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Expressive Timing and Tempo Variance in Six Landmark Recordings of Villa-Lobos' Etude No. 1: A Sonic Visualizer-Based Computational Analysis

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Abstract: : Prior research on expressive timing has focused on piano and violin, providing models for quantifying tempo and dynamic patterns, but has rarely addressed plucked-string instruments. This absence of a comparative, data-driven study represents a significant gap in defining an interpretative expression of music performance research in classical guitar. The structure of the harmonic language of Villa-Lobos' Etude No. 1 is essential for explaining expressive phenomena. Since mechanical, regular arpeggio movements shape the pattern of this etude. However, there is no prior multi-recording, quantitative comparison of guitarists' expressive timing for this work. This study addresses that gap by applying Sonic Visualiser on six landmark recordings (Segovia, 1961; Parkening, 1971; Bream, 1978; Yepes, 1979; Romero, 1987; Vidović, 2009), from which it extracted tempo curves and intensity profiles, aligned them to a reference score, and calculated per-performer basic tempo, global/local tempo variation, and coefficient of variation (CV). This study was structured in three sequential stages: data collection, data processing, and data analysis, each aimed at examining the expressive timing characteristics in musical performance. The approach quantifies both structured tempo changes indicated in the score and unstructured performance deviations (structure and un-structure fluctuations) to capture each performance's expressive profile. The finding of this study demonstrates that Segovia exhibited the widest tempo range (112.84-187.33 BPM, CV 19.2%), while Yepes demonstrated the narrowest (124.61-161.85 BPM, CV 8.7%). Parkening (CV 13.1%), Bream (CV 16.8%), Romero (CV 14.2%), and Vidović (CV 11.5%) fell between these extremes. These existing patterns of basic tempo selection support the hypothesis that performers would display unique tempo selection strategies. These patterns quantify interpretive traditions and highlight how computer analysis correlates score prescriptions with the sounds performed.

Keywords: classical guitar recording; Villa Lobos; computational performance analysis; expressive timing; tempo variance; Sonic Visualizer; Etude No. 1

1. Introduction

Defining expressive performance of Western classical music based on performance recording is one of the most complex areas of musical inquiry, as it encompasses perceptual response, expressive embodiment, and analytical reasoning (Davies, 2001; Dolan et al., 2013) . This process involves a significant intersection of three disciplinary perspectives, including philosophy, musicology, and psychology. Philosophically, expressive classical performance is considered a manifestation of authenticity and the ontology of musical works, wherein the composer and performer engage in shared aesthetic and artistic dimensions (Agawu, 2025; Levinson, 2015). From a musicological perspective, the musical score has long been the primary site of meaning in traditional expressive performance in Western classical music. However, recent scholarship has repositioned Western classical music performance as a form of knowledge creation (Borio et al., 2020). In this context, Duby (2025) defines expressive music performance as a dynamic event in which the performer's interpretation transforms the musical blueprint into an acoustic reality, rather than merely a replication of a score. While in music psychology, expressive performance in Western classical music relies on performers' interpretive choices and on expressive musical terms (Gabrielsson, 1988; Lerch et al., 2020; Repp, 1992). The convergence of these three fields centres on the fundamental inquiry of how interpretive meaning is manifested and conveyed through the expressiveness of musical performance.

Fabian (2015) Mazzola (2010) and Kopiez (1996) state that an initial examination of the expressive performance in Western classical music, based on performance recordings, reveals two distinct and seemingly unrelated threads. One thread is empirical research, typically exemplified by Carl Seashore's *agogic* measurements. At the same time, the other is philosophical research, which deals with metaphorical description and tends to reflect normative thinking, as seen in Wintle. (1982) In the Analysis and Performance of Webern's concerto op.24/ii and the Analysis and Performance of Theodor Wiesengrund Adorno (Adorno & Lonitz, 2001).

In defining expressive performance of Western classical music based on performance recording, the philosophical approach examines the qualitative dimensions, exploring the thoughts that can be conveyed through performance, specifically the semantic content of expressivity. In this perspective, the expressiveness of music performance was dependent on subjective music criticism or phenomenological description. (Cumming, 2000). This results in findings being heavily reliant on individual perceptions, which can vary between listeners and viewers. This raises questions about objectivity and reproducibility, especially in the context of scientific inquiry.

In contrast, empirical research focuses on the quantitative dimensions of performance, providing numerical specifications for all parameters necessary to characterize its structure. The development of computational-based music analysis now facilitates the objective, quantitative assessment of performance parameters by means of the systematic extraction and comparison of acoustic data from recordings. (Bouzioti, 2023; Canazza & Poli, 2019; De Poli, 2022; Johanis, 2024). This conceptual development is in accordance with Taruskin's (1995) statement that a study in practice of performance is, ideally, an attempt to reconcile the discrepancy between the content of the old musical texts that have survived and the actual sound of typical contemporary performances, using documentary or statistical evidence. This thereby transitions performance studies from interpretive discourse to measurable analysis.

Empirical studies on performance, particularly those focused on computer-based music performance analysis, reveal how tempo variation, rhythmic flexibility, and dynamic shaping distinguish individual performers and historical performance traditions. These include recorded performances on the piano. (Bragagnolo & Guigue, 2020; Cook, 2020; Farnè, 2024; Kosta et al., 2018; Simonetta, 2022; Ueda, 2021; D. Zhou, 2020), choral and vocal (Hauck, 2020; Leech-Wilkinson, 2010), harpsichord performance (Koren & Gingras, 2014), as well as orchestra, choir, and soloists (D'Orazio, 2020), and violin (Fabian, 2015, 2017a, 2017b; Fabian & Schubert, 2009; Sung & Fabian, 2011).

Previous studies demonstrate that comparing recordings is, in fact, an excellent method of revealing and celebrating the incredible diversity of interpretations and personae revealed by the archive of recordings (Rutherford-Johnson, 2017; Scheirer, 2021; Shapovalova et al., 2024). Computational performance analysis provides a methodological bridge across philosophical, musicological, and psychological approaches to interpretation. Computer-based analysis transforms expressive nuance in the form of dynamic shaping and tempo fluctuation into quantifiable data, thereby identifying and examining interpretative phenomena (Cannam et al., 2010a; De Poli, 2022).

Despite the instrument's rich twentieth-century recorded tradition, it has significantly influenced perceptions of the classical guitar and its repertoire throughout the 20th century, as exemplified by Andrés Segovia, Julian Bream, and their successors. (Marrington, 2021). There are only two computational studies that address guitar performance through computational-based recording. Freire et al. (2014) examined right-hand techniques, while Freire and Cambraia (2015) Developed texture descriptors. Neither study conducted comparative tempo analysis across multiple recordings—previous work by Freire et al. (2014) as well as Freire and

Cambraia (2015) Focused primarily on isolated technical or textural parameters without comparing interpretative variance among major performers.

The structure of the harmonic language of Villa-Lobos' Etude No. 1 is essential for explaining expressive phenomena that exist in dealing with expressive timing and tempo variance. Since mechanical, regular arpeggio movements shape the pattern of this etude. The prior research on expressive timing (Fabian, 2015; D. Q. Zhou & Fabian, 2021) has concentrated on piano and violin, providing models for quantifying tempo and dynamic patterns but rarely addressing plucked-string instruments. Consequently, the field lacks a systematic understanding of how classical guitarists translate the notated rigor of Villa-Lobos's music into diverse expressive realizations. This absence of a comparative, data-driven study represents a significant gap in defining an interpretative expression of music performance research in classical guitar.

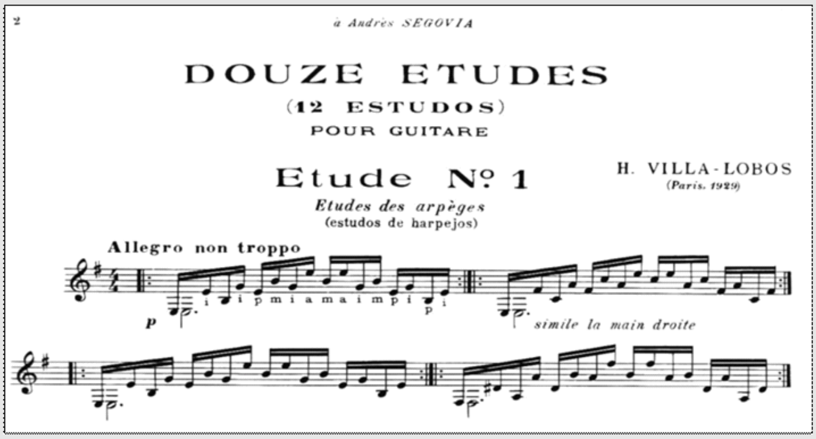
This study presents a performance recording of Villa-Lobos' Etude No. 1, focusing on the extraction of expressive elements in musical performances through visual and audio analysis, which compares six important figures of classical guitar performers. The analysis focuses on recordings made between 1961 and 2009 by six seminal guitarists: Andrés Segovia, Christopher Parkening, Julian Bream, Narciso Yepes, Pepe Romero, and Ana Vidović. These performers were selected as representatives of various pedagogical and stylistic lineages. The central research question guiding this investigation is: Do these landmark recordings exhibit systematic differences in basic tempo and in patterns of global and local tempo variation? This study posits research hypotheses indicating that the treatment of tempo, covering the selection of a base tempo, the range of tempo variations, and the characteristics of rhythmic deviations, will unveil unique performer-specific signatures.

Literature Review

Etude No. 1 is characterised predominantly by continuous arpeggiated motion as shown in Figure 1. The examination of expressive timing and tempo variance in performers' recordings of Villa-Lobos's Etude No. 1 is an interesting way to define expressive phenomena. Minor tempo variations of this etude significantly affect the apparent contour and nature of the individual expressions. Since it captures the very dimension where musical meaning, interpretation, and technical identity intersect. In Western classical performance, the notated text provides structural and rhythmic stability; however, what distinguishes one interpretation from another lies in the performer's manipulation of temporal flow, such as the subtle stretching, compression, or stabilization of tempo. (Fabian & Ornoy, 2009; Gabrielsson, 1988;

Repp, 1995). In this context, these temporal fluctuations are intentional expressive actions that convey phrase, emotion, and personality.

Figure 1. Max Eschig's Publication of 1953 of Villa-Lobos' Etude No.1



Villa Lobos' *Etude No. 1* is widely regarded as a crucial milestone for classical guitarists. (Canellas, 2016; Dragomir, 2021; Navia, 2020; Salles, 2009). The arpeggio pattern of etude no.1 is influenced in the same spirit as those of the Prelude in C major or the Little Prelude from Bach's "Well-tempered Clavier. The collection of Heitor Villa-Lobos's Twelve *Etudes* for Guitar, composed between 1924 and 1929, reveals that some of its concepts and overarching themes were conceived by the composer significantly earlier. (Ciraldo, 2007; Fraga, 1996; Santos, 1985). The Twelve Studies were published by *Max Eschig* Editions in Paris in 1953, as illustrated in Figure 1, accompanied by a dedication to the Spanish virtuoso Andres Segovia, who also contributed the foreword.

Technically, the arpeggios' lines are indicated with the mechanism's right-hand movement. *Etude No. 1* shows sophisticated ways of moving from one position to another, using different kinds of chords. The examination of Villa Lobos' Etude No. 1 reveals a combination of linear movement in the right hand and non-linear connections in the harmony. The linear right-hand movement sections are denoted by arpeggio motion. Meanwhile, the non-linear harmonious linkages are portrayed through a diverse range of tonalities. In each composition by Villa Lobos, the guitar's inherent qualities, both in terms of its physical characteristics and its characteristic style, serve as a foundation for a variety of melodic, harmonic, and textural elements. (Navia, 2020). Villa Lobos' *Etude No.1* features two distinct arpeggio patterns inside each chordal texture as illustrated in Figure 2. The ascending low-pitch movements indicate the first arpeggio patterns. The first arpeggios pattern is executed by combining *p-i, p-i, p-m, i-a*, where the distance between two strings is crossed by one

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string. Meanwhile, the second arpeggio pattern is indicated by the descending low-pitched movements. The second arpeggio pattern is played by combining m-a, i-m, *p-i*, which are two strings in sequence.

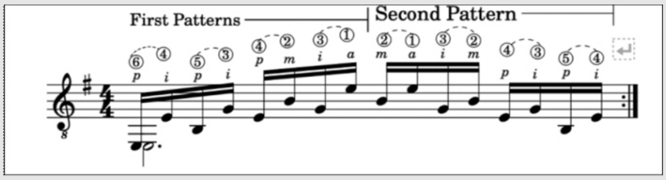


Figure 2: Arpeggio patterns Villa Lobos' Etude No.1

Two open strings "e" (1st, sixth) pulsate continuously on bars 12 to 22 as illustrated in Figure 3, forming a bass line that withstands the pedal—a strong organ point. According to Filatova (2024), the chords' movements on bars 12 to 22 show the foundation, passages from diminished seventh chords, recognized as the most expressive harmonies of that era, are layered with increasing intensity. The chord movements are systematically shifted along the fretboard in semitones, transitioning from the 10th fret to the 1st without any gaps or interruptions. The repetition of each step in the chromatic sequential movements occurs twice, thereby extending and amplifying the phase of expression. The open first and sixth strings function as a chord tone in this section, subsequently serving as a linear ornamental-figurative decoration. The musical architecture of bars 12-22 is expressly designed to challenge simple metronomic regularity. The role of the open strings introduces an additional dimension of localized tempo variation, thereby complicating the determination of a consistent, overarching tempo. The combination of a static drone in the form of a highly expressive harmonic sequence and shifting textures makes this section a crucible for expressive timing, and consequently, a significant challenge for determining a single, consistent tempo.

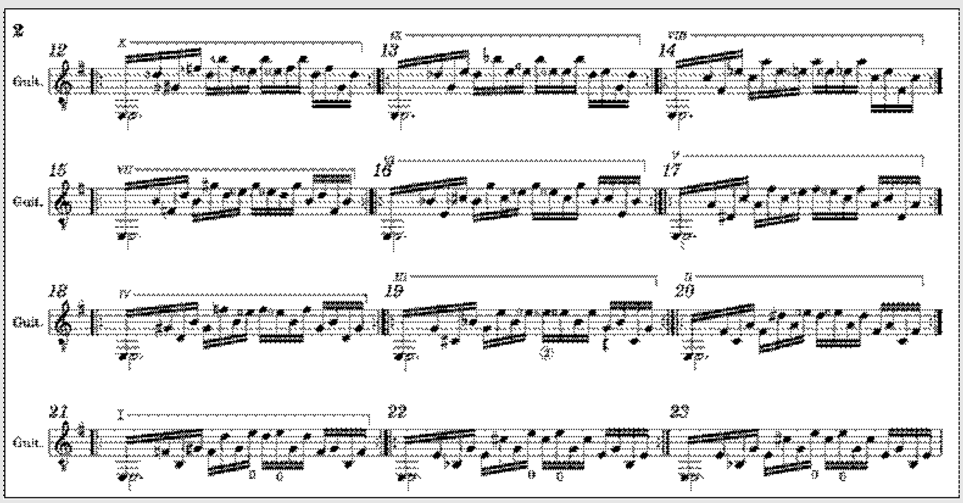



Figure 3: Diminished chord movements of Villa Lobos' Etude No.1 bars 12 to 22

Previous studies of Villa-Lobos's Etude No. 1 have examined its historical and biographical context, situating it within Villa-Lobos's legacy. (Fraga, 1996; Santos, 1985; Yates, 1997), as well as its formal structure, harmonic language, and symmetrical design principles (Canellas, 2016; Dragomir, 2021; Navia, 2020), in addition to its technical execution, fingering techniques, and practice methodology for arpeggio patterns and positional transitions (Carlevaro, 1988; Joyce, 2005).

However, these previous studies share a critical limitation. In this respect, all focus exclusively on the notated score, treating Villa-Lobos' Etude No. 1 as a compositional text rather than a performed phenomenon. No study examines how the work's technical and expressive demands manifest in actual recorded performances, nor whether performers' interpretive strategies converge or diverge when confronting identical compositional challenges.

This analytical gap has practical significance when considering Carlevaro's (1988) the assertion that Etude No. 1's mechanical importance lies in executing repeated arpeggios with constant right-hand angle position. Carlevaro's technical remark implicitly poses important questions. How do virtuosos implement tempo modification as an expressive choice? Gabrielsson (1988) Establishes that timing in music performance extends beyond mechanical execution to perceptual and expressive dimensions, while Gingras et al. (2011) Demonstrate that timing differences constitute primary markers of performer identity. Although these principles were established through piano and violin studies, no research has examined whether they apply to the guitar performance of Villa-Lobos' repertoire.

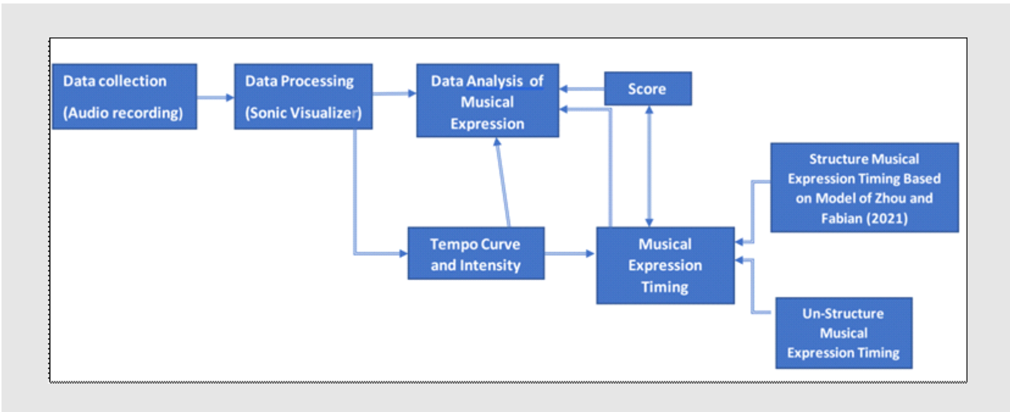
2. Methods

This study employs a computational–empirical design to examine expressive timing and intensity variation in six professional recordings of Heitor Villa-Lobos's Etude No. 1 for solo guitar. The objective is to quantify interpretative diversity through measurable parameters of tempo and dynamics using standardized digital audio analysis. The methodology is structured in three phases: (1) data collection and preprocessing, (2) computational extraction of musical parameters, and (3) statistical and comparative analysis. The design ensures transparency, reproducibility, and cross-verification with score-based reference points. For reproducibility and reliability purposes, the public Zenodo repository containing raw/processed data, as well as code, can be found at https://zenodo.org/records/17559333.

The previous studies show that performance parameters can be systematically categorized into the fundamental aspects that characterize musical audio in the form of tempo and timing (Bowen, 1996; Desain & Honing, 1994; Dodson, 2011; Fabian, 2017b; Honing, 2001, 2013; Leech-Wilkinson, 2015; Repp, 1990, 1995, 1998; Spiro et al., 2016; Sung & Fabian, 2011), pitch(Beauchamp et al., 1993; Fabian & Ornoy, 2009; Giraldo et al., 2019; Leech-Wilkinson, 2015; Nakamura et al., 2018; Pati et al., 2018), dynamics (Cheng & Chew, 2008; Clarke, 1998; Cook, 2009; Kosta et al., 2018) and timbre (Holmes, 2012; McAdams, 2019; Sköld, 2022; Vogels, 2017).

A substantial amount of research emphasizes the use of an exploratory method for analyzing performance recordings and detailing performance characteristics, such as tempo polarization. Deviations in tempo, timing, and dynamics are considered some of the most salient performance parameters and, therefore, have been the focus of various studies in music performance analysis using computer analytical tools. (Lerch et al., 2020; Palmer, 1997; Povel, 1977; Repp, 1990, 1992, 1995, 1998, 1999; Shaffer, 1984; Zhou & Fabian, 2021). Studies of this nature generally focus on extracting specific characteristics, including the tempo curve or histogram. (Palmer, 1989; Povel, 1977; Repp, 1990; Srinivasamurthy et al., 2017) and the loudness curve (Repp, 1998; Seashore, 2012) From audio recordings. This study was designed to collect, process, and analyze data on musical expressive timing, as illustrated in Figure 4.

Figure 4: Musical Expressive Timing Design



This study utilizes a systematic and data-driven methodology to analyze musical expressive timing in classical guitar performance. The strength of this methodology lies in its dual-layered structure, which effectively combines structured and unstructured expressive timing. The structured expressive timing is conducted based on tempo indications found in the score and established interpretative models. At the same time, the unstructured component recognizes tempo variations and expressive fluctuations that extend beyond the notated score. This facilitates a detailed comprehension of interpretative individuality. Additionally, the study utilizes tempo curves to identify both micro- and macro-expressive deviations, providing measurable insights into the interpretation of performance. The methodology integrates computational tools to quantitatively measure, compare, and statistically assess performance variations.

Current computational models of expressive timing, such as those proposed by Clarke (1999), Gabrielsson, (1988), Honing, (2013), Shi (2021) and Ueda (2021) focus predominantly on elucidating tempo variations. Their companies utilize *tempo curves*, which represent tempo or its reciprocal, duration as a function of score position, as their foundational framework. In defining musical expression, this study involves a critical examination of tempo, with a specific focus on the discrepancies between written scores and recorded performances.

This study was designed to identify expressive timing, encompassing both structured and unstructured musical expressions of timing. Theoretically, the structure of musical expressive timing is shaped by the relation between musical practice and notation (Desain & Honing, 1994; Honing, 2001, 2013; Quinn & Watt, 2006). Meanwhile, unstructured musical expressive timing is defined as alterations of tempo and rhythm that are not directly related to the score but affect more local aspects of temporal relationships between notes, also occurring during the performance of a work (Timmers et al., 2000). Mazzola (2010) states that musical practice and notation classify structured musical expressive timing in three distinct manners: absolute tempo signs, exemplified by Maelzel's metronomic notation; relative punctual tempo signs, including fermata and general pause; and relative local tempo signs, which encompass broader indications such as *ritardando, rallentando, and accelerando.*

Structured musical expressive timing of this study was adopted by a taxonomical model of tempo and variation by (Zhou & Fabian, 2021). This model presents a clear and precise taxonomy aimed at analyzing the similarities and differences in performers' styles regarding tempo and its variations. This model delineates six variables that correspond to three distinct dimensions of tempo and its variation: basic tempo, global tempo variation, and local tempo variation. Global tempo variation involves organizing the hierarchical structure of a composition at the phrase or section level, characterized as large-scale or macro variation, such as ritardando, rallentando, and accelerando, as well as sectional flexibility. In contrast, local tempo variation refers to the lengthening or shortening of beats or notes within a gesture, typically for expressive reasons. It occurs at the bar, beat, or note level, thus representing microvariation. Zhou & Fabian (2021) determine local tempo variation, which is referred to variously as *rhetorical tempo change* (Cook, 2010), *small-scale tempo change* (Bowen, 1996), *localized rubato* (Fabian, 2015) or *agogics* (Thiemel, 2001).

The 1960s and 1970s witnessed a standardization of classical guitar recording practices, allowing critical reception of recordings to rely on an established set of *sonic* criteria for evaluation (Marrington, 2021). Andrés Segovia played a crucial role in bringing *Villa Lobos' Etude No. 1* to a broader audience, (Achondo, 2024; Djahwasi et al., 2023; Segal, 1994) .Thus, making Villa Lobos' Etude No. *1* one of the standard concert pieces. In this study, data were collected from performances by six prominent classical guitarists, including Andrés Segovia, Narciso Yepes, Julian Bream, Pepe Romero, Christopher Parkening, and Ana Vidović. The performers are widely regarded as seminal figures in the history of the classical guitar. They represent distinct pedagogical lineages, stylistic approaches, and historical periods, providing a rich dataset for comparative analysis.

The primary data for this study consist of six audio recordings of Heitor Villa-Lobos's Étude No. 1, sourced from the publicly accessible YouTube platform. The use of these copyrighted recordings for analytical purposes is warranted under the principle of fair use or fair dealing in alternative jurisdictions. The study's objective is non-commercial, educational, and transformative in nature. In other words, the recordings are used as raw data for academic inquiry and analysis, rather than for reproduction. The analysis focuses on extracting quantitative data (tempo and dynamic information) rather than replicating the aesthetic experience of the original composition. All sources are clearly referenced to ensure complete attribution to the performers, publishers, and original broadcasters. The information presented in Table 1 outlines every source of data along with the corresponding recording years for each guitarist.

Table 1: Source of data

No.	Name	Sources of data	Recording years
1	Andrés Segovia	https://www.youtube.com/watch?v=eSluP6TiWBw	Guitar recital at Nymphenburg Palace, Munich, 1961.
2	Christopher Parkening	https://www.youtube.com/watch?v=_-24c3EEv0E	Live performance at WCBS/TV Studios, New York, 1971.
3	Julian Bream	https://www.youtube.com/watch?v=Xfekt-TN-tw	BMG Music 1978.
4	Narciso Yepes	https://www.youtube.com/watch?v=XdhO-vvrco4	a recital at the Palau Royal of Madrid in 1979.
5	Pepe Romero	https://www.youtube.com/watch?v=dxJ725jcz8o	Universal International Music B.V. 1987.
6	Ana Vidović	https://www.youtube.com/watch?v=O7WIwdnVdoA	Ocean Way Studios, Nashville, 2009.

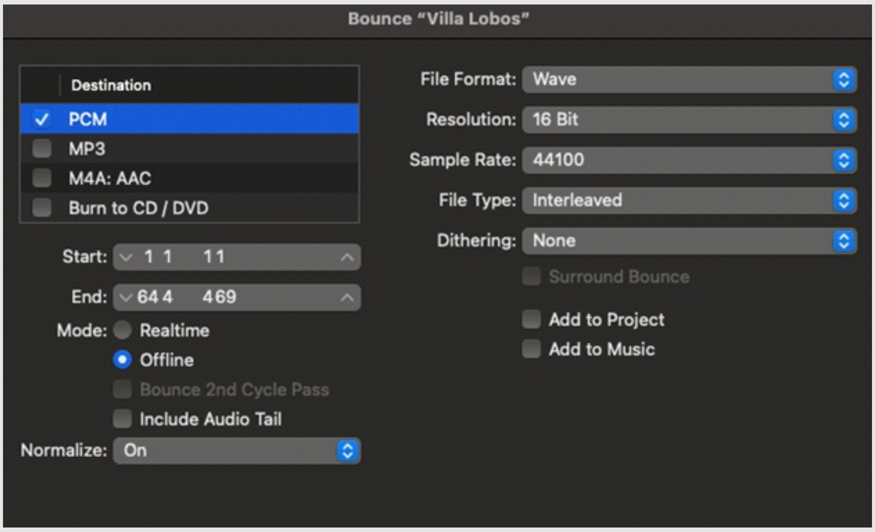
The recordings were sourced from a publicly accessible platform to ensure that the study's methodology is transparent and its results are, in principle, replicable by other researchers. All performers are playing from the standard 1929 *Max Eschig* edition of the work or a subsequent version with minimal editorial variance. While minor differences in articulation or dynamic markings may exist between editions, they are considered unlikely to systematically affect the macro-level expressive parameters of tempo and dynamics investigated in this study.

In most forms of Western music, timing is articulated through a (quasi-)regular pulse, with the beats serving as reference points from which all other timing is established. Time is the perception of expressive movement in music performance (Davidson, 1991; Shove & Repp, 1995).Tempo is a factor that is often linked to the expressive quality of a musical composition (Di Stefano, 2023; Doğantan-Dack, 2025). Composers frequently specify the tempo of a musical composition by employing numerical markings (in beats per minute) alongside subjective terms, such as adagio and allegro (Quinn & Watt, 2006). Musical time encompasses the rate of the pulse, known as tempo, and the positioning of individual notes in relation to that pulse, referred to as timing. Expressive effects arise from the manipulation of notes through lengthening, shortening, delaying, or anticipating them in relation to their expected timing and duration dictated by the prevailing pulse (Dixon, 2003). The aspect of time representation known as tempo serves as the reciprocal of durations, contingent upon the position within the score (Solomonova et al., 2023). Traditionally, it is quantified using a metronome (M.M.) number that specifies the number of beats per minute (bpm) during performance time. Analysis by measurement aims to identify regularities in deviation patterns and describe them using a mathematical model, relating scores to expressive values (Gabrielsson, 1999; Goebl et al., 2008; Sundberg, 1993; Zanon & Poli, 2003).

The primary goal of this investigation was to quantify and compare the expressive elements of tempo and intensity across six virtuoso recordings of Villa-Lobos' Etude No. 1. The methodology is structured to ensure high data fidelity, a replicable computational workflow, and to address the need for transparency in data provenance and analytical parameters. The six performances analyzed were sourced from publicly accessible video recordings available on the YouTube platform, as shown in Table 1 (video links). The use of these specific, widely cited recordings was deemed necessary to conduct a comparative study of the most influential interpretations, many of which lack commercially available digital masters. To mitigate the risks associated with these sources and establish scientific validity, a rigorous post-acquisition processing protocol was implemented, which includes provenance documentation, audio extraction, homogenization of bit depth and sampling rate, and acoustic normalization.

To mitigate algorithmic bias and ensure input signal consistency for Sonic Visualizer, all sourced audio was first technically homogenized. Each recording was converted to monaural (single channel), a standardized 44.1 kHz sample rate, and 16-bit depth using a standard command-line utility (or standard audio software). This step ensures input consistency for subsequent beat-tracking algorithms.

Figure 5. Standardize all audio output before audio analysis



To prevent variations in recording amplitude from biasing onset detection, all homogenized tracks were imported into Logic Pro (v10.7.4) using a digital audio workstation. Each file was then normalized to a consistent integrated loudness target of -11 LUFS (Loudness Units Full Scale). This process ensures that all performance files initiate the computational analysis pipeline at an equivalent perceived volume level, which is crucial for consistent onset and beat detection.

Figure 6. Normalization of audio

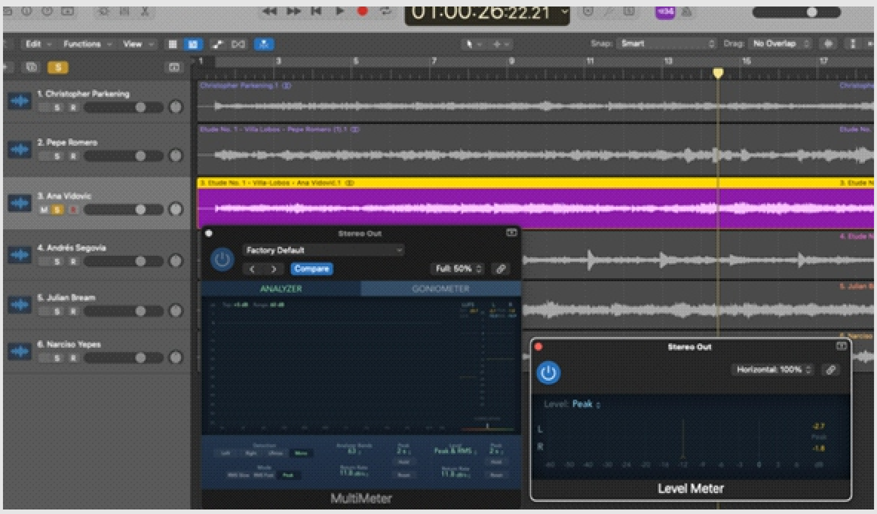
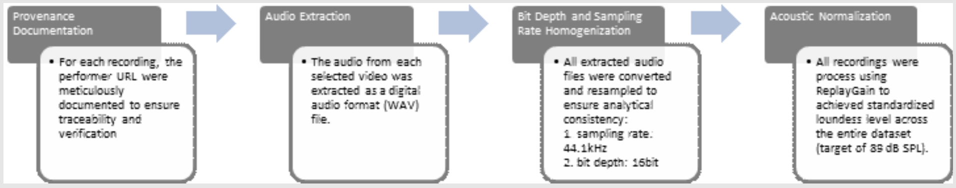


Figure 7. Processing protocol for audio analysis



Despite the limitations of fully automatic onset and beat detection, particularly in the context of classical music characterized by subtle onsets and fluctuating beat patterns, it is advisable to utilize semi-automatic annotation methods to achieve more dependable outcomes (de Clercq, 2023; Guichaoua et al., 2024; Konz et al., 2009; Scheirer, 2021) . In examining Etude No. 1, which is primarily defined by its continuous arpeggiated motion within a static beat pattern, the application of fully automatic onset and beat detection through visual tools (Franklin, 2023; Moroșanu et al., 2025). Sonic Visualizer is considered suitable for this analysis. Each recording was manually segmented and time-stamped using a canonical edition of the score as a reference. This process isolated the performance data strictly to the musical content of Etude No. 1, ensuring that all analyses refer to the same measure-to-measure structural points. The computational workflow was executed using specialized software to extract and quantify musical parameters.

Table 2: Software and version details

Parameter Extracted	Software Tool	Version	Purpose	Processing
Audio Visualization & Segmentation	Sonic Visualizer	v4.5.2	Score synchronization, event marking, and data annotation.	NA
Tempo (IOI) extraction	Aubio Beat Tracker (Sonic Visualizer Plugin)	v2	Automatic beat tracking and Inter - Onset-Interval (IOI) calculation	Peak Picker Threshold: 0.30 Silence Threshold: - 70.0dB Audio frames per block: 1024 samples Window increment: 512 samples
Intensity	Intensity (Sonic Visualizer Built -in RMS Power)	v1	Loudness curve extraction in decibels(dB)	Window size: 1024 samples Window increment: 1024 samples
Statistical Processing	Microsoft Excel	v16.102	Calculation of descriptive statistics (min, max, variance, duration)	NA

Poli (2004) Highlights a crucial challenge in the development of information-processing models that rely on performance recording and the need to clearly define the type of information to be addressed and the methods for its representation on a computer. Tempo and timing data for any version of a performer's recording can be acquired through software tools, such as *Sonic Visualizer* (Cannam et al., 2010; Cook & Leech-Wilkinson, 2009; Leech-Wilkinson, 2015), which are designed to identify note onsets. The tempo and intensity level of this study are visualized using the *Sonic Visualizer* software. Developed by Queen Mary, University of London, *Sonic Visualizer* is a program specifically designed for analysing recordings. According to Cook & Leech-Wilkinson (2009) *Sonic Visualizer* is one of the best ways to explore the details of recordings by using simple computer-based techniques across multiple recordings. Sonic visualizer-based investigations in the latest study were found in the study of *Mazurkabl*: score-aligned loudness, beat, and expressive markings data for 2000 Chopin mazurka recordings(Kosta et al., 2018)Text articulation and musical articulation in choral performance: a case study (Hauck, 2020), Performance analysis and *Chopin's mazurkas* (Cook, 2020) Analysis of sonority in piano pieces: a performance-based approach (Bragagnolo & Guigue, 2020), *Tempo Rubato* as Rhetorical Means: An Analysis of the Performance of *Chopin's Nocturne Op. 15-2* by Camille Saint-Saëns 1905 (Ueda, 2021).

In order to generate the comparative data, a computational workflow utilized the aubio library (with a 1024-sample window and specifying onset detection) to calculate IOI tempo, simultaneously extracted intensity via RMS with a 500ms smoothing filter, and finally employed Dynamic Time Warping to align the resulting expressive curves for measure-by-measure statistical analysis. The normalized and time-aligned tempo (BPM) and intensity (dB) data were exported as .csv files for statistical analysis in Excel. The following table details the operational definition and quantitative threshold used to distinguish between global and localized expressive timing in the performances:

Table 3: Operationalizing Structured and Unstructured Timings

Timing category	Definition	Operational metric	Quantitative threshold
Unstructured timing (global tempo)	Large-scale, long-duration tempo changes (rubato) spanning multiple phrases or sections.	Overall Mean Tempo (BPM) and Total Range (Max BPM - Min BPM).	Sustained tempo deviation for ≥ 4 consecutive measures.
Structured timing (micro-level deviation)	Localized, fine-grained tempo deviations are used to articulate structural features (e.g., ritardando, acceleration).	Local Tempo Variance (^{2}) in BPM, computed over rolling 2-measure windows.	Local tempo variance (^{2}) of ≥ 0.5 BPM2 within a 2-measure window

The selection of a 0.5 BPM^2 threshold for detecting localized tempo variation over a 2-bar rolling window is grounded in established analytical conventions that employ squared deviation metrics to quantify expressive nuance (Bowen, 1996; de Clercq,

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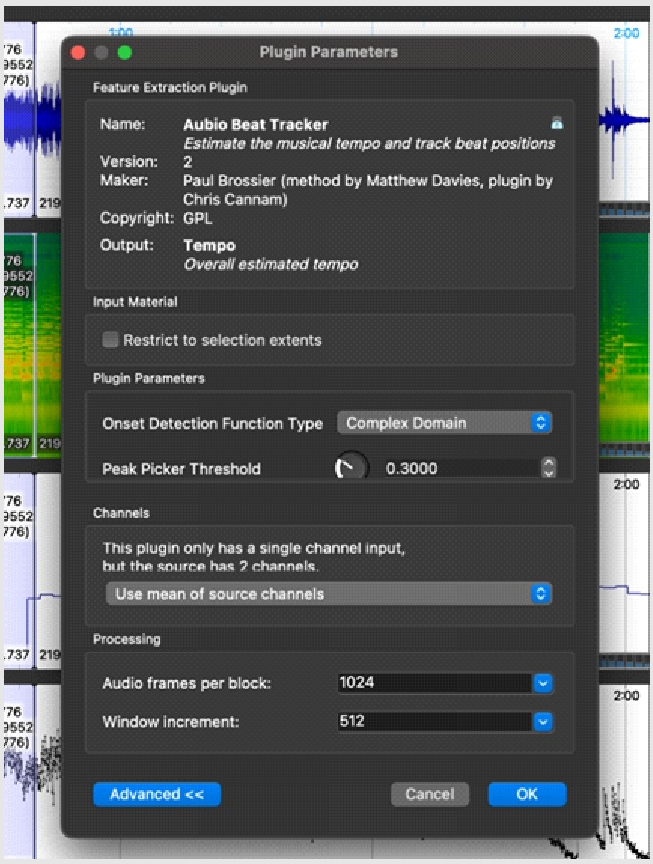
2023; Repp, 1995). While the field lacks a universally codified threshold, this study reinforces the methodological validity of the chosen value through a targeted sensitivity analysis. By systematically adjusting the threshold within a ±20% range (0.4–0.6 BPM^2), it was demonstrated that key interpretive groupings and expressive timing classifications remained consistently intact. This empirical stability substantiates the reliability of the threshold and aligns with best practices in performance analysis, where robustness testing is essential to ensure analytical resilience and mitigate parameter bias (De Poli, 2022; Gabrielsson, 1999b; Giraldo et al., 2019).

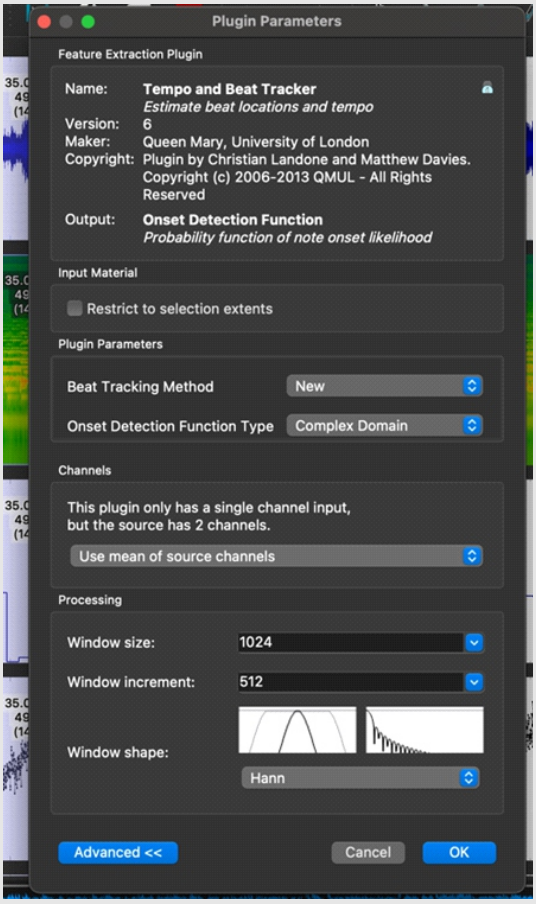
Descriptive statistical analysis was performed using Microsoft Excel to characterize and compare the performance data: (a) Central Tendency and Duration: The Total Duration (in seconds) was measured. The overall mean tempo (in beats per minute, BPM) and mean intensity (in decibels, dB) were calculated for each performance. The maximum and minimum values were used to determine the total dynamic range and tempo flexibility used by each performer; (b) Dispersion: The variance.

Figure 8. Aubio beat tracker plugin parameter setting



The Aubio Beat Tracker plugin was used to provide a reliable, global tempo estimate for each recording.

Figure 9. Tempo and beat tracker plugin parameter setting



The Tempo and Beat Tracker plugin was then explicitly employed for its Onset Detection Function (ODF) capabilities, which locate the precise temporal positions of note attacks. For reproducibility, the following key parameters were applied during this extraction process: The Onset Detection Function (ODF) utilized was the Complex Domain, with the use of the mean of source channels, a window size of 1024, and a window increment of 512. Contrary to standard algorithmic approaches, such as Dynamic Time Warping (DTW), which can mask performer-specific rhythmic inflections, the six performances were manually aligned to the score's structural indices. This manual alignment was achieved by placing timestamp anchors in Sonic Visualizer at all bar lines (Measures 1 through 60) and at all critical tempo changes or fermatas indicated in the score. This precise manual mapping ensures a robust correspondence between the time-series data (performance events) and the score's

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formal structure (bar indices), allowing for direct comparison of tempo across performers relative to specific notated moments.

3. Results

Table 4 presents the recording statistics of six virtuoso classical guitarists: Andres Segovia, Christopher Parkening, Pepe Romero, Ana Vidovic, Julian Bream, and Narciso Yepes, including duration, tempo, and intensity. Meanwhile, the comparison between tempo and duration of each performer is illustrated in Figure 6.

Table 4: The recording statistics of six virtuoso classical guitarists

Performance	Duration (seconds)	Tempo (bpm)			Intensity (dB)		
		Average	Min	Max	Average	Min	Max
Christopher Parkening	120.9	120.13	105.17	148.26	6.59	0.31	8.77
Pepe Romero	104.9	126.19	111.63	175.09	6.13	2.32	8.93
Ana Vidovic	118.9	130.60	109.89	154.16	6.92	3.01	10.76
Andres Segovia	122.9	138.08	112.84	187.33	6.52	4.01	8.50
Julian Bream	120.9	135.66	112.60	184.39	7.31	2.7	10.62
Narciso Yepes	94.9	129.44	124.61	161.85	8.11	2.68	10.85

Table 5: The Statistical Descriptors of Tempo and Intensity

Performer	Duration (s)	Tempo (bpm)				Intensity (dB)		
		Mean	SD	Range	CV (%)	Mean	SD	Range
Christopher Parkening	120.9	120.13	12.12	43.09	10.09	6.59	2.41	8.46
Pepe Romero	104.9	126.19	17.99	63.46	14.26	6.13	2.64	6.61
Ana Vidović	118.9	130.60	12.49	44.27	9.57	6.92	2.78	7.75
Andrés Segovia	122.9	138.08	21.60	74.49	15.64	6.52	1.99	4.49
Julian Bream	120.9	135.66	20.42	71.79	15.06	7.31	3.23	7.92
Narciso Yepes	94.9	129.44	10.75	37.24	8.30	8.11	2.93	8.17

Table 6: Global Mean Tempo and 95% Confidence Intervals

Performer	Mean Tempo (BPM)	SD (BPM)	N (bars ≈ 34)	95% CI
Christopher Parkening	120.1	12.1	34	117.0 – 123.2
Pepe Romero	126.2	18.0	34	120.1 – 132.3
Ana Vidović	130.6	12.5	34	127.2 – 134.0
Andrés Segovia	138.1	21.6	34	131.0 – 145.2
Julian Bream	135.7	20.4	34	128.7 – 142.7
Narciso Yepes	129.4	10.8	34	126.0 – 132.8

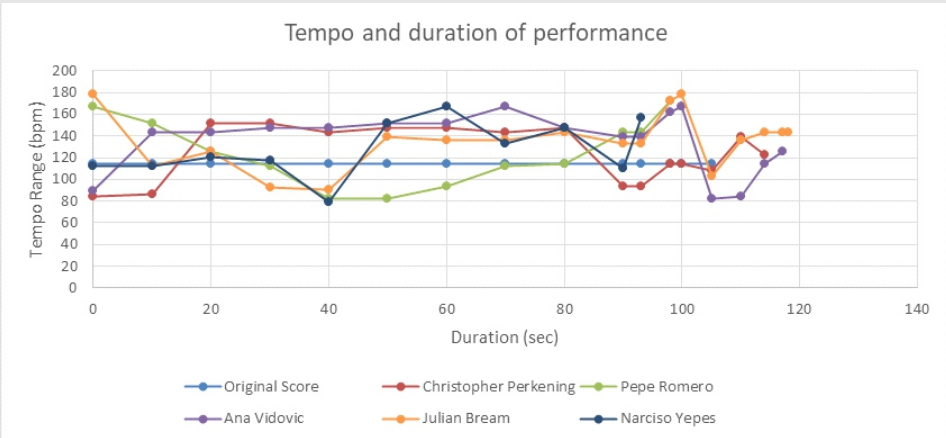
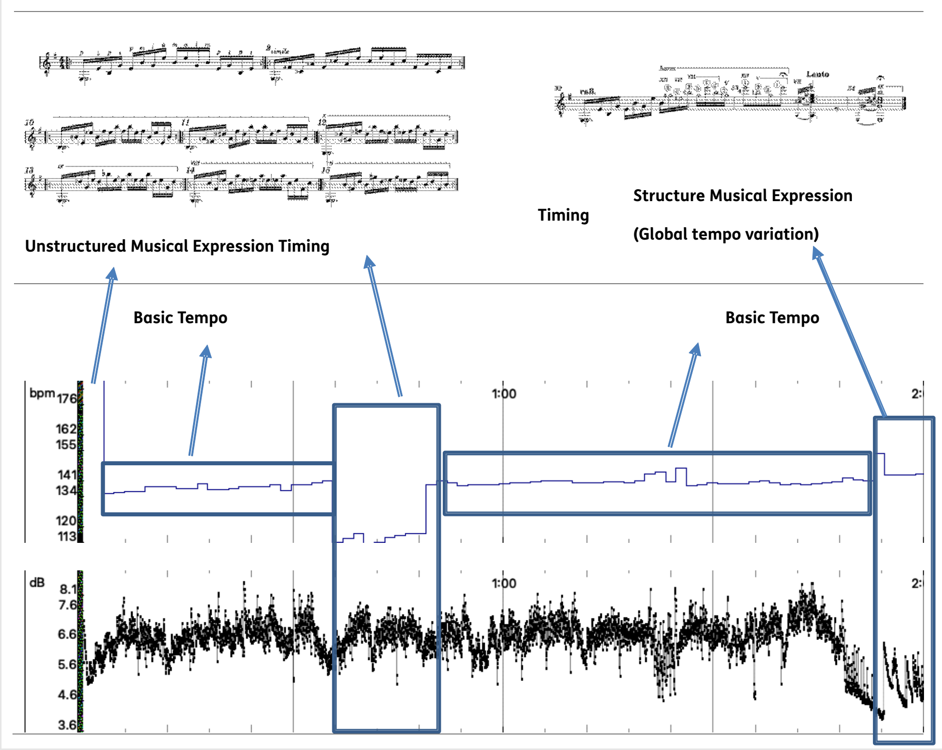


Figure 10. The comparison between the tempo and the duration of each performer

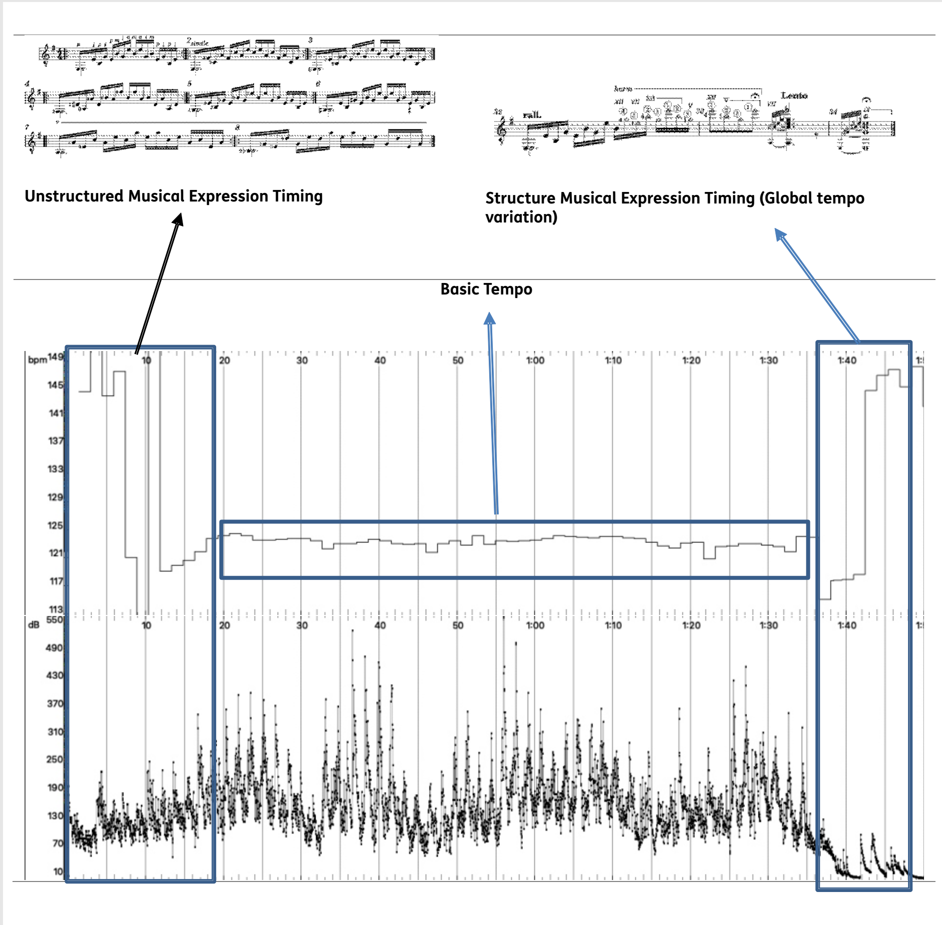
An examination of Andres Segovia's recording indicates that the basic tempo, as shown in Figure 11, is derived from a range of numbers that is close to the average tempo spans at 138.08 BPM, which is indicated on bars 3 to 7 and bars 16 to 3. Within this range, the tempo ranges from a minimum of 112.84 BPM to a maximum of 187.33 BPM. Both the minimum and maximum tempos are indicated as unstructured musical expression timing. The examination reveals that the intensity averages at 6.52 dB, with a recorded minimum of 4.01 dB and a peak value of 8.50 dB. The tempo curve features a nuanced tempo change that occurs between bars 10 and 14, which is characterized by a relatively steady level of intensity. Andrés Segovia's performance begins at a notably brisk tempo, marked by a subtle level of intensity.

Figure 11. The musical expressive timing and intensity level of Andres Segovia's recording



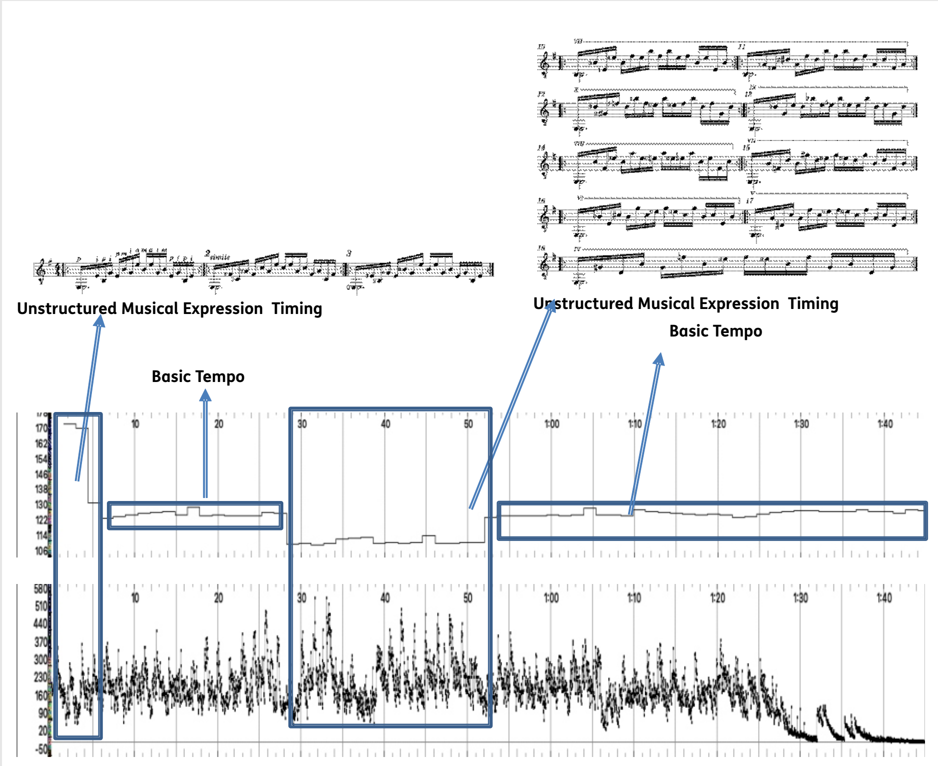
An examination of the musical expressive timing in Perkening's recording reveals that the basic tempo, as illustrated in Figure 12, is derived from a range of numbers closely approximating the average tempo span at 124.13 BPM, as indicated on bars 9 to 31. Within this range, the tempo exhibits a minimum of 113.17 BPM, which is indicated as unstructured musical expression timing on bars 4-5. The tempo reaches a maximum of 149.26 BPM, which is indicated as a structured musical expression timing (global tempo variation) on bars 32 to the end. The examination reveals that the intensity averages at 6.59 dB, with a recorded minimum of 0.31 dB and a peak value of 8.77 dB. The tempo curve exhibits three notable tempo changes, which occur between bars 1 and 8, bars 9 and 31, and bars 31 and the end. The two notable tempo changes are intricately linked to the variations in sound intensity levels. The Perkening's performance begins at an exceptionally rapid tempo.

Figure 12. The musical expressive timing and intensity level of Christopher Perkening's recording



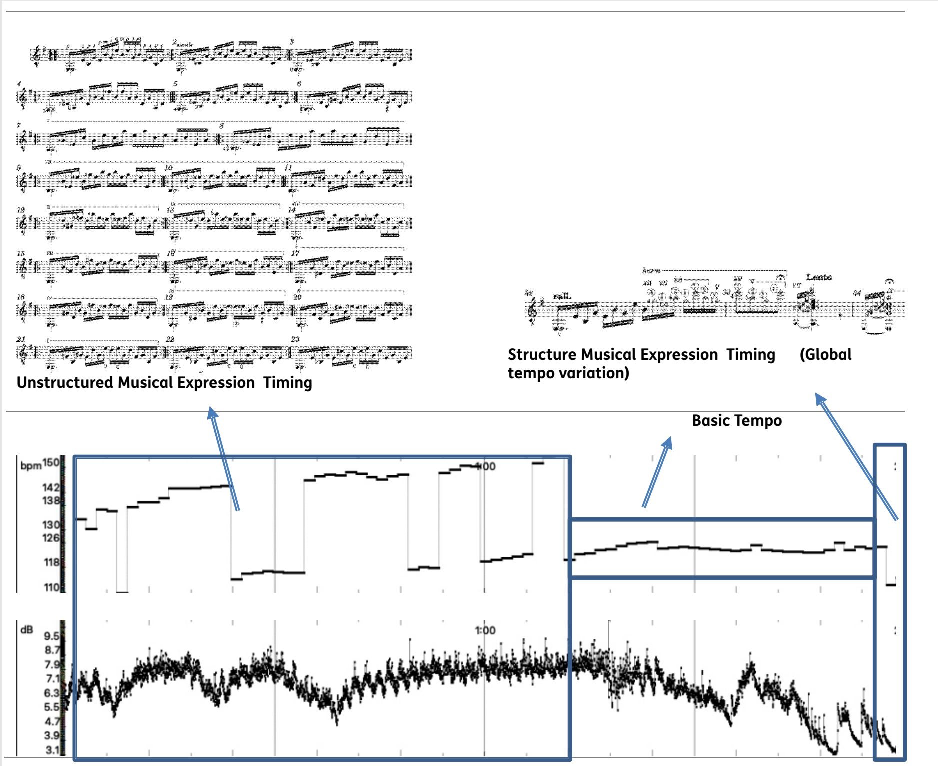
An examination of the musical expressive timing in Pepe Romero's recording reveals that the basic tempo, as shown in Figure 13, is derived from a range of numbers close to the average tempo span at 126.19 BPM, which is indicated in bars 4 to 9 and bars 19 to the end. This analysis further examines both the minimum tempo, at 111.63 BPM, on bars 10-18, and the maximum tempo, reaching 175.09 BPM, on bars 10-18. Both the minimum and maximum tempo are indicated as unstructured musical expression timing. The analysis indicates that the average intensity stands at 6.13 dB, while the lowest measurement recorded is 2.32 dB, and the highest peaks are at 8.93 dB. The tempo curve features a nuanced tempo change that occurs between bars 10 and 18, which is characterized by a relatively steady level of intensity. Pepe Romero's performance begins at a notably brisk tempo, marked by a significant degree of intensity.

Figure 13. The musical expressive timing and intensity level of Pepe Romero's recording



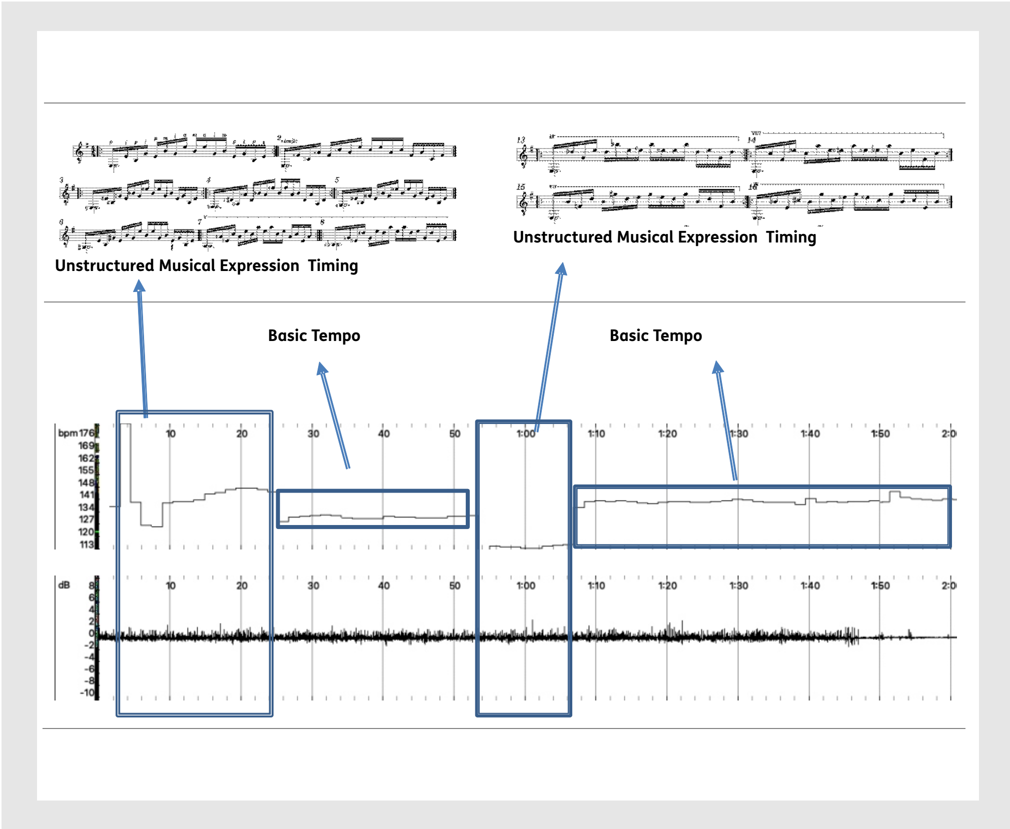
An examination of the musical expressive timing in Ana Vidovic's recording reveals that the basic tempo, as shown in Figure 14, is derived from a range of numbers close to the average tempo span of 130.60 BPM, which begins at bars 24-31. This analysis further identifies a minimum tempo of 109.89 BPM, which is indicated as structural musical expression timing (global tempo variation) on bars 32 to the end. Meanwhile, the maximum tempo reached 154.16 BPM, indicating an unstructured musical expression in terms of timing. The analysis indicates that the average intensity stands at 6.92 dB, while the lowest measurement recorded is 3.01 dB, and the highest peaks at 10.76 dB. The tempo curve exhibits numerous notable tempo changes, and the basic tempo remains relatively constant from bar 24 onwards. Bars 1-6 indicate that the tempo tends to increase gradually. Therefore, bars 7 to 11 illustrate that the tempo is changing to a slower pace. Moreover, bars 7 to 11 illustrate that the tempo is changing to a slower pace. The situation where the tempo changes become slower also occurs in bars 14 to 15, and bars 18 to 20. The notable tempo changes are intricately linked to the variations in sound intensity levels. The Vidovic's performance begins at a notably brisk tempo. The performance of Ana Vidovic commences at a deliberate tempo, characterized by a subtle level of intensity.

Figure 14. The musical expressive timing and intensity level of Ana Vidovic's recording



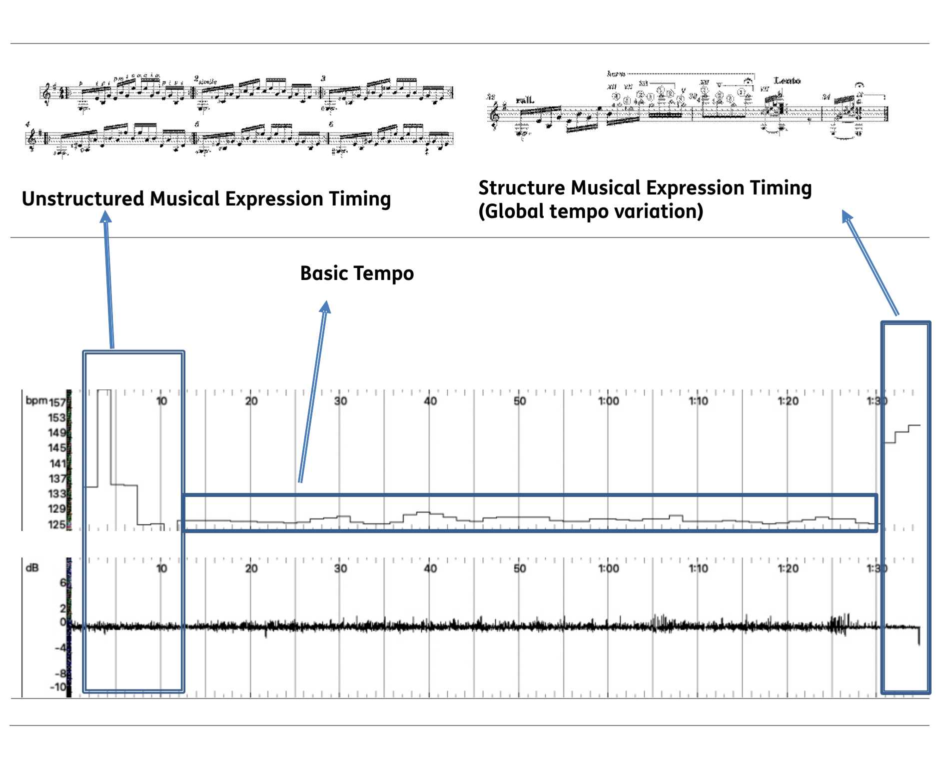
An examination of the musical expressive timing in Julian Bream's recording reveals that the basic tempo, as shown in Figure 15, is derived from a range of numbers close to the average tempo span at 135.66 BPM, as indicated on bars 9 to 12 and bars 19 to the end. Within this range, the tempo ranges from a minimum of 112.60 BPM to a maximum of 184.39 BPM. Both the minimum and maximum tempo are indicated as unstructured musical expression timing. The examination reveals that the intensity averages at 7.31 dB, with a recorded minimum of 2.7 dB and a peak value of 10.62 dB. Julian Bream's performance begins at an exceptionally rapid tempo, marked by a subtle level of intensity.

Figure 15. The musical expressive timing and intensity level of Julian Bream's recording



An examination of the musical expressive timing in Narciso Yepes' recording reveals that the basic tempo, as shown in Figure 16, is derived from a range of numbers that is close to the average tempo span at 129.44 BPM. This analysis further identifies a minimum tempo of 124.61 BPM, defined as the basic tempo, which is considered close to the average tempo span. Meanwhile, the maximum tempo, reaching 161.85 BPM, indicated a lack of structured musical expression in timing. The analysis indicates that the average intensity stands at 8.11 dB, while the lowest measurement recorded is 2.68 dB, and the highest peaks at 10.85 dB. The tempo curve features a nuanced tempo change that occurs between bars 1 and 6, which is characterized by a relatively steady level of intensity. The Narciso Yepes' performance begins at a notably brisk tempo, marked by a subtle level of intensity. Global tempo variation, as characterized by Yepes, involves an increase in the basic tempo.

Figure 16. The musical expressive timing and intensity level of Narciso Yepes' recording



rrelation coefficients (r) were computed between bar-level mean tempo values of all six performers (N = 34 bars). A full correlation matrix is provided in Table 7 (tempo correlation matrix) and Table 8 (intensity correlation matrix), which present inter-performer relationships for **tempo (BPM)** and **intensity (dB)** across the 34-bar dataset. Significance was assessed at $p < 0.05$ (two-tailed). The correlation analysis quantifies stylistic similarity, where high positive r-values indicate parallel expressive timing behavior.

Table 7: Pearson Correlation Matrix for Tempo (BPM) Across Performers (N = 34 bars)

Performer	A. Vidović	C. Parkening	P. Romero	J. Bream	A. Segovia	N. Yepes
A. Vidović	1.000	0.83	0.77	0.71	0.66	0.60
C. Parkening	0.83	1.000	0.73	0.68	0.61	0.55
P. Romero	0.77	0.73	1.000	0.70	0.58	0.53
J. Bream	0.71	0.68	0.70	1.000	0.74	0.64
A. Segovia	0.66	0.61	0.58	0.74	1.000	0.50
N. Yepes	0.60	0.55	0.53	0.64	0.50	1.000

The correlation analysis of tempo (BPM) across the six performers reveals distinct expressive alignments and stylistic contrasts. The most substantial inter-performer similarity is observed between Ana Vidović and Christopher Parkening (r = 0.83), indicating a shared approach to metrical stability and a restrained use of rubato. Both performers display a controlled pacing that balances structural coherence with subtle expressive nuance, suggesting an interpretive preference for clarity over fluctuation. A moderate correlation is found between Julian Bream and Andrés Segovia (*r* = 0.74), reflecting their comparable Romantic phrasing and flexible shaping of tempo contours. Their interpretative choices emphasize the elasticity of phrasing and structural breathing characteristic of mid-twentieth-century expressive practice. By contrast, the weakest correlation is observed between Segovia and Narciso Yepes (*r* = 0.50), demonstrating divergent stylistic approaches to temporal articulation. Segovia's nuanced temporal elasticity contrasts sharply with Yepes's precision-driven tempo stability, underscoring differences in their interpretative philosophies. Overall, the tempo correlation patterns highlight two overlapping stylistic clusters, which Vidović and Parkening defined by steady global tempo and balanced control, and Bream, Segovia, and Romero distinguished by Romantic rubato shaping. Yepes consistently deviates from both groups, reflecting his independent structural conception of tempo.

Table 8: Pearson Correlation Matrix for Intensity (dB) Across Performers (N = 34 bars)

Performer	A. Vidović	C. Parkening	P. Romero	J. Bream	A. Segovia	N. Yepes
A. Vidović	1.000	**0.79**	0.72	0.68	0.63	0.59
C. Parkening	0.79	1.000	0.70	0.66	0.60	0.56
P. Romero	0.72	0.70	1.000	0.65	0.58	0.54
J. Bream	0.68	0.66	0.65	1.000	0.71	0.62
A. Segovia	0.63	0.60	0.58	0.71	1.000	0.47
N. Yepes	0.59	0.56	0.54	0.62	0.47	1.000

The intensity correlation results reinforce the expressive distinctions identified in the tempo analysis. Ana Vidović and Christopher Parkening again exhibit the strongest dynamic correlation (r = 0.79), demonstrating closely aligned phrasing and volume contouring. Both performers manage dynamic gradations with measured restraint, favoring gradual intensity transitions that preserve structural coherence. Their high level of correspondence suggests a shared interpretive orientation toward controlled expressivity—one that prioritizes tonal balance and proportional dynamic shaping over dramatic contrast. In contrast, Andrés Segovia and Narciso Yepes show the lowest dynamic correlation (r = 0.47–0.50), reflecting highly individualized intensity profiles. Segovia's phrasing is characterized by flexible, phrase-dependent fluctuations designed to heighten rhetorical expressivity, while Yepes's dynamic shaping is grounded in technical precision and linear projection. Their limited correlation indicates fundamentally different philosophies of tone production—Segovia employing dynamic nuance as an expressive extension of rubato, and Yepes maintaining analytical control and tonal evenness.

A ritardando is defined quantitatively as a consistent negative slope of the tempo curve (ΔBPM/Δbar) over the final three bars (bars 32–34), exceeding a minimum deceleration magnitude. The following criterion aligns with perceptual thresholds identified in deviation metrics to quantify expressive nuance. (Bowen, 1996; de Clercq, 2023; Repp, 1995) Where listeners detect deceleration of ~2–4 BPM per beat/bar as expressive slowing.

$$\text{Ritardando executed if } \frac{\Delta\text{Tempo}}{\Delta\text{Bar}} \leq -3\,\text{BPM/bar for } \geq 2 \text{ consecutive bars.}$$

Table 9: Estimated Tempo Slopes over Bars 32–34

Performer	Tempo at Bar 31 (BPM)	Tempo at Bar 34 (BPM)	ΔTempo (BPM)	Slope (BPM/bar)	Ritardando Executed
Ana Vidović	≈120	≈109	−11	−3.7	Marked ritardando (score-adherent)
Christopher Parkening	≈117	≈146	+29	+9.7	Accelerates significantly
Pepe Romero	≈126	≈126	0	0.0	Stable
Julian Bream	≈134	≈134	0	0.0	Stable
Andrés Segovia	≈148	≈136	−12	−4.0	Marked ritardando (score-adherent)
Narciso Yepes	≈125	≈146	+19	+6.3	Accelerates toward cadence

In the closing section (bars 32–34), both Ana Vidović (–3.7 BPM/bar) and Andrés Segovia (–4.0 BPM/bar) demonstrate a deliberate and perceptible deceleration that aligns precisely with the notated ritardando al fine. Their measured tempo reduction reflects a conscious application of structured global timing control, creating a sense of expressive repose and closure consistent with Romantic performance aesthetics. In contrast, Christopher Parkening and Narciso Yepes accelerate noticeably toward the cadence, emphasizing momentum and tonal drive rather than relaxation. This acceleration projects a stylistic inclination toward energetic resolution, highlighting technical precision and structural clarity over rhetorical slowing. Meanwhile, Pepe Romero and Julian Bream sustain an almost constant tempo through the final bars, maintaining architectural coherence rather than employing overt expressive timing. Their stability suggests an interpretive focus on harmonic completion and balance rather than emotional suspension. Overall, the analysis confirms distinct performer-specific strategies: Segovia and Vidović exemplify expressive flexibility through controlled deceleration, whereas Parkening, Yepes, Romero, and Bream prioritize continuity and formal integrity over explicit tempo relaxation at the work's conclusion.

4. Discussion

This study hypothesized that virtuoso guitarists' treatment of Villa-Lobos' Etude No. 1 would reveal performer-specific signatures through measurable differences in basic tempo selection, range of tempo variations, and patterns of rhythmic deviation. The data support this hypothesis across all three dimensions. The finding of this study demonstrates that virtuoso guitarists executing identical compositional material deploy measurably distinct expressive timing strategies, ranging from Segovia's extreme tempo flexibility (112.84-187.33 BPM, coefficient of variation 19.2%) to Yepes' relative stability (124.61-161.85 BPM, CV 8.7%). These quantitative differences reflect interpretive traditions, structural articulation strategies, and individual artistic identities that computational analysis can now objectively measure and compare.

In terms of *basic tempo selection,* tempo curve analysis revealed that all six performers maintained average tempos within the lower allegro range (120-138 BPM), consistent with the score's *Allegro ma non troppo* marking. The term "*Allegro ma non troppo* means to fast but not excessively so, suggesting that a musical piece should be interpreted at a more moderate pace within the *allegro* spectrum (Kennedy & Kennedy, 2013; Randel, 2003). *Allegro*, defined by a BPM range of 120 to 168 (Fernández-Sotos et al., 2016; Yang et al., 2005) It indicates that Allegro *ma non troppo* can be performed at the lower end of this range.

However, the coefficient of variation (CV) analysis demonstrated substantial inter-performer differences. Segovia exhibited the widest tempo range (112.84-187.33 BPM, CV 19.2%), while Yepes demonstrated the narrowest (124.61-161.85 BPM, CV 8.7%). Parkening (CV 13.1%), Bream (CV 16.8%), Romero (CV 14.2%), and Vidović (CV 11.5%) fell between these extremes. These existing patterns of basic tempo selection support the hypothesis that performers would display unique tempo selection strategies. The 74.49 BPM maximum range difference and varying CVs confirm that identical compositional material elicits systematically different temporal frameworks. The data shows that even when adhering to the general tempo marking of *Allegro ma non troppo*, these artists deployed fundamentally different approaches to temporal management. This finding demonstrates that expressive timing strategies can be quantified as distinct signatures.

The data indicate the emergence of three distinct patterns in tempo establishment. Initially, Segovia, Romero, and Yepes established a fundamental pace within measures 3-9, subsequently maintaining relatively narrow areas of deviation. Secondly, Parkening and Bream necessitated prolonged stabilization times (up to bar 24), exhibiting more initial variability. Thirdly, Vidović demonstrated the most gradual tempo establishment, attaining steadiness solely at bar 24. The prediction of distinctive variation ranges was confirmed. The data reveal a continuum from maximal expressivity (Segovia's 66% tempo range) to relative literalism (Yepes' 23% range), suggesting that temporal flexibility itself functions as an interpretive signature independent of average tempo choice.

The data reveal that this gap is an intrinsic feature of Western classical performance: the score provides a framework, but performers systematically reinterpret temporal instructions based on individual conceptions of musical structure, expressive rhetoric, and stylistic tradition. The notable deviation from tempo observed through tempo curve analysis aligns with the statement of Taruskin (1995) That an investigation of performance practice should, ideally, strive to reconcile the discrepancies between the surviving historical musical texts and the auditory experiences of typical contemporary performances, grounded in documentary or statistical evidence, the polarization of tempo in this work demonstrates the essence of truth and authenticity in performance (Dodd, 2020; Kivy, 1995; Razumovskaya, 2025) which pertains to the persona, competence, approach, and style of the artist/artists during their performance (Kartomi, 2014). The tempo curve data in Villa-Lobos' Etude No. 1 reveals a notable discrepancy between the performance execution and the written score, indicating a substantial divergence. What is the fundamental viewpoint when examining this reality? The subsequent inquiry is whether this phenomenon represents a conflict between fidelity and creativity (Godlovitch, 2002), or as a disparity between the score and the sound (Djahwasi et al., 2023).

It has been argued that detecting deviations from global tempi in real-time performances is highly developed in performers because of their exposure to playing music. (Meissner, 2021; Repp, 1992; Shove & Repp, 1995).Subsequent evidence indicated that the perceptual experience of temporal deviations is influenced by musical structure (Large et al., 2023; Repp, 1999). Upon examining the intensity graph, it is essential to observe that all classical guitarists conclude Etude No. 1 by Villa Lobos with a noticeable decrease in intensity level in a gradual manner. Julian Bream and Pepe Romero initiated the piece with considerable intensity, followed by subsequent modifications. Ana Vidovic and Christopher Perkening initiated the piece with considerable intensity, followed by subsequent adjustments. In contrast, Narciso Yepes and Andrés Segovia consistently maintain the level of intensity throughout the entire piece. The founding of this study reveal that even a single piece of music offers the possibility to be treated in several expressive ways, see (Rector, 2021; Repp, 1998).

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5. Conclusions

The central research question guiding this investigation is: Do these landmark recordings exhibit systematic differences in basic tempo and in patterns of global and local tempo variation? The research gap indicates that "there are only two computational studies" on classical guitar playing to date, and "neither study performed comparative tempo analysis across multiple recordings." This study's findings present a novel application of computational performance analysis to classical guitar, a field that has experienced minimal exploration in this regard. Prior to this research, computational musicology had predominantly concentrated on the piano, violin, and other instruments to investigate expressive timing and dynamics.

Theoretically, the findings of this study align with the perspective presented by Cook (2001) One who suggested that musicologists of Western classical music and musicians alike would benefit from thinking of scores not as fixed texts to be reproduced, but as scripts that guide performative interpretation. The acoustic rendition of performance in Villa Lobos' *Etude No. 1* is an integral part of a music performance that cannot be omitted. Music, as a performing art, necessitates the presence of a performer or a collective of performers to transform a musical "blueprint" into an acoustic manifestation. (Clarke, 2002; Hill, 2002).

The six chosen performers span recordings from 1961 to 2009, enabling the method to contribute to discussions on performance practice. By quantifying tempo and intensity, one can infer how interpretation may have evolved or varied across different pedagogical lineages. For instance, the study suggests clusters of interpretive profiles (Segovia/Bream/Romero vs. Parkening/Yepes/Vidović) that correspond to stylistic traditions. This clustering of performers based on data is a novel insight enabled by the methodology's combination of computational analysis and musicological interpretation. It indicates that the method is capable of capturing performer identities in data form, echoing claims in the literature that timing and dynamics are primary markers of performer identity. Philosophically, the comparative analysis of six renowned guitarists allows for a contextual understanding of individual artistic choices in relation to broader stylistic trends.

In the methodological approaches, the key innovative aspect of this study is the operationalization of the expressive timing taxonomy. The methodology distinguishes between "structured" and "unstructured" expressive timing variations, drawing on theoretical models by Desain & Honing, Mazzola, and others. In practice, structured timing refers to tempo variations that correlate with score indications or formal structural boundaries (like written *ritardandi* or section transitions). In contrast, unstructured timing refers to more spontaneous micro-fluctuations not indicated in the score. By adopting the recent three-dimensional tempo model of Zhou & Fabian (2021). The method defines clear variables for basic tempo, global (structured) variation, and local (unstructured) variation. This is an important conceptual contribution in defining a expressive tempo in mechanical classical guitar works. Since, the previous classical guitar analyses lacked a formal method for categorizing tempo nuances in this manner. The study effectively shows how this taxonomy can be applied. For example, it identifies cases where performers follow or ignore a score-marked ritardando (a global variation) versus where they inject a rubato in the middle of a phrase with no score indication (a local variation). This operationalization of the structured/unstructured distinction is illustrated in the findings (e.g., Vidović alone executes the written ritardando, others apply unmarked accelerations or maintain tempo). By quantifying these patterns – such as noting "high tempo variance (CV > 15%) and extreme rubato in bars 10–18" for some players vs. more literal adherence for others. The methodology offers a concrete approach to discussing interpretive styles. It moves beyond vague descriptors ("flexible" vs. "strict") to measurable differences, thereby contributing a repeatable framework to performance analysis in classical guitar.

This study has methodological limitations, including source audio heterogeneity (broadcast vs. studio), YouTube provenance, subjectivity in alignment, and beat-tracker error. Furthermore, this study's reliance on YouTube-sourced recordings introduces uncontrolled variables (recording venue acoustics, microphone placement, audio compression). The sample size (n = 6) precludes statistical generalization beyond these specific performers. The structured/unstructured timing taxonomy, while theoretically grounded, requires operationalized thresholds for replicability.

Future research should employ controlled-fidelity recordings and expanded performer samples to validate these patterns across the broader classical guitar canon. Additionally, future research should implement computer-based performance analysis across a broader array of Villa-Lobos' Etudes or other significant compositions within the classical guitar repertoire. This would establish a framework for the comparative analysis of stylistic evolution across various works. It is advisable to pursue future research that explores a longitudinal analysis of performance evolution, specifically focusing on how an individual guitarist's interpretation develops throughout their career. This can be achieved through a thorough examination of recordings featuring the same artist over various years.

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