Effect of Indian Raga Music on Conditions of Heart

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Abstract – Phenomenology or statistical survey to study the effect of music in human gives us only human feedback, which comes from their intuition and feelings. Different conclusions derived from such survey are prone to questions on accuracy. Here we tried to study the effect of Indian Raga Music [IRM] on Autonomic Nervous System through the study of ECG data in general, and HRV data in particular. For this purpose we chose sitar recitals of some ragas. We chose a raga that had mostly the major tones [tivra svaras] and the other had mostly minor tones [komal svaras]. We also compared the effects between the slow renditions [alap, slow jod] and faster renditions [drut gat] of the music. We observed the effect on two types of subjects. One group had general understanding of IRM and the other had no or negligible understanding of the music genre. We collected HRV data of the subjects in the normal conditions. Then they were allowed to listen to the music samples, each sample for ten minutes. The HRV data were collected.
All the acquired signals were put to scientific study for their long term dynamics. The investigations were made to find out the changes, if any, in the heart conditions of the subjects when they were listening to music of different parameters in terms of notes and speeds of execution. Finally the results were compared to identify any significant changes in stress conditions as found in Yoga practitioners.

Key Words – Indian Raga Music; major tones; minor tones; alap; jod; drut gat;komal svaras; tivra svara; Yoga, heart rate variability(HRV).

1. Introduction:

Raga performances create sensations in human mind. The raga-generated sensations are different for different ragas; these are commonly called as ‘moods of ragas’. The sensation also changes with the progress of a raga performance. The slow beginning in the vilambit alap and the fast jhala clearly create different sensations. We hypothesize that the amount of effect on human is different when they are exposed to different raga generated moods. There are two types of Nervous systems in human body - one is ANS, the Autonomic Nervous System and the other one is CNS, the Central Nervous System. Moreover the effects of music on mind are mostly realized in brain through CNS, although music also affects the conditions of heart through the dominance of Para-sympathetic nerves of ANS. The latter effects of music are also presently studied in details in the literature. This is why it is no less important to study the effect of music through

analysis of (Heart Rate Variability-signal) HRV signal [1] extracted from the corresponding ECG signals [1] of the heart, when we listen to music.

2. Experimental basics

a. Yaman and Malkauns ragas

The Yaman takes five tivra svaras [R, G, tivra-m, D and N] when Malkauns takes four komal svaras (komal-g, komal/shudh-M, komal-d and komal-n). We chose to expose our subjects to sitar recitals. We chose instrumental music because this type of music only uses musical components like pitch, intensity, rhythm and timbre and it does not use any component like verbal language (lyric). So, the effects get generated exclusively from the musical components.

Some comparative features of the used two ragas Yaman and Malkauns are:

Sn	**Description**	**Yaman**	**Malkauns**
1	Number of notes used	07	05
2	Number of notes used in ascending	05	05
3	Number of notes used in descending	07	05
4	Number of Tivra svaras	05 out of 07 [71.43%]	0
5	Number of Komal svaras	0	04 out of 05 [80%]
6.	Playing duration for each piece	10 mins	10 mins.

b. ECG and HRV

ECG signal means an electrical response of human heart. It carries five major components - P, Q, R, S & T. Among them the segments, consists of Q, R and S, is called QRS-complex. This QRS complex compelled by sympathetic and para sympathetic nerves.

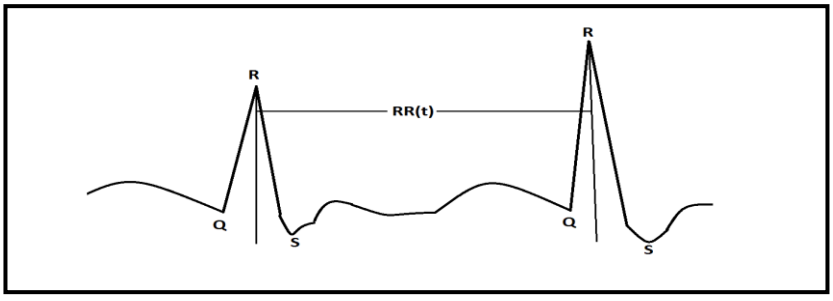


Figure.1. QRS complex in a ECG signal.

HRV signal is a sequence of time-intervals of successive R-R peaks. If ANS affected by any sources (whatever it might be music, songs or natural phenomenon), then this must reflect on HRV rhythm.

3. Experimental procedure

A. Subject selection and musical set-up

A considerable number of people love listening to Indian Raga Music [IRM]. A section of these people understand this musical nuances nicely, and the rest are simply IRM-lovers and may not understand the fine nuances but enjoy the music. But there are huge numbers of people those do not understand or appreciate IRM. For a fair experiment we have given importance to both sections of people, namely,

I. Persons who understand and appreciate IRM

II. People those are not IRM-lovers and do not generally enjoy IRM.

We hypothesize that the amounts of affectivity on human are different for different musical qualities. We examined the effects of speed and the effects of tivra svaras and komal svaras. So, we compared:

(i) the effects of slower rendering (Alap or slow jod) and faster rendering (drut gat).

(ii) the variations in the effect of Tibra Svras with Komal Svaras through ragas like Yaman and Malkauns .

Finally we went through rigorous scientific analysis to examine the effects of such music on minds of human being.

B. HRV- signal extraction from ECG signal

All the signals are recorded at Instrumental Music Department, Rabindra Bharati University under normal room temperature and least noisy environment. Recording has been done in two stages. All signals are taken in ten minutes duration. Finally, recorded signals are processed by MATLABR2010a software [2] using moving window integration of a digital filter and converted into HRV signals.

One of the extracted ECG among the subjects is given in figure.2

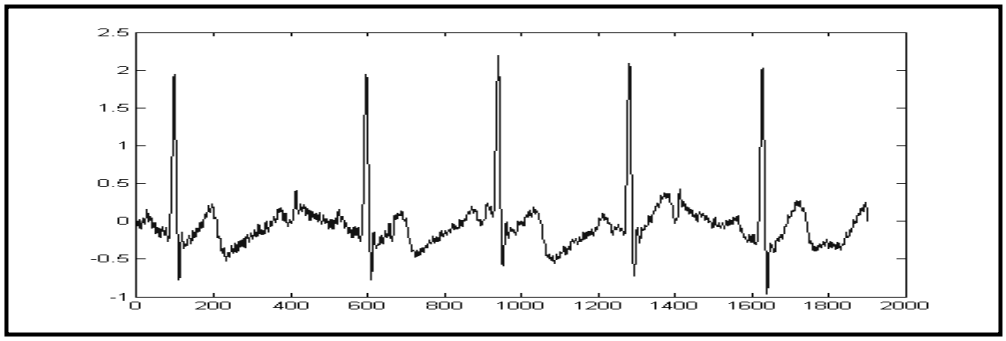


Figure.2. ECG signal extracted for 10 minutes (only 2000 samples is plotted for visual purpose).

C. Auto-correlation in Frequency domain, Frequency-delay plot and its Quantification

Let $\{x(k)\}_{k=1}^{N}$ be the HRV signal and $\{X(j) = a_j + ib_j \equiv (a_j, b_j)\}_{j=1}^{N}$ be its Fourier spectrum [3].Then autocorrelation [4] of $\{x(j)\}_{j=1}^{N}$ in frequency domain corresponding to lag variable μ is defined by

$$R_X(\mu) = \frac{\sum_{j=1}^{N} \left| \{(a_j, b_j) - (\bar{a}_j, \bar{b}_j)\} \cdot \{(a_{j+\mu}, b_{j+\mu}) - (\bar{a}_{j+\mu}, \bar{b}_{j+\mu})\} \right|}{\sqrt{\sum_{j=1}^{N} \left| \{(a_j, b_j) - (\bar{a}_j, \bar{b}_j)\} \right|^2} \cdot \sqrt{\sum_{j=1}^{N} \left| \{(a_{j+\mu}, b_{j+\mu}) - (\bar{a}_{j+\mu}, \bar{b}_{j+\mu})\} \right|^2}}, \mu = 1, 2, 3, 4, 5, \ldots\ldots (1)$$

where $(\bar{a}_j, \bar{b}_j), (\bar{a}_{j+\mu}, \bar{b}_{j+\mu})$ are the means of $\{(a_j, b_j)\}_{j=1}^{N-\mu}$ and $\{(a_j, b_j)\}_{j=1+\mu}^{N}$ respectively and $(a_r, b_r) \cdot (a_s, b_s) = (a_r a_s - b_r b_s, a_r b_s + b_r a_s)$ for $r, s = 1, 2, 3, 4, 5, \ldots\ldots N$.

The construction of the frequency-delay plot is carried out by choosing that value of μ for which

$R_X(\mu)$ comes nearer to zero for the first time in the 2D correlogram diagram.

The frequency-delay plot [4] is constructed by plotting the independent coordinates $(|x_j|, |x_{j+\mu}|, |x_{j+2\mu}|)$ in 3D space, obtained for the proper frequency-delay μ as discussed in the previous section. Here $|x_j|$ denotes the energy of the HRV signal. The frequency-delay plots are found to be almost dense and well-shaped. This dense region is fitted by an ellipsoid and lengths of its three axes are calculated. Axes of ellipsoid stand as a strong indicator of the changing energy dynamics of HRV. Figure.1 shows how an ellipsoid is fitted to the dense region of the phase space.

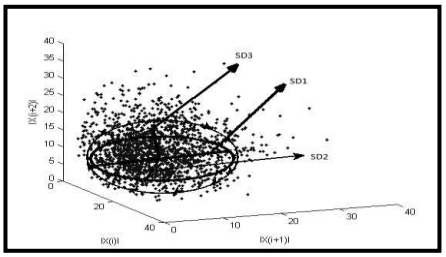


Figure.3. Ellipsoid fitted on the dense region, where SD_1, SD_2 and SD_3 are the axes of the ellipsoid.

The lengths of the three axes of the ellipsoid are given by
$SD_1 = \sqrt{Var(x_m)}$, $SD_2 = \sqrt{Var(x_n)}$, $SD_3 = \sqrt{Var(x_p)}$, where

$$\begin{pmatrix} x_m \\ x_n \\ x_p \end{pmatrix} = \begin{pmatrix} \cos\frac{\pi}{4}\cos\frac{\pi}{4} & \cos\frac{\pi}{4}\sin\frac{\pi}{4} & \sin\frac{\pi}{4}-\cos\frac{\pi}{4}\sin\frac{\pi}{4} & \cos\frac{\pi}{4}\cos\frac{\pi}{4}\sin\frac{\pi}{4}+\sin\frac{\pi}{4}\sin\frac{\pi}{4} \\ \cos\frac{\pi}{4}\sin\frac{\pi}{4} & \cos\frac{\pi}{4}\cos\frac{\pi}{4}+\sin\frac{\pi}{4}\sin\frac{\pi}{4}\sin\frac{\pi}{4} & -\cos\frac{\pi}{4}\sin\frac{\pi}{4}+\cos\frac{\pi}{4}\sin\frac{\pi}{4}\sin\frac{\pi}{4} & \\ -\sin\frac{\pi}{4} & \cos\frac{\pi}{4}\sin\frac{\pi}{4} & \cos\frac{\pi}{4}\cos\frac{\pi}{4} & \end{pmatrix} \begin{pmatrix} x^{+} \\ x^{-} \\ x^{--} \end{pmatrix} \text{ and}$$

$$x^{+} = \left\{\left|X(J)\right|\right\}_{J=1}^{n-2}, x^{-} = \left\{\left|X(J)\right|\right\}_{J=2}^{n-1}, x^{--} = \left\{\left|X(J)\right|\right\}_{J=3}^{n}.$$

The volume of the fitted ellipsoid is given by $V = \pi.SD_1.SD_2.SD_3$.

4. Experimental Results and discussion

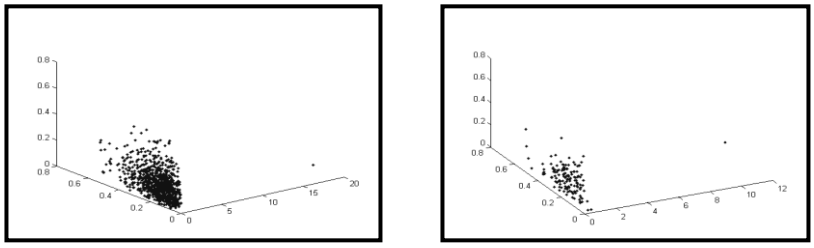
The following table shows the short description about the subjects:

Name of the subjects	Category	Profession	Code
Bidyut Kanti Chowdhaury	IRM initiated	Academician	bkc
Sanjay Bandhopadhay	IRM initiated	Musician	sb
Asit lahiri	IRM initiated	Musician	al
Uma Mitra	IRM initiated	Musician	um
Sushmita Das	IRM initiated	Music Students	sd
Raju Upadhya	IRM ignorant	Car Driver	ru
Gopal Das*	IRM ignorant	Official staff	gd

* Gopal Das was unhappy and denied to listen to *Malkauns*

A. frequency-delay plot of HRV under normal condition

The frequency delay plot of IRM initiated person and IRM ignorant person are shown in figure.4



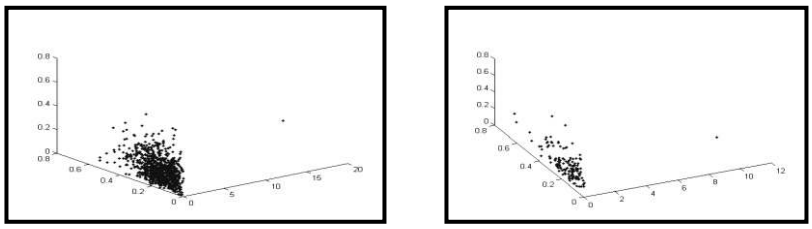
(a) **(b)**

Figure.4. (a) freq-delay plot of normal HRV of IRM initiated person,(b) freq-delay plot of normal HRV of IRM initiated person and IRM ignorant person.

B. frequency-delay plot of HRV while listening to Malkauns

a. alap

The frequency-delay plot of IRM initiated person and IRM ignorant person are shown in figure.5

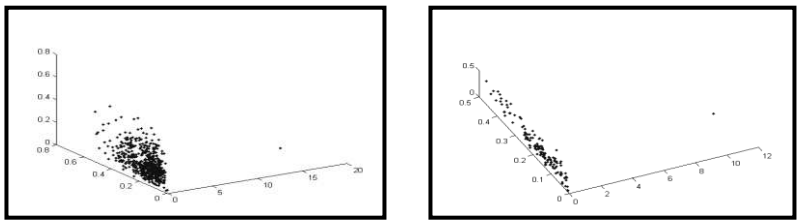


(a) **(b)**

Figure.5. (a) freq-delay plot of HRV (when they listening alap-Malkauns) of IRM initiated person,(b) freq-delay of HRV (when they listening alap-Malkauns) of IRM initiated person and IRM ignorant person.

b. drut gat

The frequency- delay plot of IRM initiated person and IRM ignorant person are shown in figure.6



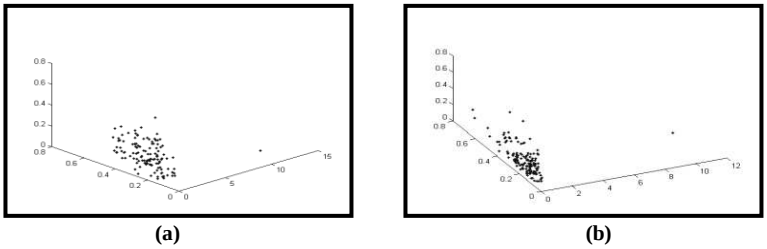
(a) **(b)**

Figure.6. (a) freq-delay plot of HRV (when they listening drut-Malkauns) of IRM initiated person,(b) freq-delay of HRV (when they listening drut-Malkauns) of IRM initiated person and IRM ignorant person.

C. frequency-delay plot of HRV while listening to Yaman

a. alap

The frequency-delay plot of IRM initiated person and IRM ignorant person are shown in figure.7

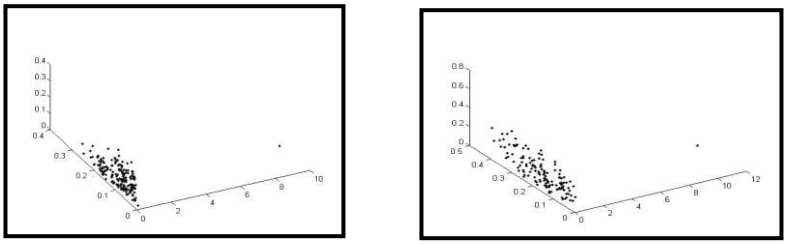


(a) **(b)**

Figure.7. (a) freq-delay plot of HRV (when they listening alap-Yaman) of IRM initiated person,(b) freq-delay of HRV (when they listening alap-Yaman) of IRM initiated person and IRM ignorant person.

b. drut gat

The frequency-delay plot of IRM initiated person and IRM ignorant person are shown in figure.8



(a) (b)

Figure.8. (a) freq-delay plot of HRV (when they listening drut-Yaman) of IRM initiated person, (b) freq-delay of HRV (when they listening drut-Yaman) of IRM initiated person and IRM ignorant person.

D. Comparison by quantification

The patterns in the numerical values of the quantifying parameter, viz., the volume of the ellipsoid (fitted in the frequency-delay plot) are obtained from the following tables:

Table-I: Malkauns

HRV-signal	Volume		
	Normal	Alap	Drut-gat
bkc	2.28165874638994	1.82922039548648	1.50182715601550
sb	0.734829501111781	0.810446500051954	0.59843281348461
al	1.47343633408124	1.57194189862057	1.47800518762729
um	0.817864203929319	0.926509259295867	0.579726235785750
sd	0.557698116215315	0.536075927193731	0.512204557157203
ru	1.48618011191542	1.33236010875682	1.33055722146273
gd	1.49887054703347	----------	----------

Table-II: Yaman

HRV-signal	Volume		
	Normal	Alap	Drut-gat
bkc	1.84958917953654	1.16870478103502	1.03605278365171
sb	0.734829501111781	0.807738593554127	0.671875060403904
al	1.84958917953654	1.16870478103502	1.03605278365171
um	0.817864203929319	1.22433804099770	0.714984288531894
sd	0.557698116215315	0.849273677070719	0.555646317894679
ru	1.48618011191542	1.79671701768637	1.61290548448752
gd	1.49887054703347	1.92663909985322	1.88412421192744

From table-I, it is found that there is a mixed trend in the quantifying parameter, when the subjects listen to alap/slow gat of raga Malkauns. But for all subjects, IRM conversant or IRM ignorant, the trend is always a decreasing one when they listen to drut gat in raga Malkauns. Moreover in all such cases the volumes of the frequency-delay plots are always less than the corresponding volumes of the frequency-delay plots of normal HRVs of the subjects.

From table-II, it is found that so long as we consider alap/slow gat of raga Yaman for all subjects (IRM conversant and IRM ignorant), there is no definite trend in the volumes of the frequency-delay plots for all subjects. However

volumes of the frequency-delay plots of HRVs (when the subjects listen to drut gat of raga Yaman) are always less than the volumes of the frequency-delay plots of HRVs (when they listen to alap/slow gat of raga Yaman). But even then it can not be said that these volumes are always less than the corresponding volumes as compared to the frequency-delay plots of normal HRVs. Although this is the general scenario for all subjects, still for IRM knowledgeable persons the scenario is completely different. In fact, for such persons volumes of the frequency-delay plots of HRVs (when IRM-knowledgeable persons listen to drut gat of raga Yaman) are always less than the volumes of the frequency-delay plots of HRVs (when IRM-knowledgeable persons listen to alap/slow gat of raga Yaman); further the former volumes are always less than volumes of the frequency-delay plots of their normal HRVs.

5. Conclusion

To make the final conclusion on the effect of music on human ANS, we like to remark that for persons on meditation, the tendency of the aforesaid parameter, viz., the volume of the ellipsoid is always found to decrease [5].

Physiologically this means that decrease in volume indicates minimization of stress of mind by the dominance of the parasympathetic nerves. With this argument, it can be clearly concluded that, the raga Malkauns always creates dominance of parasympathetic nerves in all subjects (IRM initiated and IRM ignorant) when they listen to faster part or drut gat. But no such effect is reported in a positive sense when they listen to only the alap or slow portion of raga Malkauns. We may further state that, such parasympathetic dominance is also achieved by only the IRM knowledgeable persons when they listen to the drut gat or fast portion of raga Yaman but not for the IRM ignorant subjects.

From musical point of view, the results indicate that use of the minor tones or komal svaras always create positive impact in minimizing the stress of mind. But the use of tivra svaras mostly failed to be effective especially when applied on IRM ignorant persons. The raga showed positive effect in fast renditions when applied to IRM knowledgeable persons. Now, if we compare slow and fast renditions, we see that fast renditions always gave positive results in bringing down stress levels to all persons irrespective of their association with Indian Raga Music. As a matter of fact, fast renditions, whether in raga Yaman or in raga Malkauns, always play a positive role in minimizing the stress of mind. So in addition to the preference of Komal Svaras, speed of rendition is also a determining factor in stress management.

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