How Do Ragas of the Same *Thaat* which Evoke Contrasting Emotions like Joy and Pathos Differ in Entropy?

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§ I raga che appartengono allo stesso *thaat* possono evocare emozioni abbastanza differenti, alcune volte anche contrastanti, come gioia e *pathos*. I due raga *Kafi* e *Bageshree* nella tipica musica Hindustani appartengono allo stesso *thaat*, vale a dire il *Kafi thaat*, e usano le stesse note, ma mentre il *Kafi* suscita gioia, il *Bageshree* rimanda al raga *karuna rasa* o a un raga patetico. Queste note sono adatte ad avere diverse probabilità, con o senza condizionamenti e perciò anche le loro entropie sono differenti nei due raga in questione. Il presente contributo fornisce una quantificazione di queste informazioni, che differenziano i due raga in aggiunta alle loro diversità estetiche.

§ Ragas belonging to the same *thaat* can evoke quite different emotions, sometimes even opposite emotions such as joy and pathos. The two ragas *Kafi* and *Bageshree* in Hindustani classical music belong to the same *thaat*, namely the *Kafi thaat*, and use the same notes, but while *Kafi* evokes joy, *Bageshree* is referred to as a *karuna rasa* raga or a raga of pathos. These notes are likely to have different probabilities, conditionally and unconditionally and hence their entropies are also different in the two ragas in question. The present paper gives this quantified information differentiating the two ragas as a supplement to their aesthetic difference.

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Introduction

Indian classical music has two forms: Hindustani and Carnatic or North Indian classical music and South Indian classical music. In either form, the raga is taken as the nucleus. A raga may be defined as a melodic structure with fixed notes and a set of rules characterizing a certain mood conveyed by performance (CHAKRABORTY *et al.* 2009a). By a set of rules we mean the note sequence allowed to in aroh (ascent) and in awaroh (descent), the specific note combinations that are typical of the raga and the way a particular note or a particular note combination is to be rendered. Despite the bindings, which are actually meant to express the raga mood rather than handicap the artist, it is observed that the performer has infinite freedom to express the musical emotion. The tonic Sa can be kept at any pitch (which is a major difference with western classical music where a particular musical piece is in a particular key from where we get harmony and counterpoint; Indian classical music does not support harmony and counterpoint and is monophonic i.e. having a single melody line) and melody and rhythm are the technical ingredients. Indian classical music is very rich in emotion and devotion while western classical music seems to be richer in technicalities (JONES, see the ref. [7] for website address). According to Vishnu Narayan Bhatkhande (1860-1936), one of the most influential musicologists in the field of North Indian classical music in the twentieth century, each one of the several traditional ragas is based on, or is a variation of, ten basic *thaats*, or musical scales or frameworks. The ten *thaats* are Bilawal, Kalyan, Khamaj, Bhairav, Poorvi, Marwa, Kafi, Asavari, Bhairavi and Todi; if one were to pick a raga at random, it should be possible to find that it is based on one or the other of these *thaats* (see <http://www.itcsra.org/sra_raga/sra_raga_that/sra_raga_that_index.html>. See also [7]).

Ragas belonging to the same *thaat* can evoke quite different emotions, sometimes even opposite emotions such as joy and pathos. The two ragas *Kafi* and *Bageshree* in Hindustani classical music belong to the same *thaat*, namely, the *Kafi thaat* and accordingly use the same notes (the converse may not be true; the ragas *Bhupali* and *Deshkar* use the same notes but have been placed in different *thaats*! *Bhupali* belongs to the *Kalyan thaat* while *Deshkar* belongs to the *Bilawal thaat*) but while *Kafi* evokes joy, *Bageshree* is referred to as a *karuna rasa* raga or a raga of pathos. These notes are likely to have different probabilities, conditionally and unconditionally and hence their entropies are also different in the two ragas in question. We shall provide a quantified information differentiating the two ragas as a supplement to their aesthetic difference.

Definition 1: If P(E) is the probability of an event, the *information content* of the event E is defined as $I(E) = -\log_2(P(E))$. Events with lower probability will signal higher information content when they occur.

Definition 2: Let X be a discrete random variable which takes values x_1 x_2 x_3.....x_n with corresponding probabilities p_1 p_2 p_3.....p_n. Since X is a random variable, the information content of X is also random which we denote by I(X) (what value I(X) will take depends on what value X takes). When $X = x_j$ which is an event with probability p_j then $I(X)=-\log_2(p_j)$. Accordingly, it makes sense to talk about the mean value of I(X) called its *entropy*, denoted by H(X), so that we have

$$H(X) = - \Sigma\, p_j \log_2(p_j), \text{ where the summation is over } j = 1 \text{ to } n.$$

It should be emphasized here that entropy is measuring surprise which should not be confused with meaning. If I write stuoqqzf it is meaningless but since q is coming after q which never happens in English, there is definitely the surprise element. Similarly, the statement that the President danced non stop for seven hours yesterday carries more surprise than meaning. For further literature on entropy, see APPLEBAUM 1996 (chapter 6) and the references cited therein. The use of entropy in music analysis has been successfully tried in Western music. We are motivated by the work of Snyder (SNYDER 1990). Although only raga structure is analyzed in the present work, the ideas are applicable to performance as well. Note that for an impossible event E, P(E)=0, I(E)= -∞. As negative information is ruled out, it indicates the non-feasibility of ever obtaining information about an impossible event.

Remark: We shall define plog(p) = 0 when p = 0. The range of plog(p) is thus [0, ∞).

Statistical Analysis

As the two ragas Kafi and Bageshree using the same notes are different, occurrences of a particular note, unconditionally or conditionally, should be conveying different information contents in them. The argument can be easily extended to note combinations. The database consists of two sequences of 90 notes, one in each raga, taken from a standard text (DUTTA 2006).

Table 1A compares the musical features of the two ragas. Table 1B compares them on the basis of probability of notes and information content.

Table 1A: Comparison of musical features of ragas Kafi and Bageshree

MUSICAL FEATURE	RAGA *KAFI*	RAGA *BAGESHREE*
Thaat	*Kafi*	*Kafi*
Aroh (ascent)	S R g M P D n **S**	S g M D n **S**
Awaroh (descent)	**S** n D P M g R S	**S** n D, M P D g, M g R S
Vadi (most imp note)	P	M
Samvadi (second most imp note)	S	S
Pakad (catch)	S S R R g g M M P	S *n D*, S M D n D, M g R S
Jati (no. of distinct notes used in ascent and descent)	Sampoorna-Sampoorna (7 distinct notes in ascent; 7 distinct notes in descent)	Aurabh-Sampoorna (5 distinct notes in ascent; 7 distinct notes in descent)
Nyas swar (stay notes)	R, g, M, P	g, M, D
Anga	*Difficult to classify as Poorvanga-pradhan or Uttaranga-pradhan as both halves are important* ***	*Poorvanga-pradhan* (first half more important)
Time of rendition	Midnight	2nd phase of night (9PM-12PM)
Nature	Restless	Restful and serious

***Generally the Poorvanga pradhan ragas evoke sadness while the Uttaranga pradhan ragas evoke joy. The 'joy' aspect in Kafi is actually the joy that is associated with romance. This is called the *shringar rasa* and should not be confused with humour or *hasya rasa*. Kafi is mostly used in thumris and semi-classical items. The first author thanks Dr. Vanamala Parvatkar, renowned vocalist of Banaras Gharana, also formerly Head, Faculty of Performing Arts, Banaras Hindu University, Varanasi and Pt. Falguni Mitra, leading Dhrupad singer, member of the expert committee, ITC Sangeet Research Academy.

Table 1B: Differences in information contents of notes in Kafi and Bageshree

Raga *Kafi*		Raga *Bageshree*	
NOTE	INFORMATION CONTENT	NOTE	INFORMATION CONTENT
S=10	I(S) =-log2 (10/90) = 3.1713	S=17	I(S)=-log2 (17/90) = 2.4044
R=15	I(R) =-log2 (15/90) = 2.5850	R=5	I(R)=-log2(5/90) = 4.1699
g=17	I(G) =-log2 (17/90) = 2.4044	g=7	I(g)=-log2 (7/90) = 3.6845
M=22	I(M) =-log2 (22/90) = 2.0324	M=20	I(M)=-log2(20/90) = 2.1699
P=15	I(P) =-log2 (15/90) = 2.5850	P=2	I(P)=-log2 (2/90) = 5.4919
D=5	I(D) =-log2 (5/90) = 4.1699	D=22	I(D)=-log2 (22/90) = 2.0324
n=6	I(n) =-log2 (6/90) = 3.9069	n=17	I(n)=-log2 (17/90) = 2.4044

Tables 2 and 3 compares the transitory probability matrices of the ragas assuming a first order Markov chain**.**

Table 2: Transition Probability Matrix Of Raga Bageshree (figures in parenthesis give the information content)

	S	**R**	**g**	**M**	**P**	**D**	**n**
S	3/15 (2.3219)	1/15 (3.9067)	0	4/15 (1.9067)	0	1/15 (3.9067)	6/15 (1.3219)
R	1 (0)	0	0	0	0	0	0
g	0	3/7 (1.2224)	0	4/7 (0.8074)	0	0	0
M	1/20 (4.3219)	0	6/20 (1.7370)	1/20 (4.3219)	2/20 (3.3219)	7/20 (1.5146)	3/20 (2.7370)
P	0	0	0	0	0	1 (0)	0
D	2/21 (3.3923)	0	1/21 (4.3923)	11/21 (0.9329)	0	0	7/21 (1.5849)
n	5/17 (1.7655)	0	0	0	0	12/17 (0.5025)	0

Note: The 90th note in Bageshree is a *D* (D of lower octave) hence we shall not consider any transition beyond that. Since D occurs 22 times, there are 21 possibilities of a transition. This 21 is taken as the denominator for calculating the conditional probabilities from D to the next note.

Table 3: TPM Of Raga Kafi (figures in parenthesis give the information content)

Note: The 90th note in *Kafi* sequence is n. Since n occurs 6 times, there are 6-1=5 possibilities of transition from n to the next note.

	S	**R**	**g**	**M**	**P**	**D**	**n**
S	0	5/10 (1)	0	1/10 (3.3219)	0	0	4/10 (1.3219)
R	3/15 (2.3219)	3/15 (2.3219)	8/15 (0.9069)	1/15 (3.9069)	0	0	0
g	0	7/17 (1.2801)	2/17 (3.0875)	8/17 (1.0875)	0	0	0
M	0	0	7/22 (1.6521)	3/22 (2.8745)	12/22 (0.8745)	0	0
P	2/15 (2.9069)	0	0	9/15 (0.7370)	0	3/15 (2.3219)	1/15 (3.9069)
D	1/5 (2.3219)	0	0	0	3/5 (0.7370)	0	1/5 (2.3219)
n	3/5 (0.7370)	0	0	0	0	2/5 (1.3219)	0

MEAN ENTROPY OF RAGA *KAFI*		MEAN ENTROPY OF RAGA *BAGESHREE*	
Ignoring Octave	Considering Octave	Ignoring Octave	Considering Octave
H(X) = 2.6570	**H(X)**= 2.8383	**H(X)**= 2.4057	**H(X)**= 3.2265

Discussion

It is interesting to observe that the mean entropy of notes for raga *Kafi* is somewhat less than that of raga *Bageshree* (about 13.7%) if octave is taken into account but it is marginally greater (about 9.5%) when octave is ignored. We hope this result will definitely excite musicologists to debate as to why a note, in general, carries greater surprise in raga *Kafi* compared to raga *Bageshree* but when we talk about a note specifying also its octave, it carries more surprise, on the average, whenever it comes in raga *Bageshree* than in raga *Kafi*! Perhaps this has to do with the fact that *Kafi* is a restless raga and hence a note in any octave will carry greater surprise. But for a restful and serious raga, like *Bageshree*, the octave becomes crucial and, given the note with its octave, it carries more surprise when it comes. But this is only a subjective opinion.

It is of interest to compare tables 1A and 1B. The note P in *Bageshree* is a weak note and hence has a small probability and consequently greater surprise when it comes. The same note is the most important note in *Kafi*! So it has a considerably greater probability and less surprise when it comes. All the nyas

swars have large probability in Kafi but only the nyas swars M and D have large probability in raga Bageshree. It is also clear that the most important note is not necessarily the one which comes the maximum number of times. In Kafi, M comes most and in Bageshree, D comes most. In CHAKRABORTY et *al.* 2008, it has been argued that the most important note statistically speaking is one which has a high probability (but not necessarily highest!) and maintains this probability *more than the rest* from instance to instance of note occurrence. This gives rise to a concept of *statistical stability* (credited to the first author who is a statistician) which is different from the concept of (*psychological) pitch stability* of Krumhansl (see CASTELLANO *et al.* 1984) that is based on note duration.

The conditional probabilities, assuming a first order Markov chain, also reflect quite different pictures in the two ragas. For example, the probability from going to D from P is unity in Bageshree (due to the patent {M, P, D} combination) but this probability is only 3/15 in Kafi, i.e. only 0.2.

One may ask why we chose these two ragas and not others for our analysis. In fact, we were looking for two ragas of the same *thaat* that evoke not only different emotions but opposite emotions. By opposite, we mean going from happy to sad.

Conclusion

The present paper compares the melodic structures of two ragas of the same *thaat* that evoke contrasting emotions – joy and pathos – using entropy but we emphasize that such (musical) emotions actually have to do with the note combinations and how they are rendered. In the 'how' part, the note duration and the transitory and non-transitory pitch movements taking place between the notes become crucial. For the latter (see CHAKRABORTY *et al.* 2009b apart from onset, point of arrival), the pitch contour (or pitch class) of notes and their loudness. Further, joy and pathos reflect only the commonality aspect in raga-rasa theory. For instance, when we *Bageshree* and *Sivaranjani* are clubbed as "karuna-rasa" ragas or ragas of pathos, we are seeking what is common. It is, however, more appropriate to say that each raga has its own characteristic emotional content or *its own rasa* so to say reflecting the diversity analysis. Finally, what kind of physical stimulus lead to what kind of emotion is a subject matter of psycho-physics for which the classic text is by Roederer (ROEDERER 2008). Rao has discussed the acoustical perspectives of raga-rasa theory (RAO 2000). To find out what happens in the brain when a certain musical stimulus is given, we need sophisticated instruments like PET (Positron emission tomography which gives a three dimensional image of the functional processes in the body) and fMRI (functional Magnetic Resonance Imaging, a specialized MRI scan which measures the change in blood flow related to the neural activity in the brain). It should be understood that whether the data are coming from PET or fMRI, or from some MIR (musical

information retrieval) software applied to an audio sample or just a sequence of notes taken from a standard text, as in this case which helps in structure analysis without bringing the style of the artist into play, it is always a statistician's delight to analyze them. Finally, since ragas of the same *thaat* can create not only different but opposite emotions, the reader can well imagine what can happen if we pick up ragas of different *thaats* – such are the emotional contrasts in Indian classical music!

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