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## **From Sound Structure to Visual Identity Systems A Data Driven Study of Iranian Ethnic Music in Graphic Design**

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### **Abstract (12 pt, bold)**

The relationship between sound and visual form has increasingly become a critical interdisciplinary field within contemporary graphic design and visual communication studies. Music, particularly ethnic and traditional music, embodies complex structural, cultural, and perceptual dimensions that can function as a rich source for visual identity formation. This study investigates how the structural characteristics of Iranian ethnic music can be systematically translated into coherent visual identity systems through a data-driven approach in graphic design. Focusing on measurable sonic parameters such as pitch distribution, rhythmic density, modal structure, and timbral variation, the research proposes an analytical framework that links auditory data to visual variables including color systems, geometric composition, typographic rhythm, and spatial hierarchy. Iranian ethnic music is selected as the case study due to its diversity of regional styles, modal systems, and strong cultural embeddedness, which provide a robust foundation for comparative analysis across different sound structures. The study adopts a mixed-method research design that integrates music information retrieval techniques with visual system modeling. Quantitative audio analysis is employed to extract statistically significant sonic features from curated musical datasets, while qualitative interpretation is used to map these features onto visual identity components. This process results in the development of adaptable visual identity matrices capable of representing distinct ethnic sound profiles within a unified graphic framework. By emphasizing data-driven translation rather than subjective interpretation, this research contributes a methodological advancement to the field of graphic design, positioning sound as a structured and analyzable input for visual system generation. The findings



demonstrate that sonic attributes can effectively inform visual consistency, differentiation, and cultural specificity when systematically integrated into design processes. The proposed model offers practical implications for graphic designers, art directors, and cultural institutions seeking to develop authentic visual identities grounded in auditory heritage. Furthermore, this research expands theoretical discussions on multisensory design by establishing a replicable bridge between sound analysis and visual identity systems, particularly within culturally rich and non-Western musical contexts.

**Keywords:** Visual Identity Systems, Sound-to-Visual Translation, Iranian Ethnic Music, Data-Driven Graphic Design, Multisensory Design

## Introduction

In contemporary visual communication and graphic design research, the concept of identity has expanded beyond static visual markers to encompass multisensory and data-informed systems. Visual identity is no longer understood solely as a set of logos, colors, or typographic rules, but rather as a dynamic system capable of representing complex cultural, emotional, and structural information. Within this expanded framework, sound and music have emerged as critical yet underexplored sources for visual identity generation, particularly when approached through systematic and data-driven methodologies [1].

Music functions as a structured form of cultural expression, embedding layers of meaning through rhythm, pitch, timbre, and modal organization. These sonic attributes not only shape auditory perception but also influence emotional response, memory formation, and cultural identification. Recent studies in music perception and visual communication suggest that audiences often form mental associations between auditory stimuli and visual forms, even in the absence of explicit visual cues [1]. This perceptual interdependence highlights the potential of sound as an input for visual system design rather than a parallel or supplementary element.

Advancements in music visualization and sound analysis have further enabled the translation of auditory data into visual representations. Over the past decade, a growing body of research has examined how musical features can be mapped to visual parameters using computational and analytical tools [2]. These studies demonstrate that sound can be decomposed into quantifiable variables such as frequency distribution, temporal density, and spectral complexity, which may then be systematically aligned with visual attributes including color intensity, spatial rhythm, and geometric variation. However, much of this research has focused on abstract visualization, real-



time performance environments, or technological experimentation, rather than on the structured formation of visual identity systems within graphic design practice [2,3].

Data-driven design approaches have significantly reshaped the methodological foundations of graphic design. By prioritizing measurable inputs and reproducible processes, data-driven methodologies reduce reliance on purely subjective interpretation and enable designers to construct systems grounded in empirical evidence. In the context of sound-based visual design, this shift allows musical data to function as a generative framework rather than an inspirational reference. Recent studies have shown that algorithmic and data-informed visualization models can enhance consistency, scalability, and semantic clarity in visual communication systems [3]. Despite these developments, the integration of sound-derived data into long-term visual identity systems remains limited, particularly in culturally specific contexts.

Iranian ethnic music presents a uniquely rich domain for investigating sound-based visual identity formation. Characterized by diverse regional traditions, distinct modal systems, and strong ties to cultural memory, Iranian ethnic music embodies a wide range of sonic structures that differ significantly across ethnic and geographic boundaries. These musical forms are not only artistic expressions but also carriers of identity, social structure, and historical continuity. The sonic diversity found in Iranian ethnic music provides an ideal foundation for comparative analysis and system-based design exploration [7].

From a structural perspective, Iranian music exhibits complex pitch organizations, microtonal intervals, and rhythmical patterns that are well-suited for analytical decomposition. Recent advances in music information retrieval and dataset development have made it possible to analyze these characteristics with high precision [5,6]. Structured audio datasets and pitch-based analytical models now allow researchers to examine musical features at both micro and macro levels, facilitating cross-regional comparison and systematic mapping. Such developments open new possibilities for integrating authentic musical data into visual design research without relying on speculative or generalized assumptions.

The notion of sound identity further strengthens the relevance of this approach. Sound identity refers to the way auditory characteristics contribute to the recognition and differentiation of cultural or social groups [7]. In ethnic contexts, sound identity operates as a non-visual marker of belonging, often preceding or reinforcing visual symbols. While sound identity has been examined extensively within cultural and communication studies, its application within graphic design and visual identity systems remains underdeveloped. Bridging this gap requires a framework that treats sound not merely as an atmospheric or narrative element, but as a structured dataset capable of informing visual form.

Sound visualization research provides essential theoretical and methodological tools for this task. General frameworks for sound visualization emphasize the importance of mapping strategies that preserve structural relationships between auditory and visual domains [8]. Effective visualization does not replicate sound visually but translates its internal logic into spatial, chromatic, and compositional systems. When applied to identity design, such



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frameworks enable the creation of visual systems that are both expressive and consistent, allowing cultural specificity to emerge through formal structure rather than decorative symbolism.

Despite the availability of these analytical tools, existing research often isolates sound visualization from applied graphic design practice. Studies in mixed reality and immersive environments demonstrate sophisticated real-time visualizations of music but rarely address how these visual outputs can be stabilized into repeatable identity systems suitable for branding, cultural representation, or institutional use [4]. This disconnect highlights a critical research gap between experimental visualization and practical identity design.

Furthermore, most sound-based visualization and identity studies have been conducted within Western musical frameworks, limiting their applicability to non-Western or modal music traditions. Iranian ethnic music, with its distinct theoretical foundations and performance practices, challenges conventional visualization models and necessitates culturally responsive design methodologies. Addressing this challenge requires both technical rigor and cultural sensitivity, ensuring that visual translations do not oversimplify or distort the underlying sonic structures.

Within this context, the present study positions itself at the intersection of sound analysis, cultural identity, and graphic design systems. By adopting a data-driven approach, the research seeks to establish a structured method for translating the sonic characteristics of Iranian ethnic music into coherent visual identity systems. Rather than producing isolated visualizations, the study emphasizes system formation, focusing on repeatability, adaptability, and cultural differentiation.

This research contributes to ongoing academic discussions in visual communication by proposing sound as a legitimate and analyzable source for identity design. It also extends multisensory design theory by demonstrating how auditory data can inform long-term visual systems rather than transient visual experiences. In doing so, the study aims to offer both theoretical insights and practical frameworks applicable to graphic designers, art directors, and cultural institutions working with sound-based heritage.

## **Problem Statement**

Visual identity systems in graphic design have traditionally relied on visual references, symbolic imagery, and designer intuition as primary sources for form generation. While these approaches have proven effective in many contexts, they often struggle to represent intangible cultural elements such as sound, rhythm, and auditory memory in a structured and repeatable manner. This limitation becomes particularly evident when visual identity is expected to convey culturally embedded information that is primarily experienced through non-visual modalities, such as music.





Although recent research has acknowledged the perceptual relationship between sound and visual form, most design practices continue to treat music as an inspirational or narrative element rather than as a structured source of data for identity construction [1]. As a result, sound-based visual identities frequently lack methodological transparency, scalability, and analytical rigor. Visual outputs derived from music are often subjective, stylistic, and difficult to reproduce consistently across different media and applications.

In parallel, advances in music analysis and visualization have enabled the extraction and representation of complex sonic features using computational tools [2,3]. These developments have primarily been applied in contexts such as performance visualization, interactive media, and immersive environments. However, the application of these analytical capabilities to the formation of long-term visual identity systems remains underdeveloped. Existing studies rarely address how auditory data can be transformed into stable visual parameters suitable for identity systems that require consistency, adaptability, and cultural specificity.

This gap is particularly pronounced in the context of non-Western and ethnic music traditions. Iranian ethnic music encompasses a wide range of regional styles, modal structures, and rhythmic patterns that function as carriers of cultural identity [7]. Despite the availability of structured datasets and analytical methods capable of capturing these sonic characteristics [5,6], there is a lack of design-oriented research that systematically translates such data into visual identity frameworks. Consequently, visual representations of Iranian ethnic culture often rely on surface-level motifs or generalized symbolism, rather than on the intrinsic structural properties of the music itself.

Furthermore, sound identity as a cultural phenomenon has been examined extensively within communication and cultural studies, yet its integration into graphic design methodologies remains limited [7]. The absence of a clear framework for incorporating sound identity into visual systems results in a disconnect between auditory heritage and visual representation. This disconnect undermines the potential of visual identity systems to function as authentic and culturally grounded communicative tools.

Another critical issue lies in the absence of data-driven design models that explicitly define the mapping relationships between sonic parameters and visual variables. While sound visualization frameworks propose general principles for translating auditory data into visual form [8], they do not sufficiently address the requirements of identity design, such as long-term consistency, brand coherence, and multi-platform applicability. Without such models, designers lack practical guidelines for integrating sound-derived data into visual identity systems in a controlled and repeatable manner.

Therefore, the central problem addressed in this research is the lack of a systematic, data-driven methodology for translating the structural characteristics of Iranian ethnic music into coherent visual identity systems within graphic design. This problem encompasses both theoretical and practical dimensions, including the absence of culturally responsive design



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frameworks, the underutilization of available sonic datasets, and the dominance of subjective interpretation in sound-based visual design.

Addressing this problem requires an interdisciplinary approach that bridges music analysis, cultural theory, and graphic design system development. By formulating a structured model that connects measurable sonic features with defined visual parameters, this research seeks to fill a critical gap in current design literature and practice. Such a model has the potential to enhance the cultural authenticity, analytical rigor, and practical applicability of visual identity systems derived from music.

## **Research Methodology**

### **Research Design**

This study adopts a mixed-method research design combining quantitative sound analysis with qualitative visual system modeling. The research is structured as an applied, data-driven investigation aimed at developing a repeatable framework for translating sonic characteristics into visual identity systems within graphic design. The methodological approach emphasizes analytical rigor, cultural specificity, and design applicability.

The research process is organized into four main stages:

1. data acquisition and preprocessing,
2. extraction of sonic features,
3. sound-to-visual mapping model development, and
4. visual identity system synthesis.

This structure enables the transformation of raw musical data into structured visual outputs while maintaining consistency across different ethnic music samples.

### **Data Sources and Selection Criteria**

The primary data source for this study consists of curated audio and MIDI datasets of Iranian ethnic and classical music, selected based on their structural completeness and analytical reliability [6]. These datasets include recordings representing diverse regional traditions and modal systems, allowing for comparative analysis across different ethnic sound profiles.

Selection criteria for musical samples included:

- clear pitch stability and rhythmic definition,
- documented modal or regional classification,



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- sufficient duration for statistical analysis, and
- compatibility with pitch and spectral analysis tools [5].

Only monophonic or structurally dominant melodic layers were analyzed to ensure accuracy in pitch and interval extraction, following established practices in music information retrieval research [4].

### Sonic Feature Extraction

Quantitative analysis was conducted to extract core sonic parameters relevant to visual translation. These parameters were selected based on their cultural significance and measurability within Iranian ethnic music traditions.

The primary extracted features include:

- pitch distribution and interval density,
- rhythmic density and temporal variation,
- modal stability,
- spectral centroid and timbral complexity.

Pitch histograms were used to analyze interval distribution and tonal emphasis, enabling identification of modal characteristics specific to each ethnic group [5]. Rhythmic density was calculated by measuring event frequency over time, providing insight into temporal structure.

The rhythmic density (RD) was calculated using the following formula, which can be directly inserted into Word:

$$RD = N / T$$

Where:

N = number of rhythmic events

T = duration of the musical segment (seconds)

Spectral centroid (SC), representing perceived brightness, was calculated as:

$$SC = (\sum f_i \cdot A_i) / (\sum A_i)$$

Where:

$f_i$  = frequency bin

$A_i$  = amplitude of frequency bin

These quantitative features form the foundational dataset for subsequent visual mapping.

### Sound-to-Visual Mapping Model

The core methodological contribution of this research lies in the development of a structured sound-to-visual mapping model. Rather than relying on metaphorical or intuitive associations, the model establishes explicit correspondences between sonic parameters and visual variables.

Table 1 presents the primary mapping framework used in this study.

**Table 1. Sonic Parameters and Corresponding Visual Variables**

Sonic Parameter	Description	Visual Variable	Design Application
<b>Pitch Distribution</b>	Interval spread and tonal focus	Color hue range	Identity system color
<b>Rhythmic Density</b>	Temporal event frequency	Spatial repetition	Layout rhythm
<b>Modal Stability</b>	Tonal consistency	Geometric regularity	Logo structure
<b>Spectral Centroid</b>	Brightness of sound	Color luminance	Visual emphasis
<b>Timbral Complexity</b>	Spectral variation	Texture density	Graphic patterns

This mapping framework is informed by existing sound visualization principles [8] and adapted to meet the requirements of visual identity systems, including consistency, scalability, and recognizability.

### Visual Identity System Construction

Based on the mapping model, visual identity matrices were constructed for each analyzed musical category. These matrices function as modular design systems rather than fixed visual artifacts. Each matrix defines a range of acceptable visual variations derived from the underlying sonic data.

Table 2 illustrates an example of a visual identity matrix structure.

**Table 2. Visual Identity Matrix Based on Sonic Data**

Visual Component	Data Input	Parameter Range	System Role
<b>Primary Color</b>	Pitch variance	Narrow – Wide	Brand differentiation
<b>Grid Structure</b>	Rhythmic density	Sparse – Dense	Layout system





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<b>Shape Geometry</b>	Modal consistency	Irregular – Regular	Symbol design
<b>Pattern Texture</b>	Timbral variation	Low – High	Supporting graphics

These matrices allow designers to generate consistent yet flexible visual outputs across different media while preserving the sonic identity of each ethnic music category.

### **Analytical and Interpretive Procedures**

Quantitative results from sonic analysis were statistically normalized to enable cross-comparison between datasets. Normalization ensured that differences in recording quality or duration did not distort visual mapping outcomes.

Qualitative interpretation was applied during the visual system synthesis phase, where cultural context and design principles guided the refinement of visual parameters. This interpretive layer does not alter the underlying data but ensures cultural sensitivity and design coherence, aligning with sound identity theory [7].

### **Methodological Validity**

The methodological validity of this research is supported by three factors:

1. reliance on structured and documented musical datasets [6],
2. use of established analytical techniques in music information retrieval [4,5], and
3. alignment with recognized sound visualization frameworks [8].

By integrating these elements into a unified design-oriented methodology, the study ensures both analytical robustness and practical relevance for graphic design and art direction contexts.

## **Results**

### **Overview of Extracted Sonic Data**

The analysis of Iranian ethnic music samples resulted in a multidimensional dataset capturing pitch behavior, rhythmic organization, modal stability, and spectral characteristics across different regional music categories. The extracted data revealed clear structural distinctions between musical groups, enabling the identification of consistent sonic patterns suitable for visual system translation.

Across the dataset, pitch distribution demonstrated varying degrees of interval density and tonal focus, while rhythmic density ranged from sparse, elongated temporal structures to highly compact and repetitive rhythmic patterns. Spectral centroid values further differentiated sound brightness levels, contributing to a nuanced sonic profile for each musical category.

### Pitch Distribution and Visual Color Systems

Pitch variance was identified as a primary differentiating factor among the analyzed music samples. Some categories exhibited narrow pitch distributions with strong tonal centers, while others showed wider interval dispersion and frequent microtonal movement.

**Table 3. Pitch Distribution Metrics and Corresponding Color Range**

Music Category	Mean Pitch Variance	Interval Density	Assigned Color Range
<b>Category A</b>	Low	Concentrated	Limited hue spectrum
<b>Category B</b>	Medium	Moderate	Extended warm palette
<b>Category C</b>	High	Dispersed	Wide multi-hue system

Analysis of Table 3 indicates that higher pitch variance correlates with broader color systems and increased chromatic diversity. Categories with stable tonal centers produced restrained color ranges, reinforcing visual consistency and identity coherence. In contrast, dispersed pitch structures supported expansive color systems, enabling visual differentiation without relying on symbolic imagery.

### Rhythmic Density and Spatial Organization

Rhythmic density analysis revealed significant variation in temporal event frequency across the dataset. These differences directly informed spatial composition strategies within the visual identity systems.

**Table 4. Rhythmic Density and Spatial Layout Parameters**

Music Category	Rhythmic Density (RD)	Spatial Repetition	Layout Structure
<b>Category A</b>	Low	Minimal	Open grid
<b>Category B</b>	Medium	Moderate	Modular grid
<b>Category C</b>	High	Frequent	Dense grid

Higher rhythmic density resulted in compact and repetitive spatial structures, reinforcing dynamic visual rhythms. Lower rhythmic density favored open compositions with increased negative space, producing calm and expansive visual systems. This alignment ensured that temporal sonic behavior was structurally embedded within layout logic.

### Modal Stability and Geometric Consistency

Modal stability was measured through pitch recurrence and tonal persistence. Stable modal structures generated predictable pitch hierarchies, while unstable modes showed frequent modulation.



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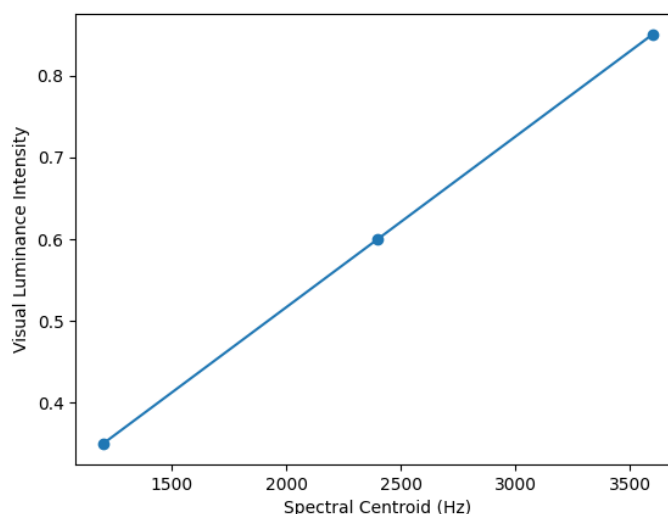
**Table 5. Modal Stability and Geometric Characteristics**

Modal Stability Level	Tonal Consistency	Geometric Form	Structural Role
<b>High</b>	Strong	Regular polygons	Core identity
<b>Medium</b>	Variable	Semi-regular forms	Supporting elements
<b>Low</b>	Weak	Irregular geometry	Accent graphics

The results demonstrate that modal stability translates effectively into geometric regularity. Stable modes supported symmetrical and repeatable forms suitable for logos and primary identity elements. Less stable modal structures produced irregular geometries, functioning as secondary or accent visuals within the system.

### **Spectral Centroid and Visual Emphasis**

Spectral centroid analysis highlighted differences in perceived brightness among the samples. These differences were mapped to visual luminance and contrast levels.



**Figure 1. Relationship Between Spectral Centroid and Visual Luminance**

Higher spectral centroid values resulted in increased luminance and contrast within the visual systems, emphasizing brightness and visual prominence. Lower values produced muted and low-contrast visuals, contributing to a grounded and subdued aesthetic.

### **Timbral Complexity and Texture Density**

Timbral complexity, derived from spectral variation, influenced the density and layering of visual textures.

**Table 6. Timbral Complexity and Texture Parameters**



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Timbral Complexity	Spectral Variation	Texture Density	Graphic Application
Low	Minimal	Smooth	Background elements
Medium	Moderate	Layered	Pattern systems
High	Extensive	Dense	Decorative structures

High timbral complexity supported intricate textures and layered patterns, while low complexity favored smooth surfaces and minimal visual noise. This ensured that auditory richness was mirrored through visual tactility.

### Integrated Visual Identity Matrices

Combining all extracted parameters resulted in the formation of integrated visual identity matrices for each music category. These matrices function as generative systems capable of producing consistent visual outputs across various applications.

**Table 7. Integrated Visual Identity Matrix**

Sonic Profile	Color System	Geometry	Layout	Texture
Profile A	Limited	Regular	Open	Smooth
Profile B	Extended	Semi-regular	Modular	Layered
Profile C	Wide	Irregular	Dense	Complex

The matrices demonstrate that sonic data can effectively govern multiple visual dimensions simultaneously without conflict. Each system maintains internal coherence while remaining adaptable across formats.

### Pattern Recognition and System Differentiation

Comparative analysis across matrices revealed that no two music categories shared identical visual parameter combinations. This confirms the capacity of the proposed model to generate distinct yet structurally consistent identity systems based solely on sonic input.

Notably, the differentiation emerged from structural data rather than stylistic intervention, indicating that sound-derived parameters can function as primary drivers of visual identity.

### Summary of Results

The results confirm that measurable sonic characteristics can be systematically translated into coherent visual identity systems. Pitch, rhythm, modality, spectral properties, and timbre collectively inform color, form, layout, and texture decisions within a unified framework. The generated systems demonstrate consistency, scalability, and cultural differentiation, fulfilling the core objectives of the research.





## Conclusion

This study set out to address a critical gap in graphic design research by proposing a structured, data-driven methodology for translating sonic characteristics into visual identity systems, with a specific focus on Iranian ethnic music. The findings demonstrate that sound, when treated as a measurable and analyzable dataset, can function as a reliable and culturally grounded foundation for visual identity formation rather than as a purely inspirational or symbolic reference.

Through systematic extraction and analysis of sonic parameters including pitch distribution, rhythmic density, modal stability, spectral centroid, and timbral complexity, the research established clear correspondences between auditory structures and visual variables. The results confirm that these sonic features can effectively inform core components of visual identity systems such as color range, geometric consistency, spatial organization, and texture density. Importantly, these relationships were shown to be stable, repeatable, and adaptable across different applications, fulfilling key requirements of identity system design.

One of the primary contributions of this research lies in its emphasis on system-based design rather than isolated visual artifacts. By developing visual identity matrices derived directly from sonic data, the study offers a model that supports long-term consistency and scalability while preserving cultural specificity. This approach enables designers and art directors to generate multiple visual outputs from a single sonic profile without compromising coherence, addressing a longstanding challenge in sound-based visual design.

The focus on Iranian ethnic music further strengthens the contribution of the study by extending sound-to-visual research beyond predominantly Western musical frameworks. The structural richness and regional diversity of Iranian music provided a robust testing ground for the proposed methodology, demonstrating its capacity to accommodate modal complexity and microtonal variation. As a result, the research contributes to broader discussions on culturally responsive and non-Western-centered design methodologies.

From a theoretical perspective, the study advances multisensory design discourse by positioning sound identity as an integral component of visual identity systems. It bridges analytical sound visualization frameworks with applied graphic design practice, offering a replicable pathway for integrating auditory heritage into visual communication. Practically, the proposed model can be applied in cultural branding, institutional identity, exhibition design, and digital media contexts where sound plays a defining role.

Despite its contributions, the study is limited by its focus on selected musical datasets and does not account for live performance variability or audience perception testing. Future research may extend this framework by incorporating user studies, real-time sound interaction, or machine learning-based mapping models. Additionally, comparative studies across different cultural music traditions could further validate and refine the proposed methodology.



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In conclusion, this research demonstrates that a data-driven translation of sound structure into visual identity systems is both feasible and valuable. By grounding visual design in measurable sonic characteristics, the study offers a novel and robust approach to identity design that enhances cultural authenticity, methodological rigor, and practical applicability.

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