2-DIMENSIONAL DESCRIPTION AND VISUALISATION OF EXPRESSED EMOTIONS IN MUSIC BY MODELLING AS A COMMUNICATION SYSTEM.

Sai Venkatesh.B

A UNIQUE CONVERSION METHODOLOGY TO MAP MUSICAL COMPOSITIONS TO EMOTIONS – USING COMMUNICATIONS THEORY – ONTO A 2D VALENCE -AROUSAL PLANE ALONG WITH EMPIRICAL DATA.

Main Idea

1. Background:

The solution addresses two main problems:

Problem 1 - Universalization of Music: Music is known for its powerful capacity to evoke emotions. Though Music differs from place to place, the primary effect of Music remains the same i.e. it evokes emotions. Moreover, there are a lot of attempts made recently to universalize music. Any such attempt should be made based on the emotions evoked. This requires a precise quantitative description of emotions, which the solution claims to have obtained.

Problem 2 – Music Therapy: Music Therapy is an alternative form of medicine gaining popularity in recent years due to the absence of side effects. However, music therapy, to date, is being carried out only by trial and error methods. A definite quantitative description of emotions would definitely improve the quality of Music Therapy, as certain ailments are linked with certain emotions. This problem is addressed to in this solution.

The emotions evoked by music are primarily due to its melody, and Carnatic Music is known for its wide repertoire of Ragas (melodies). Hence, this solution is primarily addressed towards Carnatic Music, though the same method can be applied to any other type of music as well.

2. Summary:

Any given musical composition can be precisely analyzed for its emotional impact.

This invention systematically categorizes all kinds of music on a valence - arousal plane (explained below) using a probabilistic approach akin to communication systems. All music - irrespective of region, lyrics and culture - is identified as evoking a certain combination of emotions that can be precisely quantified and located on the valence-arousal plane. A detailed

questionnaire is designed to validate the assumptions and predictions of the theoretical approach. A sample set of 79 individuals who were given the questionnaire were asked to adopt a rating scale to quantitatively assess the impact of each musical piece. Analysis of the data so gathered lends excellent support of the estimated impact (from theory) of any given musical composition.

We all know that music of any kind or culture evokes/inspires/stimulates to a large extent an emotional response that is very specific to the stimulus.

To start with, classical Carnatic Indian music is considered in all its flavor. The fundamental claim is that every note (swara) evokes a corresponding emotional response independent of the specific position in the melody (raga). We consider the collective emotional impact of the fundamental 16 notes of an octave. Of these four notes termed dissonant notes (vivadis) also play a decisive role although only 12 notes are known to be 'fundamental'.

One of the most common frameworks in the emotions field proposes that affective experiences are best characterized by two main dimensions: arousal and valence. The dimension of valence ranges from highly positive to highly negative, whereas the dimension of arousal ranges from calming or soothing to exciting or agitating.

The product of the analysis is a mapping of all the ragas - for that matter any kind of music - onto an 2-D (valence vs. arousal) plane, is enclosed.

APPLICATIONS OF THE VALENCE AROUSAL CHART:

Applications of such a representation include:

1. To visualize valence-arousal.
2. To understand the emotions and scope of emotions that a music piece can give.
3. To visualize the emotions that arise when we modify, or over-stress or under-stress a note.
4. To visualize the synthesis of a raga/ note composition for a particular emotion.

ADVANTAGES:

Advantages of the emotion description are as follows:

- Advantage1: Definite approach to Music Therapy (Ex. a lively and joyful piece of music can be played out to ease Depression).
- Advantage2: Performers can tailor their concerts so as to suit specific themes
- Advantage3: The method applied to other systems of music all around the world and universalization of music can be done on the basis of emotions. drastically improve automated methods of analyzing and synthesizing music.

- Advantage4: In Carnatic Music, a vast number of Ragas are yet to be explored. a lot of new Ragas can hit the limelight - increases the quality of music rendered.

- Advantage5: For the purpose of musical curiosity, we can understand the subtle emotional differences between similar sounding melodies.

3. Description:

VALIDATION :

The claim was validated using a questionnaire based survey of 79 individuals. The people were asked to listen to different pieces of music and assess the emotional impact, classified under 4 categories as Happy, Sad, Activating and Relaxing, under a 9-point grading system shown below... where the number beside each grade is the percentage of the extent of emotion.

Grade	Percentage
S+	100
S	87.5
A+	75
A	62.5
B+	50
B	37.5
C+	25
C	12.5
D	0

Hence for each music piece, there were 79 gradings, under the four headers. A sample snapshot for the music piece "Xiao Yanzi" as graded by 5 people is as shown below:

XIAO YANZI

SL. NO	HAPPY	SAD	ACTIVATING	RELAXING
1	A+	0	A	0
2	B	0	A+	0
3	A	0	S	0
4	A	0	S	0
5	S	0	B	0

Thus, the gradings for each music piece by all 79 members are tabulated using the percentages, and are then averaged.

The number of music pieces were formed in such a way as to assess: (The musical pieces were so selected as to validate/invalidate the following key features/assumptions of the theory :

1. The mutually exclusive nature of "Happy" and "Sad", and of "Activating" and "Relaxing". Happy and Sad conforms to positive and negative valences respectively. Similarly, Activating and Relaxing represent positive and negative arousal, respectively.

2. The independence of music-induced emotions with respect to melody (implying that the composition of musical notes, and not music patterns matter).

3. The independence of music-induced emotions with respect to lyrics, language, culture etc).

Enough music pieces were chosen so as to cover the major kinds of emotions (in all four quadrants of the valence-arousal chart).

Moreover, the survey was not just restricted to Carnatic music, as samples from Chinese, European Classical, Arabic, Japanese etc were also included.

The survey strength included 79 people in all with:

1. 36 males and 43 females;

2. 4 people aged below 15 years, 40 people between 15 and 25 years, 30 people between 25 and 40 years, and 5 people above 40 years of age.

3. 30 Hindus, 5 Muslims. 35 Christians, 2 Sikhs and 7 Others

4. 63 from Subcontinent, 2 Parsis, and 4 of a Sinitic origin.

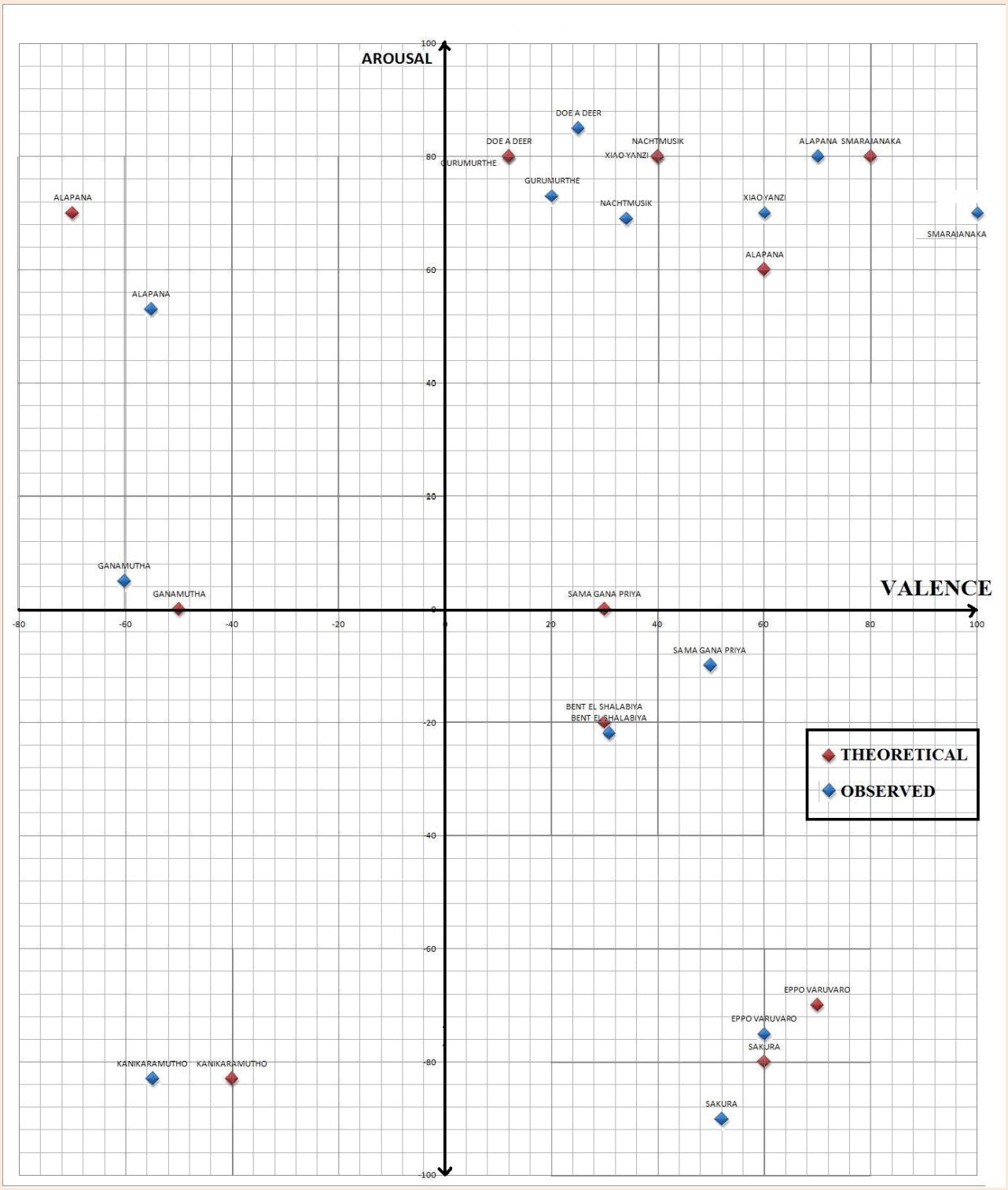
The averaged gradings are all consolidated for all the pieces, and are summarised as follows:

sl no	TITLE	SCALE	ORIGIN	HAPPY		SAD		ACTIVATING		RELAXING	
				theory	observatio	theory	observatio	theory	observatio	theory	observatio
1	DOE A DEER	SANKARABHARANAM	SOUND OF MUSIC	12	25			80	85		
2	GURUMURTHE	SANKARABHARANAM	CARNATIC	12	20			80	73		
3	SMARAJANAKA	BEHAG	CARNATIC	80	100			80	70		
4	SAMA GANA PRIYA	ANANDABHAIRAVI	CARNATIC	30	50						10
5	KANIKARAMUTHO	BHAVANI	CARNATIC			40	55			85	83
6	GANAMU THA	JYOTHISWAROOPINI	CARNATIC			50	60		5		
7	ALAPANA	RASIKAPRIYA	CARNATIC			70	55	70	53		
8	ALAPANA	BUDHAMANOHARI	CARNATIC	60	70			60	80		
9	EPPO VARUVARO	JONPURI	CARNATIC	70	60					70	75
10	NACHTMUSIK	MIXED	WESTERN CLASSICAL	40	34			80	69		
11	SAKURA	YONA NUKI	JAPANESE	60	52					80	90
12	XIAO YANZI	GONG	CHINESE	40	60			80	70		
13	BENT EL SHALABIYA	NAHAWAND	ARABIC	30	31					20	22

It is evident from the results that:

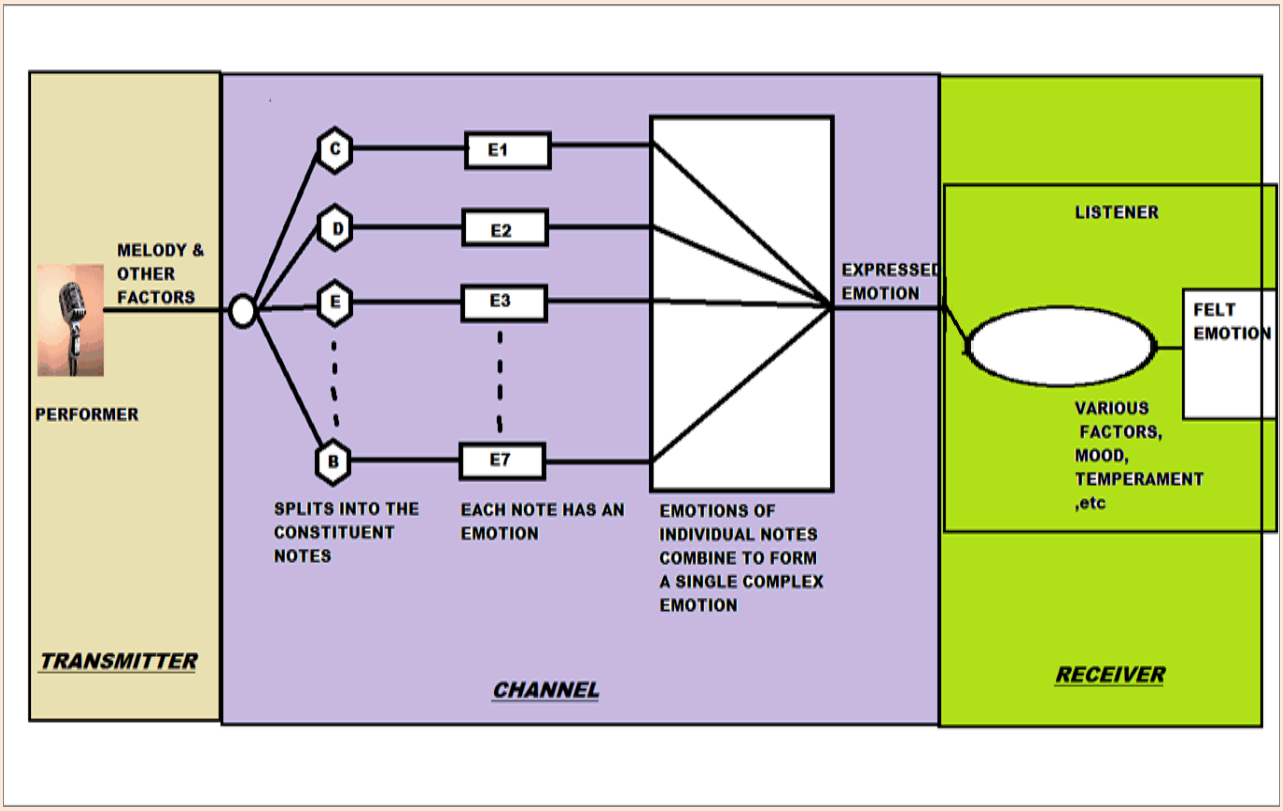
1. Happy and Sad, and Activating and Relaxing , are mutually exclusive emotions, as for any piece only one of the pairs has a value, whereas the other is zero. This confirms the notion of emotions in terms of valence and arousal.
2. From the first two pieces of music above, it is evident that variations in patterns of notes in melodies does not affect the emotions, as predicted by the theory.
3. As there has been a variety of languages, cultures, and music types on both the questionnaire as well as the individuals who participated in the exercise, the independence of emotions with respect to lyrics, culture etc. has also been highlighted.

The values of the above table has been plotted in the valence arousal plane to get a better visualization of the correlation between predicted and observed values. As shown below, there is a fairly good match between the predicted and the observed values, Moreover, it can also be observed that there is a good coverage of the questions on all the quadrants, thus indicating a good variety of emotions covered.


AROUSAL
VALENCE
100
80
60
40
20
0
-20
-40
-60
-80
-100
-80
-60
-40
-20
0
20
40
60
80
100
DOE A DEER
DOE A DEER
NACHTMUSIK
XIAO YANZI
ALAPANA
SMARAJANAKA
GURUMURTHE
GURUMURTHE
NACHTMUSIK
XIAO YANZI
SMARAJANAKA
ALAPANA
ALAPANA
ALAPANA
GANAMUTHA
GANAMUTHA
SAMA GANA PRIYA
SAMA GANA PRIYA
BENT EL SHALABIYA
BENT EL SHALABIYA
EPPO VARUVARO
EPPO VARUVARO
SAKURA
SAKURA
KANIKARAMUTHO
KANIKARAMUTHO
THEORETICAL
OBSERVED

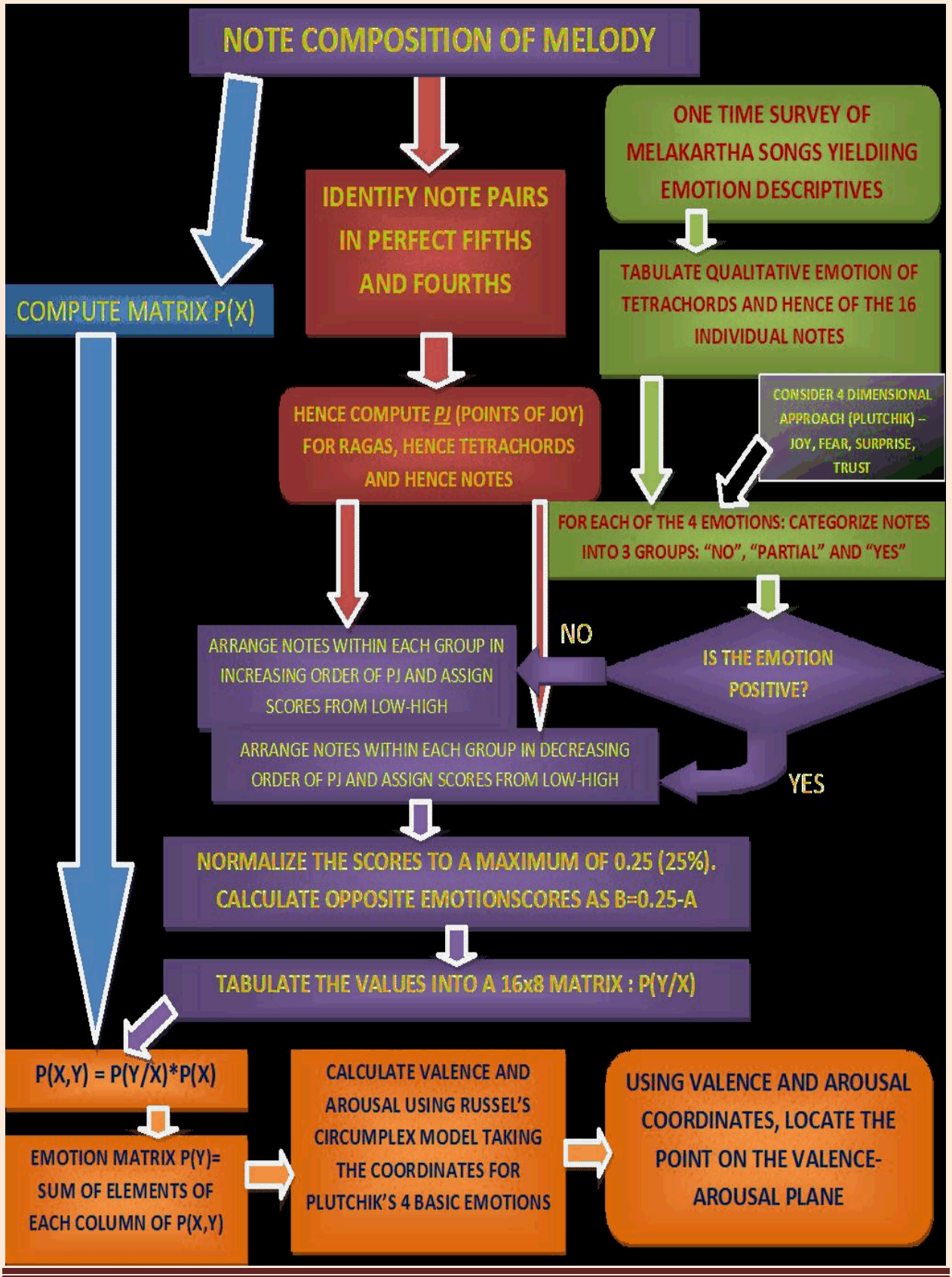
THEORETICAL APPROACH:

The theoretical approach treats the entire activity of musical perception as a communication system with appropriate mappings to derive the emotional response.



Two statistical events are described. Event ‘x’ is the singing of a note (swara). The chance of a note being sung is restricted by the melody (raga) as any raga allows only certain notes to be used. Probability matrix p(x) denotes probabilities of each swara occurring in the raga. In other words, this denotes the raga composition. Event ‘y’ is the arousing of an emotion in the listener. There is uncertainty in y as no emotion is sure of occurring until the swara is sung. However, ‘Y’ depends on the composition of the raga. Hence, before the swara is sung the probability matrix p(y) denotes the emotion profile of the raga, and after the singing of the swara, the conditional probability p(y/x) denotes the emotion of the swara sung. To obtain p(y) we can use the probability relation $p(x,y) = p(y/x)p(x)$, where p(x,y) denotes joint probability. Then the matrix created using the sum of all elements in each column of p(x,y) gives p(y).

A flow chart illustrating the procedure is shown below:


NOTE COMPOSITION OF MELODY
IDENTIFY NOTE PAIRS IN PERFECT FIFTHS AND FOURTHS
ONE TIME SURVEY OF MELAKARTHA SONGS YIELDIING EMOTION DESCRIPTIVES
TABULATE QUALITATIVE EMOTION OF TETRACHORDS AND HENCE OF THE 16 INDIVIDUAL NOTES
COMPUTE MATRIX P(X)
HENCE COMPUTE PJ (POINTS OF JOY) FOR RAGAS, HENCE TETRACHORDS AND HENCE NOTES
CONSIDER 4 DIMENSIONAL APPROACH (PLUTCHIK) – JOY, FEAR, SURPRISE, TRUST
FOR EACH OF THE 4 EMOTIONS: CATEGORIZE NOTES INTO 3 GROUPS: "NO", "PARTIAL" AND "YES"
IS THE EMOTION POSITIVE?
NO
YES
ARRANGE NOTES WITHIN EACH GROUP IN INCREASING ORDER OF PJ AND ASSIGN SCORES FROM LOW-HIGH
ARRANGE NOTES WITHIN EACH GROUP IN DECREASING ORDER OF PJ AND ASSIGN SCORES FROM LOW-HIGH
NORMALIZE THE SCORES TO A MAXIMUM OF 0.25 (25%). CALCULATE OPPOSITE EMOTIONSCORES AS B=0.25-A
TABULATE THE VALUES INTO A 16x8 MATRIX : P(Y/X)
P(X,Y) = P(Y/X)*P(X)
EMOTION MATRIX P(Y)= SUM OF ELEMENTS OF EACH COLUMN OF P(X,Y)
CALCULATE VALENCE AND AROUSAL USING RUSSEL'S CIRCUMPLEX MODEL TAKING THE COORDINATES FOR PLUTCHIK'S 4 BASIC EMOTIONS
USING VALENCE AND AROUSAL COORDINATES, LOCATE THE POINT ON THE VALENCE-AROUSAL PLANE

Hence, to obtain p(y), the first step is to get p(y/x). This is done in 3 steps as follows:
STEP 1: Major notes (white keys in piano) give more pleasant feeling than minor notes (black keys). Moreover pairs of notes in cycles of fifths and fourths (c-g, d-a, c-f, etc.) yield a pleasant feeling. Notes being major/minor contribute more to emotions than them being in the cycle of 5^{th} and 4^{th}. These facts were taken into consideration, all possible combinations of note pairs (major-5th, major-4th, minor-5th, minor-4th, major-not in cycle, etc.) were listed, and arbitrary numbers were assigned to them such that they represented the "pleasantness" in the combination. These numbers were called PJ (points of joy). All swara pairs are listed and PJ's are allotted to them based on the combination under which they fall. Using this, PJ of all Melakartha ragas (a comprehensive set of Ragas each consisting of 7 notes) were calculated by adding the PJs of all swara pairs that featured in the raga. This gives the pleasantness or "positiveness of emotion" in a raga.
For example, sankarabharanam, a happy raga has a PJ of 159. Kalyani, a soothing raga, has a PJ of 147. Sad raga subhapanthuvarali has a PJ of 70 and charukesi, a raga depicting love has a PJ of 100. Then, PJ of a swara was isolated by taking the average of PJ's of all ragas having that swara in common. For example, PJ of ma (F) is 129.5, PJ of dha (G#) is 93.67 and that of Ni (Bb) is 95.83.
STEP 2: Since any parameter measured for a Melakartha raga can be isolated to that of a single swara (just like PJ), we need some means of tabulating emotions of Melakartha ragas. Here 3 means are used:
1. Referring to books on ragalakshana
2. Browsing through various reviews, reports, opinions and blogs for comments on emotions in a particular rendering.
3. Allowing people to hear certain pieces and conducting a survey of the emotions experienced, (this was done with close friends and relatives). All 3 means were adopted and the results were tabulated. For example, Sankarabharanam - joy, love, little surprise, Mechakalyani - joy, love, little surprise, little sympathy and Charukesi - little joy, sympathy, little love, submission. Then the emotions of individual swaras were isolated.

SWARA	EMOTION
SA	ATHARA SWARA(FIRMNESS TO THE RAGA)
RA	FEAR,SYMPATHY,SORROW
RI	JOY,SYMPATHY LTTLESJRPRISE,LOVE
RU	SURPRISE_LITTLE JOY
GA	FEAR
GI	SYMPATHY. LITTLE JOY
GU	HAPPY,SURFRISE
MA	JOY,LITTLE FEAR
MI	SUBTLE JOY,SOOTHINGNESS
PA	NO EMOTION(FIRMNESSTO THE RAGA)
DHA	FEAR,SYMPATHY
DHI	JOY,SYMPATHY LTTLESJRPRISE,LOVE
DHU	SURPRISE_LITTLE JOY,LITTLE LOVE
NA	FEAR
NI	SYMPATHY. SUET_E JOY SORROW,LOVE_ITTLE SUBMISSION
NU	JOY,LOVE,SURPRISE

Figure 2 Emotions of Swaras

STEP 3: The 8 basic emotions suggested by Plutchik were taken. For each emotion the swaras are classified into 3 groups (yes, no and partial) and in each group swaras are arranged in increasing/ decreasing PJ depending on whether the emotion is positive/negative. Then numbers were arbitrarily allotted such that they represent the magnitude of an emotion in a swara. These were normalized to give probabilities. Using these values a 16x8 matrix was formed, where the 16 rows denote the 16 swaras, and 8 columns denote 8 basic emotions namely joy, fear, surprise, trust, sorrow, anger, anticipation and disgust. This is the matrix p(y/x) and is as shown.

SWARA	JOY	FEAR	SURPRISE	TRUST	SORROW	ANGER	ANTICI	DISGUST
SA	0.25	0	0.25	0.25	0	0.25	0	0
RA	0.053575	0.196425	0.10715	0.25	0.196425	0.053575	0.14285	0
RI	0.214275	0.089275	0.1607	0.193361	0.035725	0.160725	0.0893	0.05664
RU	0.125	0.1607	0.214275	0	0.125	0.0893	0.035725	0.25
GA	0.071425	0.214275	0.125	0.046657	0.178575	0.035725	0.125	0.203425
GI	0.14285	0.14285	0.071425	0.186682	0.10715	0.10715	0.178575	0.06325
GU	0.23215	0.10715	0.25	0.03975	0.01785	0.14285	0	0.210336
MA	0.25	0.178575	0.178575	0.09125	0	0.071425	0.071425	0.158755
MI	0.1607	0.125	0.089275	0.0635	0.0893	0.125	0.160725	0.186513
PA	0.25	0	0.25	0.25	0	0.25	0	0
DHA	0.01785	0.23215	0.01785	0.223337	0.23215	0.01785	0.23215	0.026675
DHI	0.196425	0.01785	0.14285	0.183364	0.053575	0.23215	0.10715	0.06675
DHU	0.089275	0.071425	0.196425	0	0.160725	0.178575	0.053575	0.25
NA	0.035725	0.25	0.035725	0.075375	0.214275	0	0.214275	0.17464
NI	0.10715	0.053575	0.053575	0.186682	0.14285	0.196425	0.196425	0.063325
NU	0.178575	0.035725	0.23215	0.0516	0.071425	0.214275	0.01785	0.198419

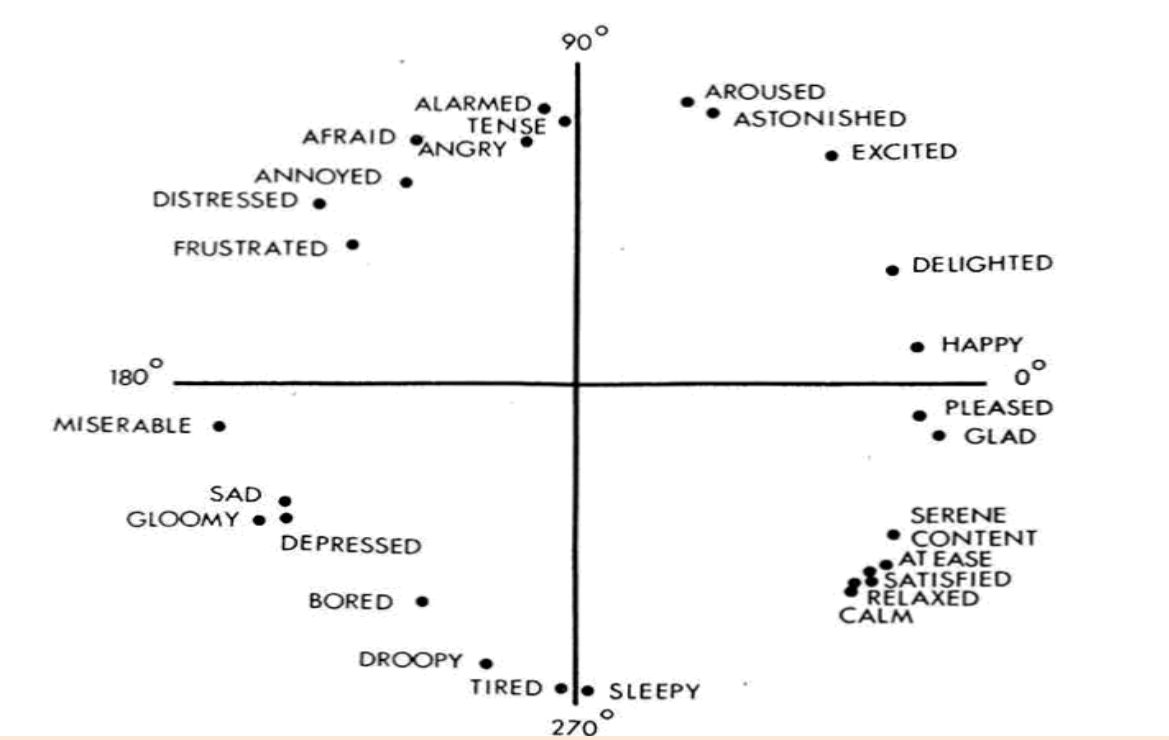
Figure 3 Matrix P(Y/X)

Thus using the relations mentioned above the matrix p(y) is calculated. This matrix is different for each raga as each raga has a different p(x). This matrix gives emotions of a raga. Such a result obtained for raga mohanam (CDEGA on the piano) is:

JOY	FEAR	SURPRISE	TRUST	SORROW	ANGER	ANTICIPATION	DISGUST	OPTIMISM	DISAPPOINTMENT
0.229	0.043	0.21	0.183	0.02	0.207	0.04	0.0667	0.1345	0.11
LOVE	REMORSE	SUBMISSION	CONTEMPT	AWE	AGGRESSIVENESS	SYMPATHY	HUMOUR	HEROISM	
0.206	0.0438	0.113	0.1337	0.1265	0.1235	0.113	0.2195	0.182	

Figure 4 Emotion values of Mohanam Raga

As depicted by Russell's Circumplex model, each emotion has a particular valence-arousal, determined as X and Y coordinates of a Cartesian coordinate system. The Russell's model is shown below:



Hence we get the valence-arousal for any music using the emotion values P(Y), and the emotion valence-arousal values. This is then plotted by treating valence and arousal as X and Y coordinates of a Cartesian coordinate system and thus the final Emotion map of music is thus created.

SUPPORTING BIOLOGICAL EVIDENCE:

a. The way Music is processed in the auditory system is similar to decomposing any given tone into its frequency components..etc .. where different frequencies emerging from a music tune is captured by the hair cells of our Cochlea of the inner ear.

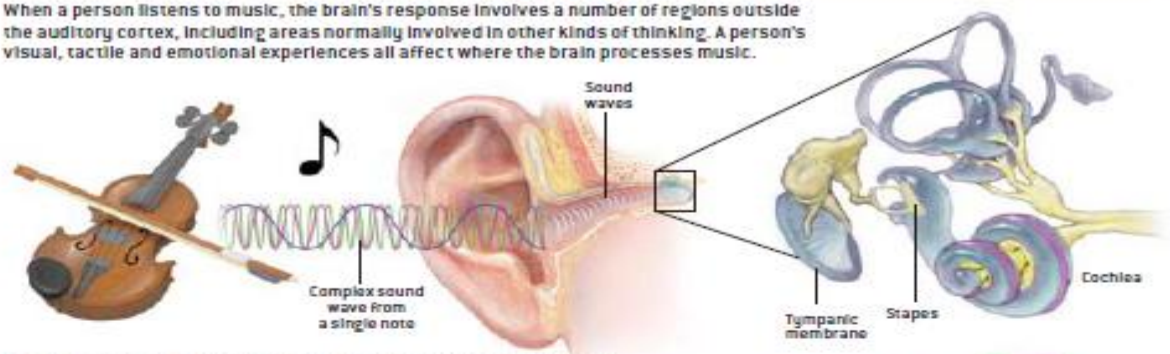
b. The brain consists of separate domains for processing the auditory processing of melodies and emotional perception and it is sometimes independent of the auditory domain thus giving a 'direct' kind of impact unlike the emotions evoked by other arts such as painting, or speech.

c. Music is universal: even animals perceive it. Is equally effective across the cultural borders in humans.

The schematic as given in the article in Scienific American, Nov.2004 is shown below. This describes the flow by which the human auditory and neural system perceives and processes music.

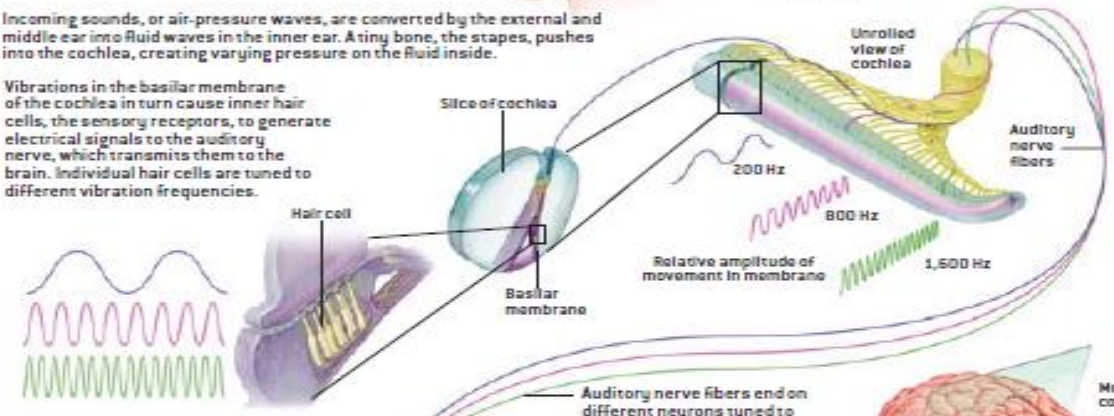
SINGING IN THE BRAIN

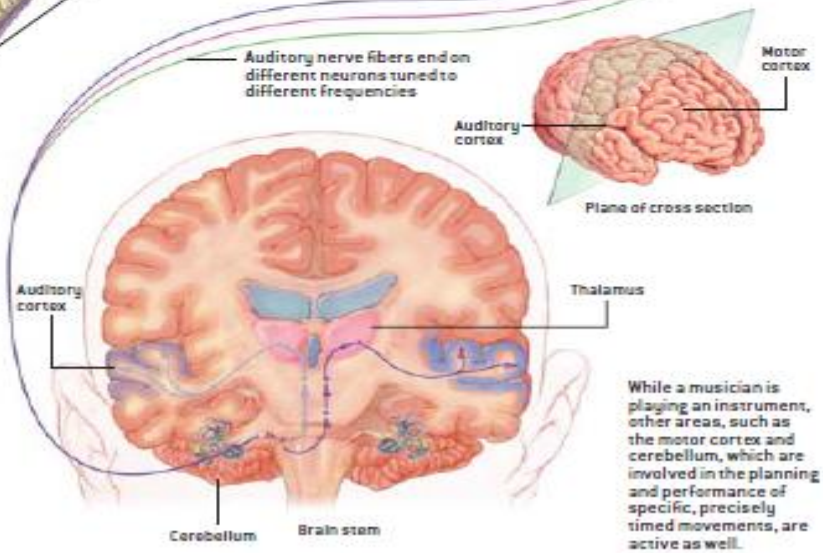
When a person listens to music, the brain's response involves a number of regions outside the auditory cortex, including areas normally involved in other kinds of thinking. A person's visual, tactile and emotional experiences all affect where the brain processes music.



Incoming sounds, or air-pressure waves, are converted by the external and middle ear into fluid waves in the inner ear. A tiny bone, the stapes, pushes into the cochlea, creating varying pressure on the fluid inside.

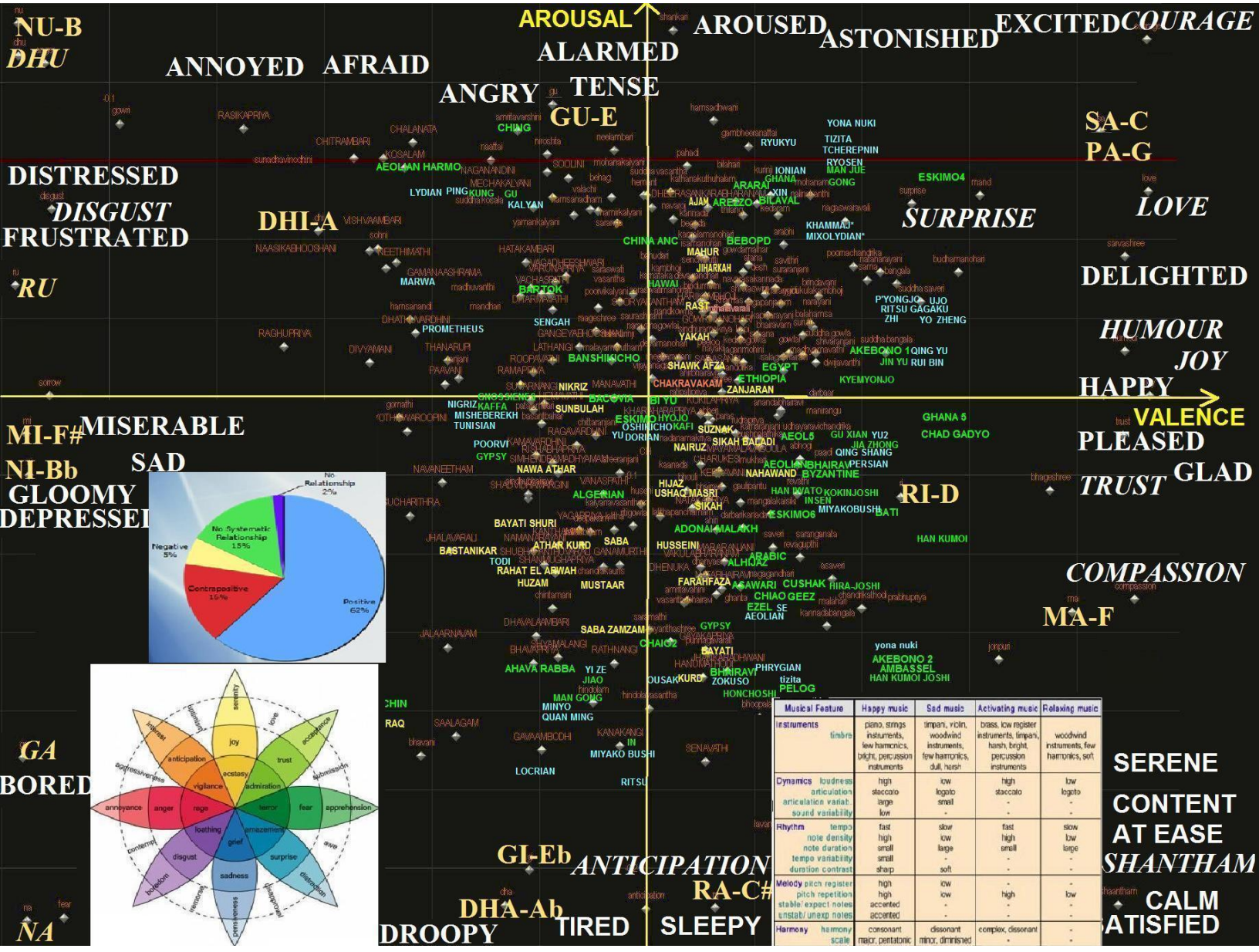
Vibrations in the basilar membrane of the cochlea in turn cause inner hair cells, the sensory receptors, to generate electrical signals to the auditory nerve, which transmits them to the brain. Individual hair cells are tuned to different vibration frequencies.





The brain processes music both hierarchically and in a distributed manner. Within the overall auditory cortex, the primary auditory cortex, which receives inputs from the ear and lower auditory system via the thalamus, is involved in early stages of music perception, such as pitch (a tone's frequency) and contour (the pattern of changes in pitch), which is the basis for melody. The primary auditory cortex is "retuned" by experience so that more cells become maximally responsive to important sounds and musical tones. This learning-induced retuning affects further cortical processing in areas such as secondary auditory cortical fields and related so-called auditory association regions, which are thought to process more complex music patterns of harmony, melody and rhythm.

While a musician is playing an instrument, other areas, such as the motor cortex and cerebellum, which are involved in the planning and performance of specific, precisely timed movements, are active as well.


AROUSAL
VALENCE
NU-B
DHU
ANNOYED
AFRAID
ALARMED
AROUSED
ASTONISHED
EXCITED
COURAGE
ANGRY
TENSE
GU-E
SA-C
PA-G
DISTRESSED
DISGUST
FRUSTRATED
DHI-A
SURPRISE
LOVE
RU
DELIGHTED
HUMOUR
JOY
HAPPY
MI-F#
MISERABLE
SAD
NI-Bb
GLOOMY
DEPRESSED
PLEASED
GLAD
TRUST
RI-D
COMPASSION
MA-F
GA
BORED
SERENE
CONTENT
AT EASE
SHANTHAM
CALM
SATISFIED
GI-Eb
ANTICIPATION
RA-C#
DHA-Ab
DROOPY
TIRED
SLEEPY
NA
No Relationship 2%
No Systematic Relationship 15%
Negative 5%
Contrapositive 15%
Positive 62%
anticipation
joy
trust
surprise
sadness
disgust
fear
anger
annoyance
boredom
pensiveness
distraction
Musical Feature
Happy music
Sad music
Activating music
Relaxing music
Instruments
timbre
piano, strings instruments, few harmonics, bright, percussion instruments
timpani, violin, woodwind instruments, few harmonics, dull, harsh
brass, low register instruments, timpani, harsh, bright, percussion instruments
woodwind instruments, few harmonics, soft
Dynamics
loudness
articulation
articulation variab.
sound variability
high
staccato
large
low
low
legato
small
-
high
staccato
-
-
low
legato
-
-
Rhythm
tempo
note density
note duration
tempo variability
duration contrast
fast
high
small
small
sharp
slow
low
large
-
soft
fast
high
small
-
-
slow
low
large
-
-
Melody
pitch register
pitch repetition
stable/ expect notes
unstab/ unexp notes
high
high
accented
accented
low
low
-
-
high
-
-
low
-
-
Harmony
harmony
scale
consonant
major, pentatonic
dissonant
minor, diminished
complex, dissonant
-
-