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Revisiting Music Perception through Hindustani Classical Music: A Neuroscientific Review with Cross-Cultural Comparisons

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Abstract: ***Hindustani Classical Music (HCM), a culturally rich and historically rooted tradition from North India, remains underrepresented in neuromusicological studies, which primarily focus on Western musical paradigms. This review aims to bridge this cultural gap by synthesizing existing empirical research on HCM and evaluating its implications for music perception, emotional response, and predictive modeling in the brain. The paper contrasts how trained and untrained listeners process tonality and emotion in HCM versus Western music, while also exploring the therapeutic potential of HCM in mental health and neurological conditions. By highlighting the limitations of existing models and advocating for culturally inclusive frameworks, this study encourages broader integration of diverse musical traditions into neuroscience and music therapy.***

Keywords: Hindustani Classical Music, Music Perception, Neuroscience, Predictive Model, Music Therapy

1. Introduction

Hindustani Classical Music (HCM) is a renowned art form sustained by generations of artistry and cultural traditions dating back to the 12th Century CE. It originates from North India and is one of India's two a predominant forms of music, the other being Carnatic music. It is based on 12 notes, ranging from pure to slightly below or above the pure frequency. However, the notes utilized directly parallel Solfege (Figure 1).

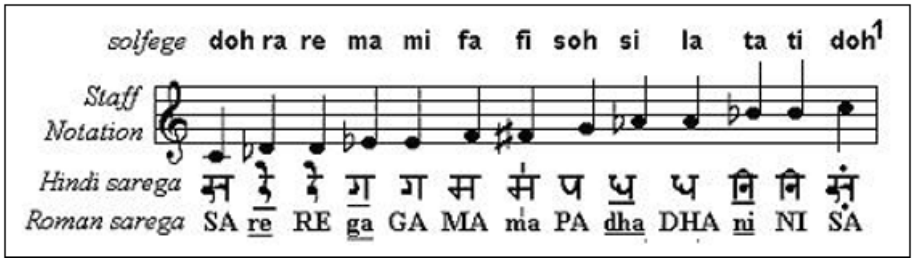

Figure 1.1: This image explains the similarities between Hindustani classical and Western music scales. It compares staff notation and the Solfege with Saragam and Sanskrit notation of HCM.

HCM expresses a theme as khyal, which translates to thoughts. These are compositions and improvisations in a melodic framework, characterized by using specific notes from the pentatonic scale in any order. These frameworks, known as ragas, are primarily instrumental, featuring indigenous instruments like the sitar and tabla. However, vocal renditions also narrate folk tales and hymns. The basis of HCM ragas is the pentatonic scale, which is also commonly found in Western Classical Music. However, the scale of an octave can range from 5-7 notes. For instance, Raag Bhoopali has a pentatonic scale, meaning it only has five notes between the octaves. Still, Raag Malkauns has seven notes between the octave and is called *sampoorna,* meaning “complete.”

The study of music perception aims to understand the underlying neural mechanisms that support a listener’s experience. To date, most music perceptual understanding has been established by studying Western classical music, enabling the generation of concepts such as the Predictive Model. The Predictive Model is the theory of how the brain understands and anticipates music, using the syntax or general rules of music, the perception of rhythm, pitch and dynamics, the emotional response elicited, the level of understanding and the listener's cultural background. This information goes through a Bayesian Inference, which updates our predictions based on new information collected to come up with an expectation for how the music will continue. Concurrently, when predictions are violated, surprise or tension can be elicited in the listener. The Predictive model has been formulated and tested solely on Western classical music. Still, as cultural influence and training are critical factors in determining a prediction, testing must be based on different music cultures. These models lack diversity due to cultural differences in music genres, which makes them less reliable. Additionally, there is a contradiction between the universal relationship between music and emotion compared to various music cultures. Hence, it is imperative to investigate various music cultures through these models to determine their applicability and formulate a ubiquitous understanding of music perception.

One of the many differences to investigate between Western Music and Hindustani Classical is accidental notes. Accidentals are notes either above or below the main or pure frequency. There are three types of notes in Hindustani Classical: shuddha, meaning pure; komal, which are notes slightly below the frequency of shudda notes; and teevra, slightly above the frequency of shuddha notes. The accidentals are similar in Western classical music, where notes above the pure frequency are referred to as sharp and below are flat. However, these notes are in larger numbers than the Hindustani Classical Scale. This is due to the instrumental capabilities in Western classical music, such as string instruments playing sub-semitone frequencies. Moreover, the emotional connotations of certain notes differ in music culture; for instance, lower frequency notes are perceived as sad in Western classical music, but in HCM, they are open to wider interpretation.

The points above indicate that there needs to be a more holistic approach to research into music perception, exploring other music cultures. Hence, this review aims to analyse the current empirical data on music perception in the Hindustani Classical Genre through the lens of music emotion, predictive modelling, tonality perception and applications to music therapy. This work is significant as it challenges the prevailing Western-centric models of music cognition and emphasizes the necessity of including non-Western traditions like HCM for a more comprehensive understanding of neuromusicology

2. Music Emotion and Perception In Hindustani Classical Music and Western Genre

Music is considered a universal language that can transcend cultures, languages and borders, with an unmatched ability to elicit deep human emotions. (Omar et al., 2011) Whether based on lyrics, rhythm or pitch, the relationship between music and emotion has been a topic of many studies and investigations. However, they are commonly based on the Western genre and the emotions that it can elicit. This can cause a more reductive understanding of music perception, which is non-inclusive of the variation in interpretations of music emotion. (Vuust et al.)

According to multiple studies based on Western music perception, cortical responses to auditory stimulation characterise music emotion. (Limb, 2006b) Upon stimulation, the auditory system transduces inputs to pass them to higher processing regions, such as the pre-frontal cortex, to be integrated into coordinated responses. For instance, the language used in music is assessed in the left hemisphere (Lepping et al., 2019), while the actual sounds are processed in the right. Other regions involved include the nucleus accumbens (reward system), the hippocampus (learning and memory), the hypothalamus (autonomic system) and the amygdala, which regulates arousal. Research via fMRI has identified the processing pathway by tracking an increase in cerebral blood flow from the ventral medial prefrontal cortex (VMPFC) to the orbitofrontal cortex, medial prefrontal cortex, amygdala and ventral striatum. (Limb, 2006b)

Moreover, Blood and Zatore have shown that the hippocampus and inferior frontal gyrus are instrumental in receiving information about musical structures or memories. Interestingly, the physiological reaction of the auditory cortex changes with the type of music listened to. (Blood and Zatore) Instead of processing the difference between sad, happy or angry music, the brain views it in a binary method, of pleasant and unpleasant music to the listener. Pleasant music triggers a significant activation in the ventral striatum and anterior insula, relative to unpleasant music, where the amygdala, hippocampus and temporal poles are more active. This indicates that pleasant music allows for greater empathy, whereas unpleasant music enables the listener to associate the music with, perhaps, an unpleasant memory. (Droit-Volet et al., 2013) (Song et al., 2016) It can also be postulated that sadder music has been shown to enhance autobiographical memory recall, as demonstrated by Melían Garcia: Alzheimer's patients can remember episodic memories while listening to more emotional music. (Garcia) Haj and Allain have also found similar evidence, where Alzheimer's patients' autobiographical memory recall was significantly better when emotional music was played than silence. This indicates a strong connection between music and memory. (Haj)

Several empirical studies have been conducted on the perception of emotion while listening to Western classical music. The general notion in this genre is that minor or diminished chords, with a slow tempo, indicate sad or more emotionally moving music. In contrast, uptempo and major chords indicate happy music, eliciting physical movement to accompany it. In a physiological sense, however, happy music generates greater arousal, making the mind more alert and attentive to the input. In contrast, sadder music causes less arousal, strengthening the potential for mind-wandering. (Liila Taruffi et al., 2017) This arousal activates the dopaminergic pathways, allowing the listener to engage with the theme further. Kallehin also found that emotional ratings between styles of Western classical music were identified primarily as joy and sadness and that the listener's background had no correlation to their rating. (Kallinen, 2016) This notion has been replicated by several other groups (Xi Wang). Confirming that binary emotions of Happy and sad were the principal emotional ratings in Western classical music.

Conversely, in HCM, Bhatkhande, a school of Hindustani Classical Music, dictates that the primary emotions of a raga include sadness, romance, peace, strength/courage, anger, dispassion, and devotion. These emotions are known as *rasas; each* raga elicits one or more forms. Junmoni has shown that *ragas* have allowed even lay listeners to identify subdominant emotions, such as calm and peace, with slightly different tonality. This change has been verified by Sanyal and the team, who have shown that altering the structure of a raga by one note can completely change the dominant and subdominant emotions perceived. (Hegde et al., 2012) This neural shift has been corroborated by EEG studies (Basu et al., 2023; Sanyal et al., 2020), indicating a clear emotional transition in brain activity. By changing one note in a characteristically sad raga, the frontal and prefrontal lobes lit up, signalling a change in the analysis of the perceived emotion from sad to happy. The verbal responses also

correlate with this change, as they verbalised that the emotion has changed at the point of alteration. Here, subjects identified subdominant emotions such as romance and peace, indicating that they can analyse them accurately, with no prior musical experience. However, it must be mentioned that they are asked to identify subdominant emotions and choose a category. Hence, this analysis is done on command but not identified while listening to the music.

Overall, the above studies show that the analysis of Western genre music emotion is based on binary feelings of happiness and sadness. In contrast, HCM demonstrates a more complex music emotion profile. This suggests a deeper connection between the pitch structure in HCM compared to Western music. Though both styles have a similar usage of accidental notes and utilise the same scale, Hindustani Classical has a more pronounced relationship with pitch structure and emotion, allowing lay listeners to distinguish subdominant themes within the music. One potential hypothesis for this finding is that this comes down to the basis of Hindustani Classical Music, which works in a *raga* framework, where different arrangements of notes dictate the emotion/feel. The repetition of the notes allows the mind to identify better and analyse the music's themes, emphasised in a concept known as *pakad*, which is the repetition of the most common phrase of notes in a *raga*. It is important to note that since the evidence collected analysed instrumental music only. (Valla et al., 2017) Therefore, the emotional responses of language-based melodies in either Western or Hindustani genres are yet to be established; however, one must look at Hindustani Classical music through the predictive model to generate a comparable understanding of the cognitive processing of this genre.

3. Applications to Music Therapy

When exploring the perception of music in the brain, an important concept to discuss is the use of music as a therapeutic option in neurological diseases and disorders - music therapy. As several studies have proven, music can regulate the autonomic system. Specifically, music can alter skin conductance, blood pressure, heart rate and respiration patterns. This allows the patient to activate similar reward pathways accessed by standard medication without damaging effects on the body. Music therapy also promotes neural plasticity, which is the brain's increased tolerance towards neural damage in the future and the ability to adapt to it.

In Western music genre experiments, it has been discovered that high physiological arousal music can increase blood pressure, respiration, heart rate, skin conductance and the sympathetic system. However, low-arousal music can decrease these factors and activate the parasympathetic system. Multiple studies, including Ledger and Baker's, have shown that through one year of music therapy, a group of Alzheimer patients have reduced their levels of agitation as compared to the controls. Another study has shown that patients with mild-severe Alzheimer's have reduced anxiety levels and fewer incidents of agitation after undergoing music therapy. This suggests a correlation between the emotional regulation pathway and the auditory cortex.

However, these are the results of music therapy being conducted with solely Western-based music. Still, given the significantly more vital relationship between pitch structure and emotions, as established previously, there could be more applications for Hindustani Classical Music in music therapy.

On the other hand, the ethnography of HCM suggests that listening to certain ragas can promote a better lifestyle and improved mental health. It is vital to note that the correlation between the auditory cortex and autonomic nervous system activity has been proved in Hindustani Classical Music. According to a study, listening to *raga* Des-Todi for 30 minutes daily for 20 days can decrease blood pressure and reduce stress, anxiety and depression. According to old Hindu scriptures, *raga* Darbari can help with depression, and raga Bageshri can help with insomnia. It is posited that performing the raga during its traditionally designated time, a feature of any raga, will express the peak of its melodic beauty and therapeutic ability. According to a study, the biggest difference in Indian Music Therapy, compared to the Western Genre, is the variety of ragas that allow for a deeper connection between the listener and the piece. (Sharma, 2019) Since the majority of music therapy is to be able to relate music to an event in life, it brings out the profound cultural and religious influences in a person's life, making it highly individualised. This has been explored by identifying the correlation between episodic memory recall and music. Playing excerpts of music, especially sad music, allowed Alzheimer's patients to recall remote memories due to the emotion conveyed by the piece.

Moreover, it also allows for gentle stimulation and increases attention span. This concept of Indian music therapy exists in Ayurveda, an ancient medical science based on spirituality and homoeopathy. Known as "raag chikitsa", Indian music therapy focuses on the cultural background, deep heritage, and the strong correlation between pitch structure and emotion to improve a patient's condition. (Hegde, 2017) This ability has been derived from ancient studies of human behaviour conducted by musicians, who used their understanding to form vibrations to control and regulate physiological changes. (Moreno, 1988)

Another study has shown that Indian music therapy is comparable to alternative medication. Fifty individuals were diagnosed with Major depressive disorder that caused trouble sleeping. Half of the patients were given selected *ragas* as music therapy, whereas the other half were treated with hypnotic medication. While both groups improved in their symptoms of depression and sleep quality, the effects of music therapy persisted beyond the treatment period and were comparable with hypnotic medication. (*Effect of Indian Classical Music on Quality of Sleep in Depressed Patients: A Randomized Controlled Trial*, 2023) To further this investigation, a study could be investigated comparing two styles of music therapy, but this study alone displays the pronounced effect of using HCM therapy to alter brain function. (*Music Therapy and Data Mining Using Indian Ragas as a Supplementary Medicine*, 2015)

HCM therapy has an untapped potential that should be explored further, given its cultural differences and current

empirical evidence proving its effectiveness in altering brain function. It would be advisable to investigate HCM therapy and compare it with the effects of the Western genre in the future to understand the applications of different genres of music.

4. Connections to the Predictive Model

The predictive model is a theory that illustrates how the brain anticipates music and enjoys it through pattern encoding and violations. It explicitly uses Bayesian Inference, which takes the information from the auditory cortex and verifies the prediction using cultural context, musical competence, brain state, attentional and emotional state, and individual traits and biological factors. The interference runs a top-down prediction about the sensory input and repeats it to minimize errors and improve the anticipation. This process is applied to melody, harmony and rhythm, the three pillars of music perception. Within the PCM model, there is a rhythmic connection between the ability to correct a prediction error. For instance, when a prediction error is detected, the brain will send an impulse to restore the prediction by prompting a rhythmic movement like tapping your foot to fit the accurate melody or accentuate the error. This adjusts the way the brain interprets the music. The same has only been tested in the Western genre of music, providing a limitation addressed in the model itself. This reduces the generalisability of the results. For instance, native Amazonian individuals with finite exposure to Western music did not exhibit a preference for consonant versus dissonant intervals, which demonstrates a preference for intervals being culturally dependent. Additionally, the statistical regularities or musical syntax which underline predictive processes about harmony are different between cultures and genres of music. (Vuust et al.)

Concerning HCM, there have yet to be empirical studies or records of applying the predictive model to this genre of music, although it would greatly benefit and widen the scope of research in this field. The model must be used with a study comparing EEG, EMG, and fMRI reports to understand which brain regions are activated and correlate them with findings from the Western learning model. Because harmonic cadences vary between the Western genre and the Hindustani genre, the idea of dissonance and consonance will change. Another study demonstrated that untrained listeners could identify emotional tone and tonality in music with notable accuracy, as supported by chi-square analysis, which indicates that the Bayesian inference hypothesis can be applied to HCM. (Junmoni Borgohain et al.) Given that untrained listeners often form musical predictions grounded in cultural familiarity, similar findings in HCM suggest the applicability of the predictive model For a more substantial understanding, it is necessary to investigate both forms under this model.

Tonality Perception in Trained and Untrained Listeners.

Tonality perception is the ability to differentiate between notes and process them in relation to music emotion and language. This is achieved through the perception of the auditory cortex, using musical syntax to understand the note. (*Describing the Perception of Tonality in Music: A Critique of the Tonal Hierarchy Theory and a Proposal for a Theory of Intervallic Rivalry on JSTOR*, 2023) (Lei et al., 2023) As described above, music perception is formed in the auditory cortex, and the differentiation of notes is achieved by applying rules from the hippocampus and prefrontal cortex. Tonality perception is a concept formed through cultural understanding and can vary with the genre of music, given its specific rules and constructs. (Chen et al., 2020)

In Western classical music, notes can be identified by lay listeners and trained musicians, although the scope of trained musicians is enormous. In the case of Western tonal music, the musical expectations are formed by rhythmic structure, tonal and harmonic structure and melodic structure. (Stevens, 2012) However, this model is reductive because it doesn't include the variety of music syntax in other musical cultures. In the case of HCM, a study showed that lay listeners of both Western and HCM genres use the same features to identify a type of *raga*. This indicates that they use the previously established pathways in the auditory cortex. However, the trained HCM musicians used features such as rules, notes, tetrachords, alankaras, and phrases to identify the *ragas*. (Lele & Abhyankar, 2019) These additional rules result from the cultural context of a musician coming into their analysis, which suggests a more pronounced use of the prefrontal cortex. This also indicates using the occipital lobe to visualise the notation, a feature found in musicians from both genres, as notation is a common form of understanding music. This formal training and learning has led to heightened perception and analysis skills, improving other aspects of daily life. It is also vital to note that these features do not fit within the theorised deeper features of Western genre musical analysis, indicating a difference in perception. (Lele & Abhyankar, 2019) Any EEG or fMRI reports haven't confirmed this, but is worth investigating given the heightened cognition and complexity of the trained musician's analysis.

5. Future Research and Conclusion

Based on the above discussion, Hindustani Classical Music requires further research into perception and tonality, as the existing data is limited but shows scope of more significant application. It has been identified that music emotion is more apparent in HCM as compared to the Western genre; however, given the method of the research, which was multiple choice, it would be advisable to repeat the experiment but in direct comparison to the Western genre. It has also been noted that there needs to be further research into the predictive model regarding HCM, as it is solely based on the surface-level features employed by the Western genre, such as melodic, harmonic and rhythmic structure. It should also be cross-referenced with EEG or fMRI reports to confirm and explore the neural pathway when listening to HCM. This will provide reliable results and allow researchers to account for more inclusive learning models. There should also be more research in the field of trained and untrained musicians, as the above study has noted a more profound use of rules that do not fit with the Western Genre and likely indicate a different or deeper pathway for the same. Finally, there should be further emphasis on using

HCM as a mode of music therapy, given its capabilities as compared to alternative medication, and the study should be repeated in comparison to the Western genre of music. Hindustani Classical Music offers unique cognitive and emotional pathways in music perception, yet remains understudied within current neuroscientific frameworks. This review highlights its potential in predictive modeling and therapeutic contexts, calling for broader, culturally inclusive empirical studies to validate and extend existing neurocognitive theories.

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