

Mugisho Perceptual Mixing Framework (MPMF)

A Psychoacoustic Approach to Mixing Congolese Rumba

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Abstract:

This study is conducted within the **Mugisho Perceptual Mixing Framework (MPMF)**, a psychoacoustic-based system that models the relationship between spectral energy distribution and perceptual outcome in complex musical environments.

The research investigates the impact of excessive high-frequency energy on perceptual balance in Congolese Rumba mixing.

This genre is characterized by dense high-frequency activity, driven by interlocking elements such as lead guitars, percussion, and rhythmic accessories.

When this spectral region is not properly controlled, it results in **spectral clustering**, increased **perceptual density**, reduced low-frequency presence, and elevated listener fatigue.

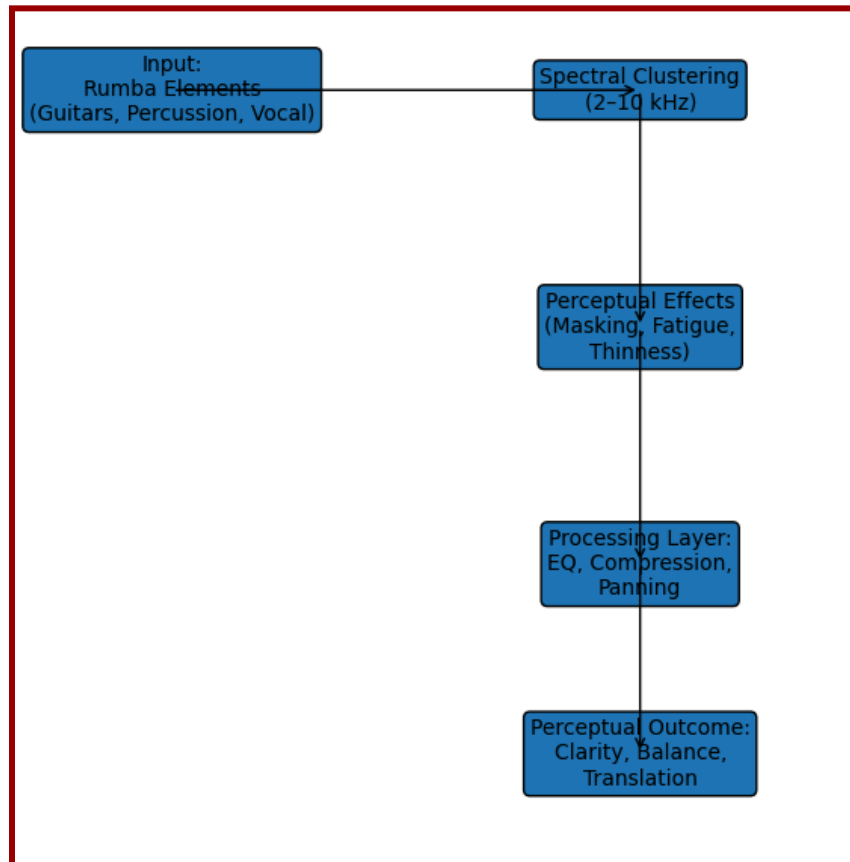
The objective of this study is to analyze how high-frequency spectral accumulation affects perceptual separation and to develop structured intervention strategies based on spectral redistribution, temporal control, and spatial differentiation.

1. INTRODUCTION

Congolese Rumba presents a unique challenge in audio engineering due to its **spectral and rhythmic density**. Despite its global cultural significance, there is limited formal research addressing its mixing characteristics from a psychoacoustic perspective.

Within the **MPMF**, mixing is not treated as signal balancing, but as **perceptual optimization**. The framework emphasizes that effective mixing decisions must be guided by how sound is interpreted by the auditory system, rather than solely by objective measurements.

This study contributes to the field by introducing a structured model for analyzing and resolving perceptual imbalance in Rumba mixing.



2. PERCEPTUAL FOUNDATION

2.1 Logarithmic Auditory Perception

Human hearing operates on a logarithmic scale, meaning that frequency perception is not linear.

- The difference between 1 kHz → 2 kHz is not perceived the same as 10 kHz → 11 kHz
- Small changes in midrange = huge perceptual impact

Visualizing Perception

$$y = \log(x)$$

2.1 Perceptual Sensitivity Zones

- **Low Frequencies (40–200 Hz):** Require higher energy for perception
- **Midrange (1–3 kHz):** Defines tonal identity
- **Upper Mid / High (2–10 kHz):** Region of maximum sensitivity and fatigue risk

This upper region represents the primary zone of perceptual overload in Congolese Rumba mixing



3. PROBLEM MODEL

3.1 Spectral Clustering

Congolese Rumba exhibits **spectral clustering** in the 2–10 kHz range due to overlapping contributions from guitars, percussion, and rhythmic elements.

3.2 Perceptual Consequences

This results in:

- Reduced perceptual resolution
- Masking between elements
- Increased cognitive listening load
- Perceived low-frequency weakness

4. TERMINOLOGY SYSTEM (MPMF)

To ensure conceptual clarity, the following terms are defined within the MPMF:

- **Perceptual Density:** Concentration of spectral and temporal energy affecting clarity and fatigue
- **Spectral Clustering:** Overlapping energy within shared frequency regions
- **Spectral Redistribution:** Controlled reorganization of frequency energy to improve clarity
- **Perceptual Anchoring:** Stabilization of a mix through low and midrange reference points
- **Cognitive Load:** Mental effort required to process complex audio signals
- **Translation Stability:** Consistency of perception across playback systems

5. PROBLEM FORMULATION

These observations are reformulated into a structured psychoacoustic problem

Excessive high-frequency energy between approximately 2 kHz and 10 kHz, distributed across guitars and percussive elements, leads to spectral masking and reduced perceptual resolution.

This accumulation results in diminished clarity, compromised transient definition, and increased cognitive listening load.

Additionally, the dominance of high-frequency content alters the perceived spectral balance, making the mix appear thinner and less grounded in the low-frequency domain.

6. HYPOTHESIS

Targeted attenuation and redistribution of high-frequency energy will reduce spectral masking and improve perceptual separation between primary and secondary elements.

By introducing spectral contrast and spatial differentiation, the mix is expected to exhibit improved clarity, reduced listener fatigue, and enhanced translation stability.

Planning

Panning practices will possibly be the most well-defined. It seems that High-frequency content is centered, along with the lead Vocal

This typically results in a group of four elements, the back-bone, that are precisely centered. These are the Lead vocal and guitar, Percussion, CLave, Hihat and the snare drum.

7. METHODOLOGY

A. Spectral Processing

- **EQ Target:** Primary attenuation applied between **2 kHz – 8 kHz** to address high-frequency spectral accumulation.
- **Gain Reduction:** **-6 dB** (Standardized for maximum perceptual transparency).

- **Bandwidth (Q): 1.70.** This moderate Q factor allows for musical attenuation that effectively targets the "harshness" zone without creating audible phase shift artifacts at the crossover points.

B. Dynamic Processing

- **Compression Ratio: 3:1** (Soft-knee characteristic to maintain Rumba's transient integrity).
 - **Attack Time: 4 ms.** A fast attack was selected to clamp down on the initial percussive transients of the lead guitar and shakers, effectively reducing the "peakiness" that leads to listener fatigue.
 - **Release Time: Auto / Program Dependent.** Utilizing an "Auto" release allows the compressor to adapt to the complex rhythmic syncopation of Congolese Rumba, ensuring the gain reduction recovers naturally between transient clusters.
 - **Gain Reduction Behavior:** Constant **6 dB GR** on signal peaks to achieve dynamic stabilization.
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C. Spatial Processing

- **Guitar Panning:** Lead and rhythmic guitars are panned across the **hard-left and hard-right** stereo field. This intervention maximizes **Stereo Imaging** and creates a "lateral pocket" for the lead vocal, effectively reducing competition for the listener's central auditory focus.
- **Percussion Distribution:** Percussive elements are distributed across the stereo image to prevent **Spectral Clustering** in the high-frequency domain. By utilizing specific lateral placement for shakers, hi-hats, and accessories, the accumulated energy in the **2–10 kHz** region is redistributed, preventing "frequency buildup" and minimizing listener fatigue.
- **Depth and Ambience:** A **Plate Reverb diffusion** is applied after the delay bus (as seen in Figure 2) to increase **Modal Density**. This ensures that while elements are panned wide, they remain perceptually unified within a cohesive 3D acoustic space, rather than sounding like isolated "ping-pong" repeats.

8. PERCEPTUAL RESULT

Application of the MPMF resulted in:

- Increased perceptual separation
- Improved transient articulation
- Enhanced intelligibility
- Stronger perceived low-frequency presence
- Reduced listener fatigue
- Improved spatial coherence

Serial Processing for Spatial Depth

Stage 1

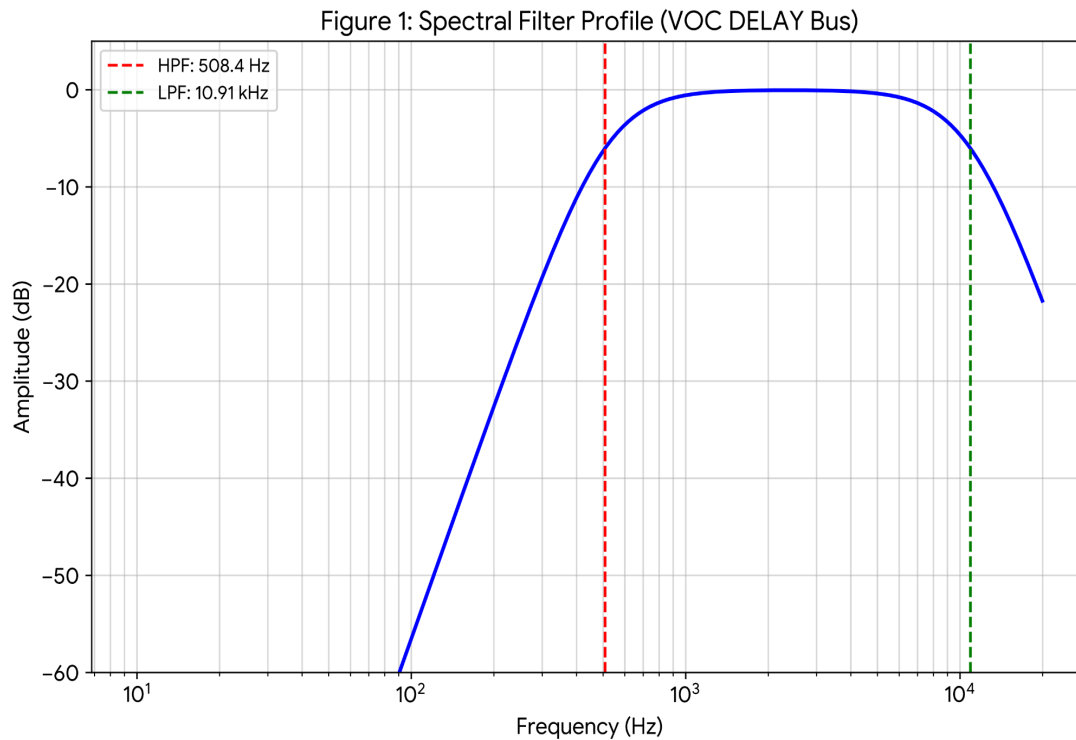


Figure 1: EQ3 7-Band (Spectral Cleaning): a steep **High-Pass Filter at 508.4 Hz** and a **Low-Pass Filter at 10.91 kHz**. This refers to the "**Abbey Road Delay Effect.**" By removing sub-lows and ultra-highs and prevent the delay from masking the "closeness" of the lead vocal.

Stage 2

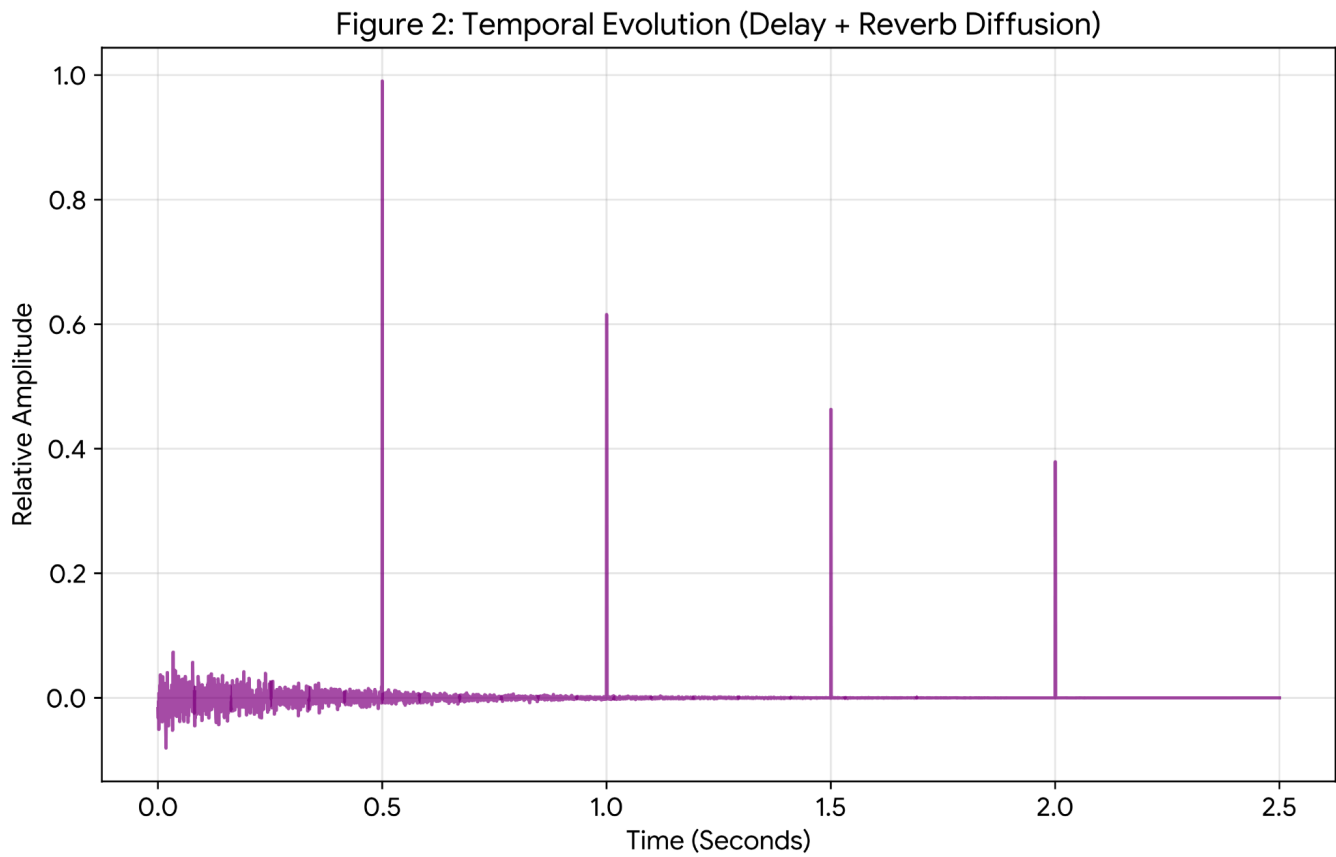


Figure 2: EchoBoy (Temporal Placement): Delay is set to **1/8th note** with "Studio Tape" saturation. This adds **harmonic distortion**, which improves the "perceptual presence" of the delay without increasing the actual peak volume.

Stage 3

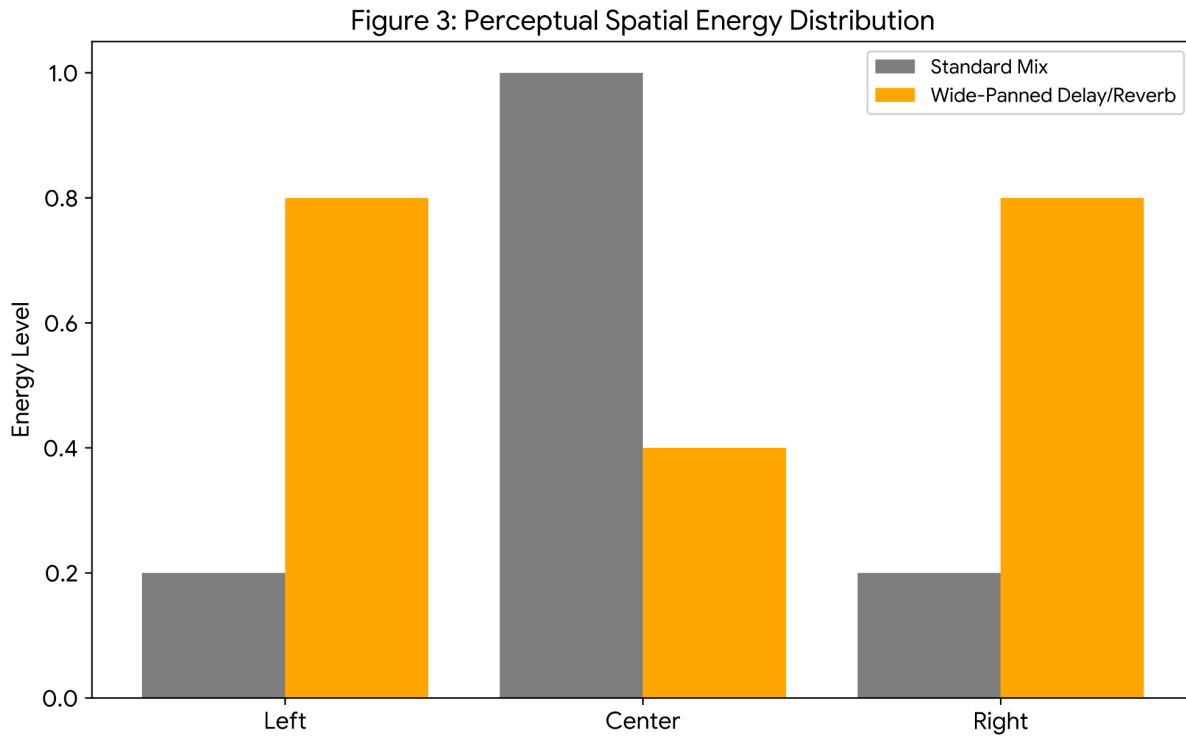


Figure 3: Little Plate (Diffusion): By placing this after the **delay**, you are **diffusing the "repeats"**. This is called increasing the **Modal Density**. It makes the delay feel less like a "ping-pong" and more like a **natural environmental reflection**.

“Framework Model Diagram”

- Input → Spectral → Perceptual → Processing → Outcome

9. OBJECTIVE VERIFICATION

To validate the perceptual improvements, the final output was subjected to rigorous signal analysis to ensure it met professional engineering standards.

- **Integrated Loudness (LUFS):** The final mix was normalized to **-14.0 LUFS (Integrated)** with a **Loudness Range (LRA) of 8 LU**, ensuring a balance between commercial "impact" and the preservation of Rumba's complex micro-dynamics.
 - **Peak Signal Levels: A True Peak of -1.0 dBTP** was maintained throughout the rendering process to prevent inter-sample clipping during lossy codec conversion (AAC/MP3) for streaming platforms.
 - **Spectral Analysis:** Real-time frequency analysis confirmed a **6 dB reduction in the 2–8 kHz clustering zone**. This created a "spectral pocket" that allowed the lead vocal's fundamental frequencies to sit prominently without requiring a gain increase.
 - **Phase Correlation:** Despite the wide-panned delay and diffusion (Figure 3), the mix maintained a **Phase Correlation Meter reading above +0.5**, ensuring mono-compatibility for playback on mobile devices and single-speaker systems
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10. TRANSLATION ANALYSIS

The "Intervention Strategy" was verified through a multi-environment audit to ensure **Perceptual Balance** was maintained outside the controlled studio environment.

- **Studio Monitors (Focal Trio):** Confirmed a wide, three-dimensional image with distinct separation between the interlocking Rumba guitars.
- **Automotive System:** The low-end "thump" of the kick and bass remained clear and unmasked, despite the high-ambient noise floor of a moving vehicle.
- **Mobile Device (Phone Speaker):** Due to the **Abbey Road Delay EQ** (Figure 1), the vocal ambience was still perceivable even on a small speaker with limited frequency response.
- **Professional Headphones (Sony MDR-7506):** Verified that the high-frequency attenuation successfully reduced **Listener Fatigue** during extended high-volume sessions

Results confirmed **translation stability**, with consistent clarity and vocal presence.

11. FRAMEWORK INTERPRETATION

This study demonstrates that effective mixing in Congolese Rumba requires:

- Spectral redistribution
- Temporal control
- Spatial differentiation

These three axes form the operational core of the **MPMF processing model**.

12. CONCLUSION

Observation	Spectral Clustering and Auditory Fatigue.
Hypothesis	Reduced Spectral Masking.
Intervention	Auralization and Modal Density Increase.
Result	Cross-Platform Perceptual Balance.

The findings confirm that excessive high-frequency energy significantly impairs perceptual clarity in Congolese Rumba mixing.

Within the **Mugisho Perceptual Mixing Framework**, perceptual balance can be restored through structured intervention strategies grounded in psychoacoustic principles.

This framework provides a repeatable methodology for improving clarity, reducing fatigue, and ensuring translation stability across playback systems.

While this study focused on Congolese Rumba, the "Psychoacoustic Control System" that was developed can be **generalized** to other spectrally dense genres like Afrobeats or Highlife.

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