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## SOUND SIGNATURES OF VIRTUOSITY: A COMPUTATIONAL STUDY OF ARA MALIKIAN'S PERFORMANCES OF J. S. BACH AND PAGANINI

### *Abstract*

Through a computational analysis of 55 solo violin recordings by Ara Malikian, this article explores how expressive identities manifest across two contrasting repertoires: Johann Sebastian Bach's Sonatas and Partitas and Niccolò Paganini's 24 Caprices. These works, recorded under similar conditions in 2003, provide a unique comparative framework to investigate stylistic divergence within the interpretive choices of a single performer. Drawing on Spotify's audio features—specifically tempo, energy, valence, loudness, acousticness, and danceability—the analysis maps the expressive contours that differentiate the Baroque structural poise of Bach from the Romantic theatricality of Paganini. While Bach's performances are marked by consistency, tonal clarity, and restrained dynamics, Paganini's interpretations reveal broader variations in tempo, higher energy levels, and greater affective contrast. These trends align with musicological perspectives that frame Bach's writing as rhetorically introspective and Paganini's as technically exuberant. A correlation matrix reveals that expressive features in Paganini's recordings are more tightly interlinked—suggesting a performance mode oriented toward emotional integration—whereas Bach's data reflects compartmentalized expressivity. Although originally designed for popular music, Spotify's descriptors prove useful when critically framed within historical performance contexts. Their application reveals how digital tools can support nuanced readings of musical interpretation, highlighting expressive tendencies that might otherwise remain implicit. Rather than supplant traditional analysis, this approach offers a new lens to engage with sound as structure, gesture, and affect.



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Malikian’s recordings demonstrate how interpretative identity adapts across repertoire, balancing fidelity with stylistic responsiveness. From harmonic clarity and contrapuntal weight to dramatic flair and expressive volatility, the findings illustrate how digital features can trace the contours of musical thought. These insights not only illuminate differences between composers, but also show how a performer’s expressive palette is reshaped by the demands and histories of the works themselves.

### *Keywords*

Violin Interpretation | Audio Feature Analysis | Baroque and Romantic Repertoire | Expressive Identity | Digital Performance Analysis.

## *1. Listening Through Data: Between Sound and Structure*

In recent years, the analysis of musical performance has been transformed by the emergence of tools that allow researchers to engage with audio recordings beyond traditional listening or score study. Streaming platforms like Spotify, through their automated extraction of audio features, offer access to a range of measurable parameters—tempo, loudness, energy, valence—that characterize the sonic identity of a performance in a quantifiable way. These descriptors, developed initially for music recommendation systems, now form the basis for interdisciplinary approaches to music analysis, allowing scholars to trace expressive patterns across genres, repertoires, and performers.<sup>1</sup> This study turns to one such performer: Ara Malikian, whose interpretations of J. S. Bach’s Sonatas and Partitas for Solo Violin and Niccolò Paganini’s 24 Caprices offer an ideal corpus for computational comparison. Recorded in the same year and under similar production conditions, these two cycles reflect not only distinct historical and aesthetic paradigms—Baroque polyphony on the one hand, Romantic virtuosity on the other—but also the stylistic versatility of a performer whose work resists easy categorization.

The choice of these two composers is not incidental. Bach’s sonatas and partitas are often regarded as a summit of contrapuntal writing for solo violin, blending formal rigor with expressive subtlety.<sup>2</sup> Paganini’s caprices, by contrast, are a manifesto of technical brilliance, designed to showcase the limits of the instrument and the performer alike. Beyond their technical demands, both repertoires serve as touchstones for interpretive

<sup>1</sup> PINTER A., PAUL J., SMITH J. & BRUBAKER J., *P4KxSpotify: A Dataset of Pitchfork Music Reviews and Spotify Musical Features*, Proceedings of the International AAAI Conference on Web and Social Media, 14, 2020, pp. 895–902, <https://doi.org/10.1609/icwsm.v14i1.7355>.

<sup>2</sup> GRATOVICH E., STEINER D., *Bach’s Solo Sonatas and Partitas for Violin: Guide to Practicing and Performing*, «American String Teacher», 35 (4), 1985, pp. 54–57, <https://doi.org/10.1177/000313138503500423>; CADEK O., *Bach—Perpetual Challenge: The Six Solo Sonatas for Violin*, «American String Teacher», 4 (1), 1954, pp. 5–8, <https://doi.org/10.1177/000313135400400105>.

identity, inviting violinists to navigate between fidelity to historical idioms and personal expressive choices. Paganini's role in shaping the history of violin technique is well documented. His command of extended techniques, from left-hand pizzicatos to ricochet bowing, redefined the expressive vocabulary of the instrument and inspired generations of performers and composers.<sup>3</sup> His caprices, often mythologized, remain a rite of passage for any violinist seeking to master the art of modern performance.<sup>4</sup> Bach's works, for their part, challenge the interpreter to articulate multiple voices within a single melodic line, calling for an understanding of harmonic function, phrasing, and historical articulation.<sup>5</sup> By analyzing audio features extracted from these recordings, this study seeks to identify expressive trends that distinguish Malikian's approach to each repertoire. Rather than offering a prescriptive reading, the aim is to show how computational tools can complement interpretive insight—revealing the contours of musical thought as they unfold in sound. The following sections develop the theoretical and methodological foundations of this approach, then move through a comparative analysis of the data, ultimately proposing new directions for the study of musical interpretation in the digital age.

## 2. Historical and Theoretical Framework

Studying musical interpretation through data might seem reductive at first glance. Yet within violin performance research, quantitative approaches can illuminate stylistic traits, expressive tendencies, and interpretive choices that complement rather than replace close listening or historical study. This section establishes the conceptual ground for analyzing Ara Malikian's recordings of J. S. Bach's Sonatas and Partitas and Niccolò Paganini's 24 Caprices through the lens of audio feature analysis.

### 2.1. Paganini and the Reinvention of Virtuosity

Niccolò Paganini holds a foundational place in the evolution of violin technique. His approach introduced extended methods—left-hand pizzicato, harmonics, ricochet bowing, and extreme position shifts—that redefined what was technically and expressively possible on the instrument.<sup>6</sup> The 24 Caprices stand as monuments of solo violin literature: technically daunting, structurally concise, and imaginatively rich.

<sup>3</sup> POLNAUER F., *Modern Research Illuminates the Violin Technique of Paganini*, «American String Teacher», 15 (3), 1965, pp. 1–6, <https://doi.org/10.1177/000313136501500302>; ISTELE E., *The Secret of Paganini's Technique*, «The Musical Quarterly», 16 (1), 1930, pp. 101–16, <https://doi.org/10.1093/mq/xvi.1.101>; KUCHERENKO S., *Violin Etudes of the 19th Century in the Aspect of the Evolution of Performing Mastery*, «Studia Universitatis Babeş-Bolyai Musica», 68 (2), 2023, pp. 267–77, <https://doi.org/10.24193/subbmusica.2023.2.19>.

<sup>4</sup> JOACHIM H., *Three Milestones in the History of Violin Playing. III. Paganini (Concluded)*, «The Musical Times», 73 (1078), 1932, p. 1079. <https://doi.org/10.2307/919427>; ANDERSON R., *Violin Concerto No.1; 24 Caprices*, «The Musical Times», 113 (1554), 1972, p. 782. <https://doi.org/10.2307/956924>.

<sup>5</sup> STINSON R., *J.P. Kellner's Copy of Bach's Sonatas and Partitas for Violin Solo*, «Early Music», 13 (2), 1985, pp. 199–211, <https://doi.org/10.1093/earlyj/13.2.199>; JOACHIM H., *Bach's Solo Violin Sonatas and the Modern Violinist*, «The Musical Times», 72 (1057), 1931, p. 221, <https://doi.org/10.2307/914851>.

<sup>6</sup> POLNAUER F., *Modern Research Illuminates the Violin Technique of Paganini*; ISTELE E., *The Secret of Paganini's Technique*.

They not only expanded the performative language of the violin but also became a proving ground for generations of virtuosos.<sup>7</sup> Paganini's influence extends far beyond the notes he wrote. Later composers, from Liszt to Schnittke, drew inspiration from his legacy. Contemporary works continue to evoke his mythos and techniques, transforming them into vehicles for sonic experimentation and virtuosic commentary.<sup>8</sup> His music has served as both artistic model and symbolic touchstone in the ongoing discourse about virtuosity's place in classical performance.<sup>9</sup> Rather than mere athletic display, Paganini's caprices explore theatricality as an expressive mode. Their compact structures invite intense personalization, allowing performers to negotiate the boundary between precision and risk, display and musicality. This duality is central to the caprices' enduring pedagogical and artistic appeal.<sup>10</sup>

## 2.2. *Bach and the Architecture of Expression*

Where Paganini's caprices revel in motion and spectacle, Bach's Sonatas and Partitas embrace complexity and introspection. These works, composed around 1720, articulate a unique vision of solo violin writing—one in which polyphonic integrity and harmonic direction are embedded in single-line textures. Their interpretative demands are both technical and philosophical, asking the performer to balance rhetorical clarity with expressive depth.<sup>11</sup>

Scholars have long debated the implications of multiple manuscript traditions. Studies of the J.P. Kellner copy, for instance, highlight how notational variants offer insight into Baroque phrasing practices and the fluidity of interpretive conventions in Bach's time.<sup>12</sup> At the same time, contemporary violinists continue to reimagine these works, negotiating historical awareness with individual artistry.<sup>13</sup> The enduring challenge of Bach's solo works lies in their synthesis of form and emotion. Movements like the Chaconne or the Fuga are not only formal constructs but expressive journeys, requiring performers to shape time and tone with architectural precision and affective sensitivity. This combination of intellectual rigor and expressive freedom makes the Sonatas and Partitas a central repertoire for both performance and scholarship.

<sup>7</sup> JOACHIM H., *Three Milestones in the History of Violin Playing. III. Paganini (Concluded)*; ANDERSON R., *Violin Concerto No.1; 24 Caprices*.

<sup>8</sup> GINSBORG J., *The Brilliance of Perfection or Pointless Finish? What Virtuosity Means to Musicians*, «Musicae Scientiae», 22 (4), 2018, pp. 454–73, <https://doi.org/10.1177/1029864918776351>; ЕРМАСОВА С., *Миф о Паганини в Современных Сочинениях для Скрипки Соло: Новые Техники и Новые Смыслы*, «Музыкальная Академия», 3 (787), 2024, pp. 48–61. <https://doi.org/10.34690/412>.

<sup>9</sup> KREGOR J., *Forging 'Paganinis of the Piano' in the 1830s*, «Studia Musicologica», 54 (2), 2013, pp. 115–34, <https://doi.org/10.1556/sm.54.2013.2.1>; KUCHERENKO S., *Violin Etudes of the 19th Century in the Aspect of the Evolution of Performing Mastery*.

<sup>10</sup> MACDONALD H., *Myths Op.30; Romance Op.23; Three Paganini Caprices Op.40; Nocturne and Tarantella Op. 28*, «The Musical Times», 124 (1688), 1983, p. 622. <https://doi.org/10.2307/961719>; SCHOENFELD M., *Niccolò Paganini*, «JAMA», 239 (1), 1978, p. 40, <https://doi.org/10.1001/jama.1978.03280280040022>.

<sup>11</sup> GRATOVICH E., STEINER D., *Bach's Solo Sonatas and Partitas for Violin: Guide to Practicing and Performing*; CADEK O., *Bach—Perpetual Challenge: The Six Solo Sonatas for Violin*.

<sup>12</sup> STINSON R., *J.P. Kellner's Copy of Bach's Sonatas and Partitas for Violin Solo*.

<sup>13</sup> JOACHIM H., *Bach's Solo Violin Sonatas and the Modern Violinist*.

### 2.3. Computational Analysis and the Grammar of Sound

The integration of music analysis with digital platforms has introduced new tools for examining performance. Spotify’s audio features, developed initially for large-scale music recommendation systems, quantify aspects of sound through metrics such as energy, valence, danceability, acousticness, and loudness. These parameters allow researchers to describe the expressive profile of a track in ways that can support stylistic comparison and trend analysis.<sup>14</sup> In recent years, such features have been applied not only to popular music, but also to classical recordings. Studies have demonstrated their potential in clustering stylistic categories, predicting musical moods, and even modeling listener preferences.<sup>15</sup> While their application to historically informed performance requires caution—given their abstraction from traditional musical categories—they nonetheless offer a consistent framework for examining expressive variance.<sup>16</sup>

When used in combination with musicological knowledge, these features become interpretive tools. Metrics like valence, for example, can signal harmonic brightness or emotional resonance, while energy may reflect bowing intensity or articulatory choices. The ability to track these variables across a corpus enables new forms of performance analysis, especially when recordings are controlled for variables such as artist and recording conditions. By focusing on Malikian’s recordings of Bach and Paganini, this study adopts an approach that is both controlled and comparative. The same performer, recorded in the same year, interpreting two dramatically different repertoires—this rare configuration provides an ideal testbed for examining how digital analysis can capture nuances of interpretative difference. The following section outlines the methodological steps used to construct, process, and analyze the dataset.

### 3. Methodology

This study follows a comparative design aimed at identifying interpretive differences between two contrasting violin repertoires—Bach’s Sonatas and Partitas and Paganini’s 24 Caprices—as performed by Ara Malikian. The methodology

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<sup>14</sup> PINTER A., PAUL J., SMITH J. & BRUBAKER J., *P4KxSpotify: A Dataset of Pitchfork Music Reviews and Spotify Musical Features*.

<sup>15</sup> DALIDA M., AQUINO L., HOD W., AGAPOR R., HUYO-A S. & SAMPEDRO G., *Music Mood Prediction Based on Spotify’s Audio Features Using Logistic Regression*, 2022 IEEE 14th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment, and Management (HNICEM), <https://doi.org/10.1109/hnicem57413.2022.10109396>; SHINDE S., KULKARNI S., KULKARNI P., BHATT A., *Machine Learning Based Clustering Using Spotify Audio Features*, 2023 1st DMIHER International Conference on Artificial Intelligence in Education and Industry 4.0 (IDICAIEI), <https://doi.org/10.1109/idicaiei58380.2023.10406332>.

<sup>16</sup> SINGH C., KUMAR T., *Efficient Pitch Detection Algorithms for Pitched Musical Instrument Sounds: A Comparative Performance Evaluation*, 2014 International Conference on Advances in Computing, Communications and Informatics (ICACCI), <https://doi.org/10.1109/icacci.2014.6968303>; TAN C., WONG K., BASKARAN V., ADHINUGRAHA K., TANIAR D., *Is It Violin or Viola? Classifying the Instruments’ Music Pieces Using Descriptive Statistics*, «ACM Transactions on Multimedia Computing, Communications, and Applications», 19 (2s), 2023, pp. 1–22. <https://doi.org/10.1145/3563218>.

combines audio feature extraction via Spotify’s API with statistical summarization and interpretive reflection. The goal is not to reduce interpretation to numbers, but to trace patterns that emerge from quantifiable sonic descriptors when applied consistently across a controlled performance corpus.

### 3.1. Corpus Construction

The dataset includes 55 recordings released by Ara Malikian in 2003: 31 corresponding to Bach’s Sonatas and Partitas for Solo Violin (BWV 1001–1006) and 24 representing Paganini’s Caprices, Op. 1. Both albums were released in the same year, under comparable recording conditions and production values. This level of consistency minimizes potential confounding factors such as microphone placement, studio ambience, or engineering bias, allowing greater confidence in interpreting expressive trends as reflections of the performer’s artistic choices. Each track was identified through Spotify’s metadata and manually verified to ensure alignment with the original scores. The uniformity of the artist and recording environment enhances the internal validity of the comparisons. The decision to focus on a single performer was motivated by the desire to isolate differences in interpretive approach across repertoires, rather than across performers.

### 3.2. Feature Selection and Data Extraction

Audio features were extracted using Spotify’s Web API, which generates metadata derived from automated analysis pipelines trained on large-scale audio corpora. While initially designed for music discovery and streaming analytics, these features have gained traction in academic research across disciplines ranging from music information retrieval to listener behavior modeling.<sup>17</sup>

The features selected for this study are among the most stable and interpretable in the context of solo instrumental music:

- \* Tempo (BPM): Beats per minute, indicating average speed.
- \* Energy: A composite measure of perceived intensity and activity.
- \* Danceability: Degree to which a track has a steady pulse and rhythmic clarity.
- \* Loudness: Overall sound level, measured in decibels (dB).
- \* Valence: Brightness or positivity of the musical affect.
- \* Acousticness: Probability that a track is acoustic in nature.
- \* Duration: Total length of the track, converted to seconds for consistency.

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<sup>17</sup> PINTER A., PAUL J., SMITH J. & BRUBAKER J., *P4KxSpotify: A Dataset of Pitchfork Music Reviews and Spotify Musical Features*; DALIDA M., AQUINO L., HOD W., AGAPOR R., HUYO-A S. & SAMPEDRO G., *Music Mood Prediction Based on Spotify’s Audio Features Using Logistic Regression*; MACHMUDIN D., NOVITA M., ARDANESWARI G., *Analysis of Spotify’s Audio Features Trends Using Time Series Decomposition and Vector Autoregressive (VAR) Model*, Proceedings of the International Conference on Data Science and Official Statistics 2023 (1), 2023, pp. 613–27. <https://doi.org/10.34123/icdsos.v2023i1.375>.

While some features such as “danceability” and “valence” are conceptually distant from traditional music theory, they can still serve as heuristic indicators of expressive phenomena. For instance, danceability may correlate with rhythmic articulation and metric regularity, while valence may align with modal brightness or major tonal centers.<sup>18</sup>

### 3.3. *Data Preparation and Preprocessing*

All feature values were standardized and cleaned using Python’s Pandas and NumPy libraries. Track durations, originally formatted as minutes and seconds, were converted into total seconds. Composer and repertoire variables were encoded categorically to allow for comparison. Outliers were retained rather than removed, on the grounds that extreme values in tempo, loudness, or energy may represent legitimate artistic decisions—particularly relevant in the case of Paganini’s stylistic volatility. Rather than treating such instances as anomalies, the analysis considers them part of the expressive fabric of the repertoire. Descriptive statistics—mean, median, range, and standard deviation—were computed for each feature across the two repertoires. These metrics were then visualized using boxplots and summary tables to reveal patterns and contrasts. Although the dataset is too small for robust inferential statistics, the consistency of performer and recording conditions allows meaningful comparative inferences to be drawn from the descriptive data.

## 4. *Interpreting Expression Through Data: A Comparative Analysis of Performance Profiles*

The expressive character of a musical performance emerges not only from the score but from a performer’s ability to shape and articulate sound in ways that resonate with historical style, personal intent, and the physicality of instrumental technique. In this context, analyzing Ara Malikian’s interpretations of Bach’s Sonatas and Partitas and Paganini’s 24 Caprices through Spotify’s audio features offers a unique lens into how two divergent repertoires are rendered through a single artistic voice. While the sonified data extracted from these performances are abstractions—relying on algorithmic interpretations of sound—they nonetheless trace patterns that align with interpretive strategies grounded in the distinct aesthetics of each composer.

Malikian’s performances of Bach display relatively lower energy and loudness, with a more consistent tempo across movements. The energy levels in Bach average below 9 on Spotify’s scale, with modest variance, suggesting a restrained and measured approach. These trends are summarized numerically in Table 1, which shows the mean and variability for each audio feature by composer.

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<sup>18</sup> HUANG R., *Uncovering Audio Features Shaping Popularity in Chart-Topping Songs: A Statistical Approach*, «AJSR - American Journal of Student Research», 2024, pp. 158-174, <https://doi.org/10.70251/hyjr2348.24158174>.

COMPOSER	BPM (Mean)	BPM (SD)	Energy (Mean)	Energy (SD)	Dance (Mean)	Dance (SD)	Loud (Mean)	Loud (SD)	Valence (Mean)	Valence (SD)	Acoustic (Mean)	Acoustic (SD)	Length_sec (Mean)	Length_sec (SD)
BACH	112.81	24.14	8.84	10.03	41.90	10.73	-20.13	2.54	66.93	33.79	99.26	0.23	270.16	187.33
PAGANINI	112.67	31.47	15.54	9.06	48.12	12.61	-18.00	2.28	41.42	24.04	98.83	1.02	269.08	192.20

Table 1. Descriptive Statistics of Spotify Audio Features for Bach and Paganini Performances (Ara Malikian, 2003)  
 Source: Author. Mean and standard deviation values reflect key expressive parameters extracted from Spotify

A more granular view of tempo is provided in Figure 1, which compares the distribution of BPM across the two repertoires. Although mean values are similar, the greater spread observed in Paganini’s performances reflects the interpretive volatility and technical flexibility demanded by his Caprices. This variability, which includes both rapid virtuosic episodes and more contemplative passages, contrasts with the tighter tempo clustering in Bach’s works, where structural cohesion guides interpretative decisions.

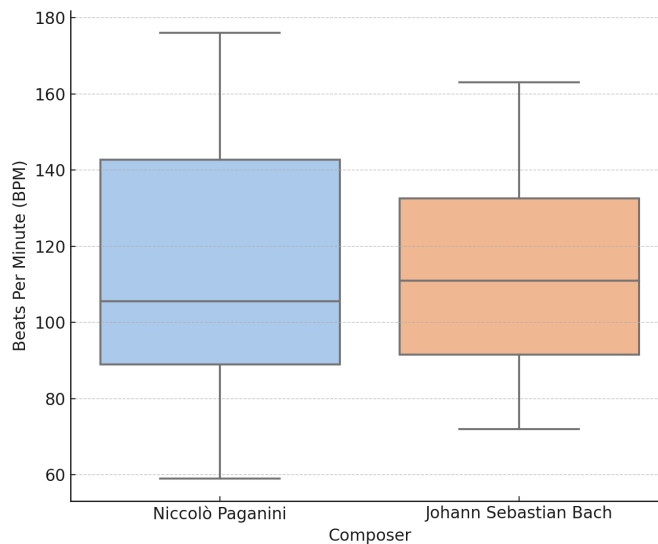


Figure 1. BPM Distribution. Source: Author

This echoes earlier musicological assessments that characterize Bach’s solo works as demanding clarity, structural awareness, and an introspective mode of expression.<sup>19</sup> Cadek’s framing of these pieces as a “perpetual challenge” speaks not only to their technical demands but to the expressive restraint they require—an interpretive stance that is difficult to quantify, yet partially reflected in such statistical consistency.<sup>20</sup> By contrast, Malikian’s readings of Paganini’s caprices exhibit higher average energy and greater variability in tempo. These differences are not merely technical markers; they illustrate the dynamic and extroverted nature of Paganini’s musical idiom. The

<sup>19</sup> GRATOVICH E., STEINER D., *Bach’s Solo Sonatas and Partitas for Violin: Guide to Practicing and Performing*.

<sup>20</sup> CADEK O., *Bach—Perpetual Challenge: The Six Solo Sonatas for Violin*.

energetic contrast is also visualized in Figure 2, where Paganini’s works show consistently higher energy levels and a broader interquartile range. While Bach’s music evokes restraint and balance, the higher energy readings in Paganini capture an expressive ethos rooted in intensity, drama, and immediacy—elements that define the Romantic ideal of musical virtuosity.

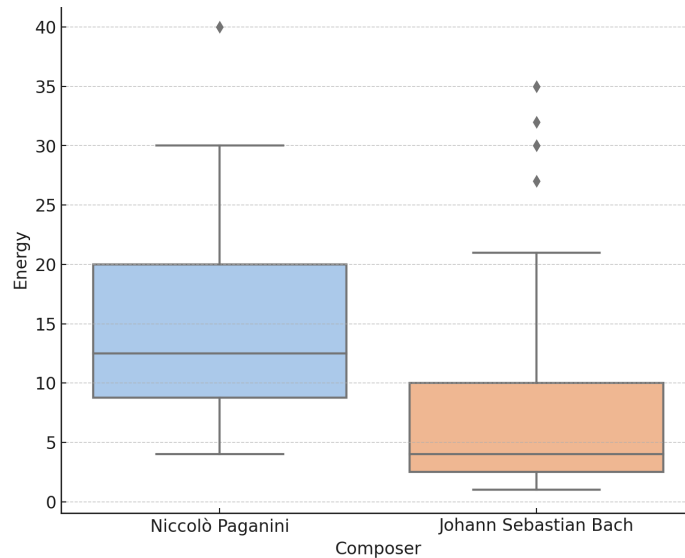


Figure 2. Energy Distribution. Source: Author

Historical research underscores that Paganini’s innovations—his left-hand pizzicatos, extended use of harmonics, and bowing gymnastics—were conceived as much for their sonic novelty as for their theatrical potential.<sup>21</sup> The expressive volatility visible in the data, particularly in the broader tempo and energy ranges, is consistent with what Penesco identifies as the “spectacular paradigm” of Romantic violinism.<sup>22</sup>

Valence offers a particularly instructive window into affective differentiation. Spotify defines valence as a measure of musical positivity, an emotional brightness derived from harmonic, rhythmic, and textural cues. In Malikian’s interpretations, Bach consistently registers higher valence values than Paganini. While one might assume Paganini’s virtuosic flair would translate into brighter expressive content, the lower valence scores reflect his frequent use of minor keys, chromatic inflections, and dramatic phrasing. Bach’s higher valence—averaging nearly 67 compared to Paganini’s 41—may correlate with more diatonically stable harmonies and rhythmically grounded phrasing, particularly in movements like the *Preludio* or *Gavotte en Rondeau*. From an analytical standpoint, this aligns with interpretations of Bach as a composer of spiritual architecture and harmonic logic. Stinson’s work on the Kellner manuscript highlights the structural intentionality embedded in Bach’s solo works, an element that may

<sup>21</sup> POLNAUER F., *Modern Research Illuminates the Violin Technique of Paganini*; ISTEL E., *The Secret of Paganini’s Technique*.

<sup>22</sup> PENESCO A., *Portrait de l’artiste violoniste en virtuose*, «Romantisme», 128 (2), 2005, pp. 19–34, <https://doi.org/10.3917/rom.128.0019>.

resonate aurally as “positivity” in algorithmic terms.<sup>23</sup> This contrast also evokes the distinctions drawn by Levinson between structural expressivity and dramatic gesturing, framing Bach as rhetorically luminous and Paganini as theatrically potent.<sup>24</sup>

Spotify’s audio features also point toward differences in rhythmic organization. Danceability—a measure derived from tempo stability, beat strength, and overall regularity—is higher in Paganini’s recordings. This is not to say that his caprices are more dance-like in genre, but rather that their phrasing is more metrically predictable and pulse-driven. This observation is consistent with Paganini’s historical use of rhythmic clarity to showcase technical brilliance, as noted in studies of his Caprices as pedagogical and performative landmarks.<sup>25</sup> Bach’s lower danceability reflects the metric ambiguity and polyphonic texture of many of his movements. Joachim, in his early reflections on these works, described them as both “polyphonic and poetic,” underscoring their rhetorical fluidity and resistance to beat regularity.<sup>26</sup> These comparative distributions are visualized in Figure 3, illustrating the central tendencies and variability of each expressive feature by composer.

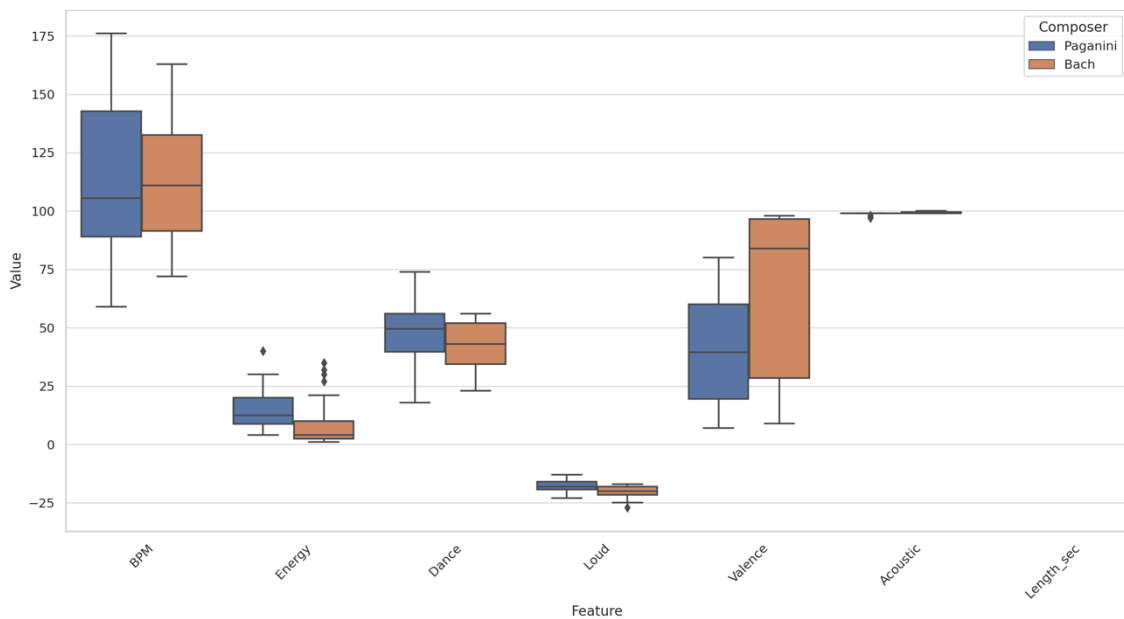


Figure 3. Comparative Distribution of Audio Features in Malikian’s Performances of Bach and Paganini. Source: Author. Boxplots show variability in tempo (BPM), energy, danceability, loudness, valence, acousticness, and duration.

An examination of acousticness confirms that both repertoires are fully acoustic, as expected from solo violin works, but minor variations may relate to ambient conditions or post-processing in recording. This consistency provides methodological confidence

<sup>23</sup> STINSON R., *J.P. Kellner’s Copy of Bach’s Sonatas and Partitas for Violin Solo*.

<sup>24</sup> LEVINSON J., *Music, Art, and Metaphysics: Essays in Philosophical Aesthetics*, Ithaca, NY: Cornell University Press, 1990.

<sup>25</sup> ANDERSON R., *Violin Concerto No.1; 24 Caprices*; KREGOR J., *Forging ‘Paganinis of the Piano’ in the 1830s*.

<sup>26</sup> JOACHIM H., *Bach’s Solo Violin Sonatas and the Modern Violinist*.

in using these recordings for comparative analysis, particularly when interpreting the acoustic profile as a stable backdrop against which expressive variations manifest. Acousticness, while not inherently expressive, becomes an anchoring parameter—it confirms that what is being measured is shaped more by interpretive choice than by extramusical intervention or technological alteration.

The loudness data further illustrate the stylistic contrast. Paganini’s recordings are, on average, two decibels louder than Bach’s. This might seem like a negligible figure, but when contextualized within performance practice, it underscores a fundamental difference in approach. The higher average loudness reflects the extroverted projection required to communicate Paganini’s virtuosic language. Ginsborg’s examination of virtuosity notes that projection and clarity are not merely technical goals but expressive imperatives in Romantic performance, where the artist must "occupy space" both acoustically and affectively.<sup>27</sup> In Malikian’s interpretations, louder performances of Paganini are not only a function of the music’s difficulty but also a reflection of its theatrical lineage. A more nuanced reading emerges from the derived expressive indices, such as the standard deviation in loudness z-scores. Paganini’s performances show a greater spread, suggesting a wider dynamic palette—more contrasts between pianissimo and fortissimo, or perhaps sharper gradations in dynamic shaping. This aligns with what Kucherenko identifies as the Romantic evolution of violin mastery: the cultivation of expressive extremes as a defining feature of interpretive identity.<sup>28</sup> These observations are detailed in Table 2, where the dispersion of expressive features across each repertoire is highlighted.

COMPOSER	Energy SD	Loud SD	Valence SD
BACH	10.03	2.54	33.79
PAGANINI	9.06	2.28	24.04

*Table 2. Variability in Expressive Audio Features Across Repertoires*

*Source: Author. Standard deviations in selected features reveal expressive volatility and control across composers.*

To further explore the internal dynamics of these expressive features, Figure 4 presents a correlation matrix of all Spotify-derived variables. The heatmap reveals notable positive correlations between tempo, energy, and valence, especially within Paganini’s interpretations—suggesting that faster tempi often coincide with heightened emotional brightness and intensity. In contrast, Bach’s profile demonstrates weaker or neutral correlations, indicating a more independent handling of expressive dimensions. These findings reinforce the idea that Paganini’s performance style is more affectively integrated, while Bach allows for expressive compartmentalization.

<sup>27</sup> GINSBORG J., *The Brilliance of Perfection or Pointless Finish? What Virtuosity Means to Musicians*.

<sup>28</sup> KUCHERENKO S., *Violin Etudes of the 19th Century in the Aspect of the Evolution of Performing Mastery*.

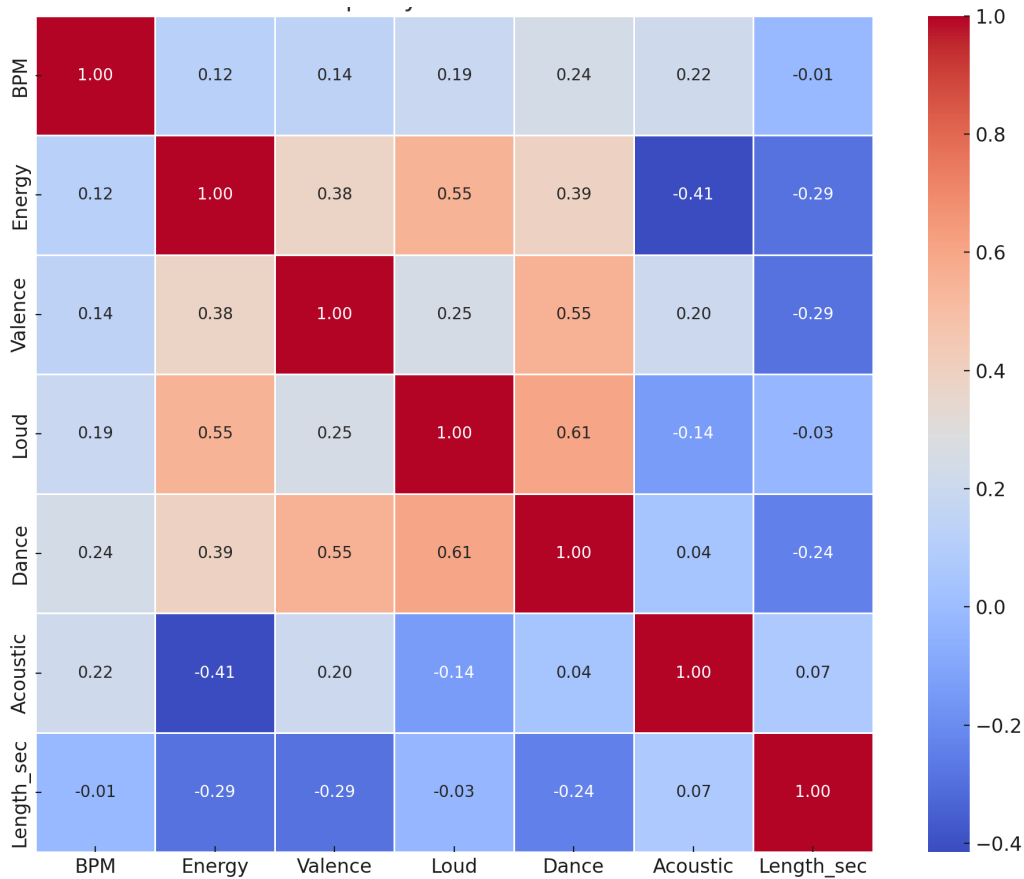


Figure 4. Correlation Heatmap of Audio Features. Source: Author.

### 5. Expression in Flux: Reading Interpretative Identities through Sound

Listening to Ara Malikian’s performances of Bach and Paganini is to experience a dialogue across centuries—one shaped not only by technical command, but by an evolving sense of expressive purpose. These are not just works separated by time and style; they embody contrasting visions of what the violin can communicate. Through the lens of digital analysis, a new contour of interpretation emerges—one that shows how even in the hands of a single artist, musical expression takes divergent forms, shaped by historical memory, physical gesture, and artistic imagination. Malikian’s approach to Bach reveals a careful balance between structural fidelity and expressive poise. His interpretations show an overarching consistency—in tempo, dynamic range, and emotional brightness—that mirrors the compositional clarity often associated with the Sonatas and Partitas. This aligns with traditional understandings of Bach’s solo violin works as “perpetual challenges” of both technique and restraint, demanding an interpretative stance that fuses control with rhetorical sensitivity.<sup>29</sup> The relatively stable expressive profile in these recordings resonates with the Baroque ideal of proportion, where emotion is not absent, but meticulously embedded in contrapuntal form.

<sup>29</sup> CADEK O., *Bach—Perpetual Challenge: The Six Solo Sonatas for Violin*.

These readings reflect a broader tradition of historically informed performance, grounded in scholarship around sources such as the J.P. Kellner manuscript,<sup>30</sup> and further developed in pedagogical guides that advocate for clarity in ornamentation, voicing, and phrasing.<sup>31</sup> As Joachim once noted, Bach’s writing requires the violinist to “speak in multiple voices,” suggesting that expressive clarity must emerge not from exaggeration, but from internal balance.<sup>32</sup> In contrast, Malikian’s treatment of Paganini is expansive, volatile, and charged with extroversion. Here, the data reflect a broader palette: greater variability in tempo, higher intensity levels, and dynamic extremes. These shifts are not accidental; they are embedded in the very fabric of Paganini’s writing, where technical ingenuity becomes a vehicle for expressive display. His innovations in violin technique—from left-hand pizzicato to ricochet bowing—were, as Polnauer (1965) and Istel (1930) observed, not merely technical feats, but expressions of an artistic persona that blended sound with spectacle. The Romantic ethos that underpins Paganini’s caprices demands more than dexterity. As Kregor (2013) suggests, it involves a performative identity forged through public charisma and virtuosic excess—a tradition that Malikian channels with intensity. His interpretations recall what Penesco (2005) describes as a “spectacular paradigm,” where expressiveness lies not in subtle inflection but in contrast, flair, and the theatrical occupation of sonic space.

This expressive dichotomy—between Bach’s rhetorical intimacy and Paganini’s affective display—finds resonance in the algorithmic approximations offered by digital audio features. Features such as valence, danceability, and energy, while originally developed for popular music contexts, illuminate underlying tendencies in interpretative strategy. Bach’s consistently higher valence in these analyses may reflect not emotional simplicity but a harmonic clarity and tonal stability rooted in diatonic design.<sup>33</sup> Paganini’s lower valence, despite his virtuosity, suggests a more unstable tonal world—one that draws on chromaticism and rhythmic fragmentation to evoke intensity and ambiguity.<sup>34</sup> Danceability, too, becomes a revealing measure. While neither composer wrote dances in a literal sense, the metric accentuation and pulse regularity in Paganini’s works translate algorithmically into higher danceability scores. This points to a rhythmic design focused on propulsion and immediacy—qualities central to his idiom.<sup>35</sup> Bach, with his frequent use of metric displacement and polyphonic layering, resists such regularity, offering instead a fluid temporal landscape that Joachim (1931) memorably described as “poetic and polyphonic.” What emerges is a view of interpretation not as a fixed template, but as a responsive continuum. Malikian does not project a single expressive identity across both composers; he

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<sup>30</sup> STINSON R., *J.P. Kellner’s Copy of Bach’s Sonatas and Partitas for Violin Solo*.

<sup>31</sup> GRATOVICH E., STEINER D., *Bach’s Solo Sonatas and Partitas for Violin: Guide to Practicing and Performing*.

<sup>32</sup> JOACHIM H., *Bach’s Solo Violin Sonatas and the Modern Violinist*.

<sup>33</sup> LEVINSON J., *Music, Art, and Metaphysics: Essays in Philosophical Aesthetics*; STINSON R., *J.P. Kellner’s Copy of Bach’s Sonatas and Partitas for Violin Solo*.

<sup>34</sup> GINSBORG J., *The Brilliance of Perfection or Pointless Finish? What Virtuosity Means to Musicians*.

<sup>35</sup> ANDERSON R., *Violin Concerto No.1; 24 Caprices*; KREGOR J., *Forging ‘Paganinis of the Piano’ in the 1830s*.

adapts. His readings of Bach and Paganini reflect two ends of a spectrum—from introspective formalism to extroverted virtuosity. And yet, there are moments when these roles blur: when a Paganini caprice receives a moment of lyricism, or when a Bach movement is delivered with striking rhythmic momentum. These crossings complicate any attempt to categorize interpretation rigidly. They reveal the elasticity of performance—the capacity to move between affective registers without undermining stylistic integrity. For educators and students, this flexibility offers important lessons. Digital tools, when used with sensitivity, can reveal patterns of expression that may otherwise remain tacit. They do not replace interpretive judgment, but provide a mirror in which stylistic choices can be seen more clearly. The data do not tell us how to play Bach or Paganini; they help us ask better questions about why we play them the way we do. More broadly, this kind of analysis affirms that interpretation is not only a matter of fidelity to a score, but of engagement with a tradition. It is shaped by the music’s origins, by the performer’s intentions, and by the listener’s expectations. In tracing these contours through data, we begin to understand interpretation as a living practice—situated between history and imagination, repetition and reinvention.

## 6. *Conclusions*

Exploring the balance between data and expression in classical performance opens new ways of thinking about interpretation—how it unfolds, how it can be understood, and how it might be taught. Observing Ara Malikian’s interpretations of Bach and Paganini through the lens of digital audio features offers more than a stylistic comparison; it reveals how expressive identity takes shape when a performer moves between two fundamentally different musical worlds. In Bach’s Sonatas and Partitas, shaped by contrapuntal logic and rhetorical poise, Malikian adopts a disciplined, almost meditative approach. The energy remains restrained, the phrasing carefully shaped, and the expressive palette subtly calibrated. There’s a clarity here—an insistence on balance, on the harmonic transparency that gives this music its inner radiance. Rather than dramatizing, the performance seems to listen inward, aligning with a long tradition that reads Bach as both architect and philosopher of sound.

Paganini’s 24 Caprices tell a different story. Here, Malikian’s interpretive voice shifts—becoming more volatile, more theatrical. The tempo pushes outward, the dynamics range wider, and the expressive profile leans into contrast and intensity. This is not only a response to technical demands but a reflection of a Romantic ethos that prizes spectacle, gesture, and unpredictability. What emerges is a sound world shaped by daring and risk, echoing Paganini’s legacy as a master of innovation and illusion. Digital features such as tempo, valence, or energy—when read not as objective markers but as traces of interpretive gesture—help make these expressive differences visible. They don’t replace listening, but they offer a complementary perspective, one that highlights how choices unfold across the arc of a piece, or a recording, or a repertoire. Rather than narrowing the scope of interpretation, they deepen our capacity to recognize how expression travels through form, phrasing, and touch.

This comparative insight also speaks to the way musicians adapt their expressive vocabulary. Between Bach and Paganini, the interpretive register doesn't just change—it transforms. Malikian doesn't apply a fixed aesthetic; he reshapes his performance language, responding not only to the score but to the cultural and historical imagination each composer inhabits. There is also something pedagogically valuable in this approach. Making expressive features visible—through charts, through descriptors, through pattern—can help students connect emotional intuition with structural awareness. It becomes possible to ask: where does the tension build? How does articulation shape mood? How does energy relate to narrative? When seen in this way, interpretation is not a stable truth but a living process. It bends with the repertoire, it reflects artistic intent, and it speaks to listeners in multiple registers. The violin, in Malikian's hands, doesn't only render sound—it creates character. What we hear in these performances is not just technique or fidelity, but expressive strategy. A way of speaking through music that respects difference, embraces contrast, and lets each work unfold on its own terms.

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