3 | 0.180022 | 0.177443 | 0.985675 |
| a4 | 0.563637 | 0.713092 | 1.265162 |
| a5 | 0.23555 | 0.244572 | 1.038301 |
| a6 | 0.181542 | 0.186061 | 1.024894 |
| a7 | 0.274641 | 0.287152 | 1.045553 |
| a8 | 0.154729 | 0.157943 | 1.020775 |
| a9 | 0.207647 | 0.251096 | 1.209247 |

Table 1:Quantification Table of 2D Poincaré Plot with proper delay of HRV signals in pre-music state.

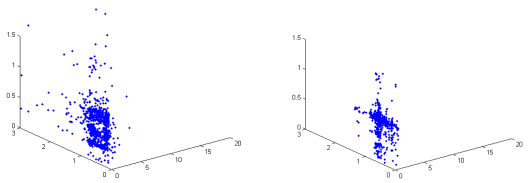
TABLE2

| subject | SD1 | SD2 | SD2/SD1 |
|---|---|---|---|
| a1m | 0.182648 | 0.18935 | 1.036693 |
| a2m | 0.11955 | 0.129195 | 1.080674 |
| a3m | 0.24773 | 0.23288 | 0.940056 |
| a4m | 0.134011 | 0.168468 | 1.257123 |
| a5m | 0.218786 | 0.209284 | 0.95657 |
| a6m | 0.211619 | 0.270061 | 1.276162 |
| a7m | 0.241921 | 0.234208 | 0.968116 |
| a8m | 0.256898 | 0.252189 | 0.981669 |
| a9m | 0.263063 | 0.258643 | 0.9832 |

Table 2: Quantification Table of 2D Poincaré Plot with proper delay of HRV signals and on-music state.

It is observed from table 1 and table 2 that the ratio of the axis length SD2/SD1 decreases most of the subjects except a6 and a2 in on-music state. So it is not able to quantify all the cases in on-music state. So 2D Poincaré Plot with proper delay is not a proper tool for distinguishing the pre-music and on-music states.. So we switch from 2D Poincaré Plot with proper delay to 3D Poincaré Plot with proper delay.

*B.2D Poincaré Plot with proper delay of HRV signal in pre-music and on-music state*



**Pre-music sate** **on-music state**

Fig 3. 3D Poincaré Plot with proper delay of HRV signals in pre-music and on-music state.

From the above figure, it is evident that both the plots are well-formed and dense compared to the previously obtained 2D Poincaré plots in pre-music and on-music states. So we have tried to quantify these plots by fitting an ellipsoid to their main cluster. For this purpose, we have computed the lengths of three axes (SD1, SD2, SD3) and then taken the ratio of SD2/SD1 and SD2/SD3. Finally the quantifying parameter is taken as the average of the two aforesaid ratios. This is given in table.3 and 4.

TABLE3

| sub | SD1 | SD2 | SD3 | SD2/SD1 (a1) | SD2/SD3 (b1) | (a1+b1)/2 |
|---|---|---|---|---|---|---|
| a1 | 0.6398 | 0.6773 | 0.4685 | 1.05861 | 1.445667 | 1.2521367 |
| a2 | 0.1704 | 0.17 | 0.1198 | 0.99791 | 1.419758 | 1.2088355 |
| a3 | 0.2413 | 0.2346 | 0.1755 | 0.97246 | 1.336872 | 1.1546641 |
| a4 | 0.92 | 0.9141 | 0.5688 | 0.99357 | 1.607158 | 1.3003659 |
| a5 | 0.3102 | 0.3247 | 0.2422 | 1.04693 | 1.340795 | 1.1938643 |
| a6 | 0.3406 | 0.3456 | 0.2175 | 1.01488 | 1.588942 | 1.3019119 |
| a7 | 0.3605 | 0.38 | 0.2854 | 1.05405 | 1.331293 | 1.1926706 |
| a8 | 0.2135 | 0.2083 | 0.153 | 0.97556 | 1.361346 | 1.1684511 |
| a9 | 0.3245 | 0.3228 | 0.2086 | 0.99478 | 1.547641 | 1.2712123 |

Table3. Quantification Table of 3D Poincaré Plot with proper delay of HRV signals in pre-music state.

TABLE4

| sub | SD1 | SD2 | SD3 | SD2/SD1 (a2) | SD2/SD3 (b2) | (a2+b2)/2 |
|---|---|---|---|---|---|---|
| a1m | 0.2449 | 0.2489 | 0.1844 | 1.0166 | 1.349781 | 1.183189 |
| a2m | 0.1986 | 0.1969 | 0.1385 | 0.99164 | 1.422129 | 1.206886 |
| a3m | 0.3458 | 0.3053 | 0.2276 | 0.8828 | 1.341541 | 1.112171 |
| a4m | 0.2173 | 0.2162 | 0.1352 | 0.99491 | 1.598874 | 1.296893 |
| a5m | 0.2872 | 0.2778 | 0.2136 | 0.96741 | 1.300821 | 1.134115 |
| a6m | 0.2413 | 0.2465 | 0.1845 | 1.02136 | 1.335565 | 1.17846 |
| a7m | 0.3155 | 0.3112 | 0.2393 | 0.98645 | 1.30068 | 1.143565 |
| a8m | 0.3343 | 0.3349 | 0.2533 | 1.00182 | 1.321874 | 1.161848 |
| a9m | 0.3343 | 0.3349 | 0.2533 | 1.00182 | 1.321874 | 1.161848 |

Table 4: Quantification Table of 3D Poincaré Plot with proper delay of HRV signals in on-music state.

It is observed from table 3 and table 4 that the average value of SD2/SD1 and SD2/SD3 decreases in all of the cases in on-music state. So 3D Poincaré Plot with proper delay is a proper tool for the purpose of distinction of the pre-music and on-music sates.

## IV CONCLUSION

It is to be noted that the average value of SD2/SD1 and SD2/SD3 of the fitted ellipsoid reduces in case of on-music state as compared to the corresponding value of the subjects in the normal condition. The possible reason is the reduction of stress in the on music states. Thus, it may be inferred that reduction in the average value of SD2/SD1 and SD2/SD3 of the fitted ellipsoid is a sufficient criteria for minimization of stress. However, the present study is limited to a smaller sample size of data and so further investigation is required on a larger sample size of data to substantiate the present work.

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