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Why Certain Music Feels More Resonant: A Frequency-Based Study of Shrutis, Natural Tuning, and The Psychoacoustic Appeal of Music - With Observations From High School Classrooms

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Abstract

This study investigates why certain music feels naturally "resonant" through a frequency-based and psychoacoustic analysis of Shrutis, natural tuning, and equal temperament (ET). The ancient Indian 22 Shruti system, rigorously clarified by Dr. Vidyadhar Oke, extends beyond just intonation, providing a uniquely Indian framework for microtonality that enriches scientific understanding, musical practice, and listening sensitivity. Grade X students participated in six classroom sessions using ET and Shruti-tuned keyboards, tone generators, and waveform analysis. Digital tools were used to visualize frequency plots and time domain waveforms. Guitar slide demonstrations highlighted continuous frequency transitions, while listening comparisons consistently showed preference for Shruti-based chords as smoother and more resonant. Waveform studies and vibrational experiments with iron filings confirmed the acoustic stability of Shruti-based tuning. Pre- and post-questionnaires revealed significant insights in students' understanding of harmonics, resonance, and frequency, alongside a clear preference for Shruti-based intonation. These findings resonate with contemporary global explorations. This interdisciplinary approach bridges centuries-old Indian theory with contemporary scientific validation, offering a replicable model for global music perception studies, with tangible educational and emotional impact on learners.

Keywords: Shrutis; Natural Tuning; Equal Temperament; Psychoacoustics; Music Education

Research Paper

Introduction

Music is a universal human experience, yet some melodies and harmonies are perceived as inherently more pleasant and resonant than others. Understanding this phenomenon requires exploring both the historical development of musical systems and the psychoacoustic principles underlying human perception. Early humans used vocalizations to mimic natural sounds and express emotions, gradually developing simple instruments such as bone flutes over 40, 000 years ago.[1] These vocal and instrumental sounds were intuitively tuned to frequencies that the human ear perceived as consonant, laying the foundation for natural tuning systems.[2]

Natural tuning systems evolved independently across cultures, each developing unique approaches to pitch, intervals, and microtonal distinctions. In Indian music, this resulted in the 22 Shruti system, which allowed fine gradations of melody and expressive nuance. Ancient theorists and musicians refined this system over centuries, and modern analysis by Dr. Vidyadhar Oke demonstrates that Shrutis correspond to precise, naturally occurring frequencies aligned with the harmonic series.[3]

As music became more complex and global interactions increased, the need for a standardized system arose. The Western twelve-tone equal temperament (ET) system was developed to allow modulation across keys and make performance and global dissemination of music more practical. While ET offers flexibility, it slightly diverges from the pure harmonic ratios of natural tuning, contrasting with the consonance preserved in microtonal systems like Shrutis. [4-5]

This study employs a frequency-based analysis alongside a psychoacoustic survey in high school classrooms to investigate perceptual preferences. Students engaged with Shruti-based, natural, and ET-based tuning systems through listening experiments, tone generators, and waveform visualization. This approach examines why certain intervals and scales feel inherently more resonant and provides learners with tools to understand the scientific and psychoacoustic foundations of musical preference.

Research Question

Although Shruti-based and other natural tuning systems are historically and acoustically aligned with consonant harmonic ratios [2][3][5], it remains unclear whether modern students without formal music training perceive these tunings as more aesthetically or psychologically appealing than the Western twelve-tone equal temperament (ET) music [4]. This study seeks to investigate:

1. **Perceptual Appeal:** Do students uninitiated in formal music training find Shruti-based and natural tuning systems inherently more resonant and pleasing compared to ET-based intervals?
2. **Psychoacoustic Basis:** Which acoustic or harmonic features contribute to the perceived appeal of Shruti-based and natural tuning relative to ET-based music?
3. **Conceptual Understanding:** If students perceive certain music as inherently pleasant or resonant, do they understand why it feels that way, when explained scientifically through frequency analysis and psychoacoustic principles?

By addressing these questions, the study links traditional Indian music theory, natural tuning systems, and contemporary classroom experiences to explore the psychoacoustic foundations of musical preference, while also evaluating the effectiveness of scientific explanations in enhancing students' conceptual understanding.

Aims and Objectives

The primary aim of this study is to investigate why certain music is perceived as inherently more resonant, focusing on Shruti-based, natural tuning, and Western twelve-tone equal temperament (ET) systems, and to understand the psychoacoustic and scientific basis for these perceptions in students without formal music training [3][5].

Specific objectives include:

1. To examine whether students perceive Shruti-based and natural tuning systems as more aesthetically and psychologically appealing than ET-based music.
2. To identify the acoustic and psychoacoustic factors that contribute to the perceived appeal of different tuning systems.
3. To enable students to understand why certain music feels resonant, using scientific explanations through frequency-based analysis, waveform visualization, and guided listening.
4. To introduce students to the scientific and mathematical aspects of music, including harmonic ratios, frequency perception, and resonance.
5. To expose students to global music examples, including blues, rock, R&B, and Indian Classical music, illustrating natural tuning, microtonality, and expressive pitch variation.
6. To promote a global and interdisciplinary perspective on tuning systems, integrating music theory, psychoacoustics, and creative expression.
7. To explore how insights from Shruti and natural tuning can inform interdisciplinary pedagogy, linking music, science, and mathematics in classroom learning.

By addressing these objectives, the study connects historical musical theory, natural tuning practices, and contemporary classroom experiments to enhance both perceptual appreciation and conceptual understanding of music in students.

Presumptions and Hypotheses

Based on historical, acoustic, and psychoacoustic evidence [2][3][5], this study is premised on the following presumptions:

1. Modern students without formal music training are capable of perceiving differences between Shruti-based, natural tuning, and equal-tempered (ET) music.
2. Shruti-based and natural tuning systems will be perceived as more aesthetically and psychologically appealing than ET-based music, due to their alignment with consonant harmonic ratios [5].
3. The underlying reason for this preference is the frequency ratios between Shrutis and naturally

tuned intervals, which resonate more closely with the human auditory system [3][5].

4. Students will be able to scientifically understand the differences between natural tuning and ET-based music, appreciate the psychoacoustic appeal, and experience distinct emotional responses when listening to different tuning systems [5].

Student responses and observations will be measured using a 5-point Likert scale, capturing perceptual preference, aesthetic appeal, conceptual understanding, and emotional response.

Relevance

This study is highly relevant because it bridges the gap between traditional musical knowledge and contemporary music education. While the 22 Shruti system and natural tuning have been shown to align with inherently consonant and psychoacoustically pleasing frequencies [3][5], most school curricula still rely primarily on the Western twelve-tone equal-tempered (ET) scale. Consequently, students are often unaware of microtonal systems, natural tuning, and the subtle scientific principles underlying musical resonance.

By introducing students to Shruti-based and natural tuning systems, alongside ET-based music, the study provides a platform for learners to perceive differences, understand the scientific basis, and recognize the aesthetic and emotional appeal of different tuning systems [2][5]. It demonstrates how acoustic principles, harmonic ratios, and psychoacoustic features influence musical perception, directly addressing the research questions and testing the hypotheses.

Furthermore, this approach has broader pedagogical significance: it promotes interdisciplinary learning, integrating music, science, mathematics, and psychoacoustics in classroom practice. By providing students with hands-on listening experiences, waveform analysis, and exposure to global music examples (blues, rock, R&B, and Indian Classical music), the study encourages conceptual understanding, perceptual sensitivity, and emotional engagement with music. In doing so, it helps cultivate a generation of learners who appreciate music not only artistically but also scientifically, laying the foundation for deeper exploration of both traditional and modern musical systems.

Methods, Materials and Tools Used

The study combined practical demonstrations with digital analysis to explore tonal and perceptual differences between Shruti-based tuning and the Equal Temperament (ET) scale.

Methods

1. Conducted comparative aural analysis of just intonation and ET tuning.
2. Recorded and visualized sound frequencies for waveform interpretation.
3. Collected psychoacoustic data through pre- and post-session questionnaires.
4. Used listening-based observation with examples from Indian Classical ragas, R&B, and Western music.
5. Demonstrated microtonal transitions through:

a. Videos of electric guitar bends in English classics.

b. Live use of guitar slides to illustrate frequencies between two frets, highlighting transitions beyond the equal-tempered scale.

Materials and Tools

1. Microsoft Office (Word, Excel): Documentation and questionnaire analysis.
2. Audacity: Recording, sound analysis, and comparison of Shruti vs. ET tuning.
3. Spectroid (Android app): Real-time spectral visualization.
4. Online Tone Generator: Generation of pure tones for tuning comparison - onlinetonegenerator.com.
5. Sound Analyzer (Compadre OSP): Waveform observation and frequency study https://www.compadre.org/osp/pwa/soundanalyzer/.
6. Shruti- and ET-tuned keyboards: For comparative listening exercises.
7. Guitar and guitar slides: For practical microtonal demonstrations of intermediate frequencies between frets.
8. Google Forms: Collection and analysis of psychoacoustic responses.
9. Reference videos and resources: YouTube waveform tutorials, Jacob Collier's Just Intonation explanation, electric guitar bend examples from English classics, and microtonal analysis content.

Background Study

1. The authors explored Shruti-based (microtonal) frequencies and their musical relevance through extensive review of online literature and multimedia resources.

2. Various research articles, academic papers, and countless explanatory videos were referred to and are listed in the references section.
3. Detailed study was undertaken on stable waveform patterns to compare Shruti-based natural tuning with the Western twelve-tone equal-tempered (ET) system.
4. Drawing from these resources, personal listening experiences, and firsthand observation of frequency "beats, " the authors designed a pilot study with music-science interdisciplinary sessions involving Grade X students to examine perceptual differences.
5. The background work involved in-depth discussions on frequency ratios, harmonic relationships, and their correlation with musical consonance.
6. The author and co-author conducted a vibrational experiment by placing a speaker beneath a floor tom and playing Shruti-based and ET-based audio chords through it. Iron filings sprinkled on the drum surface revealed stable and symmetric vibrational patterns on Shruti-tuned chords and unstable, irregular patterns on ET-tuned chords, visually reinforcing the concept of natural resonance alignment.
7. The primary theoretical foundation of this study is based on the pioneering research of Dr. Vidyadhar Oke, particularly as documented on www.22shruti.com.

Pre-Assessment Findings

1. Data from 40 students were analyzed through a pre-session questionnaire to assess their intuitive perception of musical purity.
2. While the majority of participants had no formal musical background, a few were initiated learners who had previously studied or practiced basic music.
3. Most students demonstrated an instinctive auditory understanding of what they perceived as "resonant" or "soothing" music.
4. A large portion associated this sense of resonance with bhajans, devotional songs, and old Hindi classics, often describing these as calming and emotionally peaceful.
5. Interestingly, several students also mentioned genres such as Blues, HipHop and R&B, which employ microtonal inflections and in-between note frequencies, indicating a natural perceptual sensitivity toward such tonal nuances.

Research Methodology

The research methodology included:

1. Pre and post assessment questionnaires [refer links [1] for the questionnaires] designed for Grade X students to assess their understanding of music and science concepts such as frequencies, ratios, and sound.
2. Designing and conducting six (6) music–science integrated classroom sessions with Grade X students. [refer image [1, 2, 3]]
3. Comparative listening demonstrations using Equitempered (ET) tuned and Shruti-tuned keyboards to explain consonance and dissonance. [for tuning chart refer image [4]]
4. Use of tone generators and waveform analysis tools like Audacity and spectrum analysers to visually represent waveforms and harmonic relationships.
5. Demonstration of microtones using a guitar slide to show the presence of "in-between" frequencies within a single fret.
6. Google Forms-based psychoacoustic study feedback with audios [refer links [2] for google form link] to collect perceptual data on tuning and resonance experiences.

Findings from the Study

1. Frequency Analysis:

Comparative analysis between Equal Temperament (ET) and Shruti-based tuning revealed that ET-tuned chords produced audible beats and slight dissonance, whereas Shruti-tuned chords felt more stable and naturally resonant to the ear.

2. Student Feedback:

Feedback from Grade X students indicated that Shruti-based sounds were perceived as more consonant and calming, while ET-based sounds often felt restless or vibrating.

3. Vibrational Experiment:

The floor tom experiment- conducted using a speaker placed beneath the drum with iron filings on its surface- visually demonstrated stable, symmetric patterns for Shruti-tuned chords and unstable, irregular patterns for

ET-tuned chords, supporting the hypothesis of natural resonance alignment.

4. Mathematical Ratios:

The study reaffirmed that Shruti-based natural tuning follows simple mathematical ratios such as Sa:Ga:Pa = 100:125:150, as demonstrated in Dr. Vidyadhar Oke's instructional videos. [refer image [5]] These ratios form the foundation of harmonic stability and consonance.

5. Psychoacoustic Observations:

Students, including those from non-musical backgrounds, instinctively associated Shruti-based or microtonal music with purity and natural harmony. Some also related similar sensations to genres like Blues, R&B, and Jazz, which use bent notes and microtonal transitions. [refer google form survey image [6]].

6. Waveform and Beat Analysis:

Waveform observations showed that Shruti-tuned sounds produced stable harmonic patterns with minimal beat frequencies, whereas ET-tuned chords displayed periodic amplitude fluctuations indicating interference. [refer images [7], [8]]

Discussions and Recommendations

This research is not the end - it is the beginning. The findings highlight the immense potential of integrating music and science at the school level through experiential learning. The authors aim to expand this initiative both in junior and senior classes, promoting a blended curriculum where:

a. Students of music understand the science of sound, and
b. Students of science experience and appreciate the art of music, understanding why certain music feels more resonant.

Imagine a future where a physics lab uses raagas to demonstrate waveforms, and music students analyse spectrums of a guitar bend - this interdisciplinary vision represents the next phase of music-science education.

This small-scale study indicates a possible trend; however, a larger study with diverse demographics is required to reinforce these findings. Conducting such experimental sessions within a running school curriculum is inherently challenging and would not have been possible without the support and encouragement of the management and principal of St Kabir Public School. Future researchers are encouraged to plan such sessions at the beginning of the academic year, integrating them into the school calendar for smoother execution and better continuity.

Although data from approximately 40 student participants were analysed, further in-depth impact analysis can strengthen and quantify the perceptual and cognitive outcomes more rigorously. This next phase will help refine the research model and deepen our understanding of how students experience musical resonance through frequency-based learning.

Results

Through our study, we observed that students displayed a natural inclination towards non-equal tempered or natural tuning systems, even without prior awareness of such concepts. Analysis of pre-session questionnaires indicated that a majority of the students were more drawn to musical styles such as classical, blues, and R&B - genres that often explore frequencies beyond the strict equal-tempered framework.

Post-session reflections revealed that most students perceived shruti-based (natural ratio) tuning to sound more resonant, and emotionally expressive compared to equal temperament. The six interdisciplinary sessions integrating music and science facilitated deeper understanding and engagement. Students demonstrated the ability to connect scientific principles of sound and resonance with musical expression and perception in real-life contexts.

Throughout the study, the group of 40 participants remained highly interactive- asking insightful questions, experimenting actively, and expressing curiosity about the relationship between sound, tuning, and emotional experience. Overall, the findings suggest strong support for the hypothesis that students intuitively respond more positively to natural tuning systems when given experiential exposure.

Future Scope and Directions

With the hypothesis supported by this pilot study, our next step is to extend this interdisciplinary approach to larger and more diverse participant groups, thereby enhancing the scope and reliability of the findings. The study aims to contribute towards improving current music pedagogy and curriculum design by integrating scientific understanding with traditional and contemporary musical practices.

A key objective is to help students appreciate the rich heritage of classical and ancient music traditions- not limited to Indian Classical Music- while simultaneously building a strong foundation in the technical and mathematical aspects of sound and frequency ratios. When introduced through this interdisciplinary framework, students demonstrated faster and deeper conceptual understanding compared to conventional methods of instruction.

In future iterations, this approach can be expanded globally, encouraging a new way of thinking about music education that bridges science, art, and culture. Further comparative studies are required to analyse the long-term cognitive, perceptual, and creative impacts of such integrative pedagogy.

Conclusion

This pilot study demonstrated that students were able to perceptibly differentiate between Equal Tempered (ET) and Shruti-based tuning systems, validating the central hypothesis that naturally tuned music feels more consonant and resonant to the human ear. The interventions enabled students to aurally identify relative pitch variations and develop a deeper awareness of the acoustic and psychoacoustic dimensions of sound.

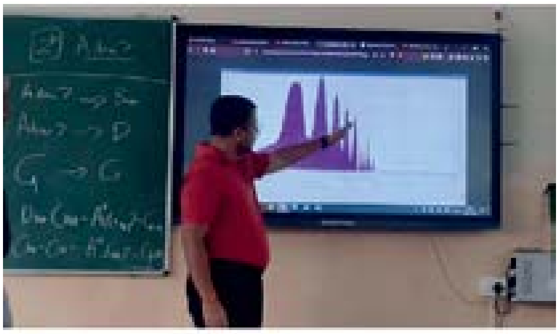
While the study was conducted on a small sample group, the outcomes indicate promising directions in perception of microtonal music especially Shruti-based music vs the ET based music further expanding to interdisciplinary research and teaching. Future studies should expand the participant base and demographic scope to establish broader and more statistically significant results, further bridging scientific and musical understanding.

The findings also reaffirm that students grasp concepts faster when taught through interdisciplinary pedagogy- an approach that connects art and science in meaningful ways. Integrating such methods into mainstream education is not only effective but also the need of the hour for holistic, experiential learning.

Links

1. Pre and Post Session Questionairres designed by author and co-author:https://drive.google.com/file/d/1fz_3owCq5v_xXohRGLeHy1rdqIRCndGP/view?usp=sharing
2. Google Form for Psychoacoustic survey and Mood Data: https://docs.google.com/forms/d/e/1FAIpQLScN7vnSsSK4juFriHcSdU9jajQaid7N6WDNJDswpkUlZNZ_bA/viewform?usp=header

Images



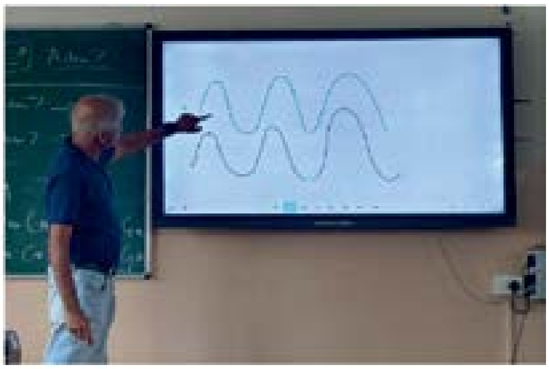


Image 1 & 2: Author and co-author teaching about harmonics and introducing waveforms to students

Image 3: Author and co-author during an interdisciplinary session

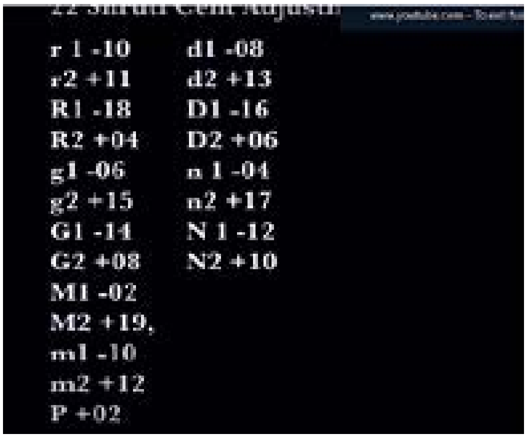


Image 4: Cent adjustment chart of shruti based tuning from video [video [6]

Image 5: Natural vs ET ratios;[video [4]

Image 6: Data from psychoacoustic survey

Image 7 & 8: Shruti vs ET waveform analysis (Audacity, Spectroid)

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Online Videos and Multimedia Resources

1. Jacob Collier – Understanding Just Intonation and Microtonality jacob collier tunes the piano
2. Equal Temperament vs Just Intonation Keyboard Listening Tuning -
3. Equal Temperament vs Just Intonation
4. Dr. Vidyadhar Oke on 22 shrutis - The science of music | Vidyadhar Oke | TEDxIITGandhinagar Raga Yaman– shrutis explained by Dr.Vidyadhar Oke 22 Shruti Positions.wmv
5. Sangeeta Shankar's Channel - 22 Shrutis Simplified - Chapter 1: In a Nutshell
6. How to tune and use 22 shrutis: 22 Shrutis Simplified - Chapter 5: How to Tune & Use
7. Waveform Tutorials – Visualizing Sound Waves and Harmonics

   Just Intonation vs Equal Temperament

   Just Intonation vs Equal Temperament (visual demonstration)
8. English Classics Guitar Bend Examples – Demonstration of Microtones and Bends

   Daniel Castro - I'll Play The Blues For You

   Norwegian Wood (This Bird Has Flown) (Remastered 2009)

   Eagles - Hotel California (Official Audio)

   Gravity (Live in L.A.)