



HAL
open science

The role of pianistic movement idiosyncrasies in musical interpretation

Antonio Somma, Jeanne Roudet, Benoît Fabre

► To cite this version:

Antonio Somma, Jeanne Roudet, Benoît Fabre. The role of pianistic movement idiosyncrasies in musical interpretation. CFA 2025 - 17e Congrès Français d'Acoustique, Société Française d'Acoustique (SFA), Apr 2025, Paris, France. <hal-05365601>

HAL Id: hal-05365601

<https://inria.hal.science/hal-05365601v1>

Submitted on 14 Nov 2025

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



HAL Authorization



17^e Congrès Français d'Acoustique
27-30 avril 2025, Paris

The role of pianistic movement idiosyncrasies in musical interpretation

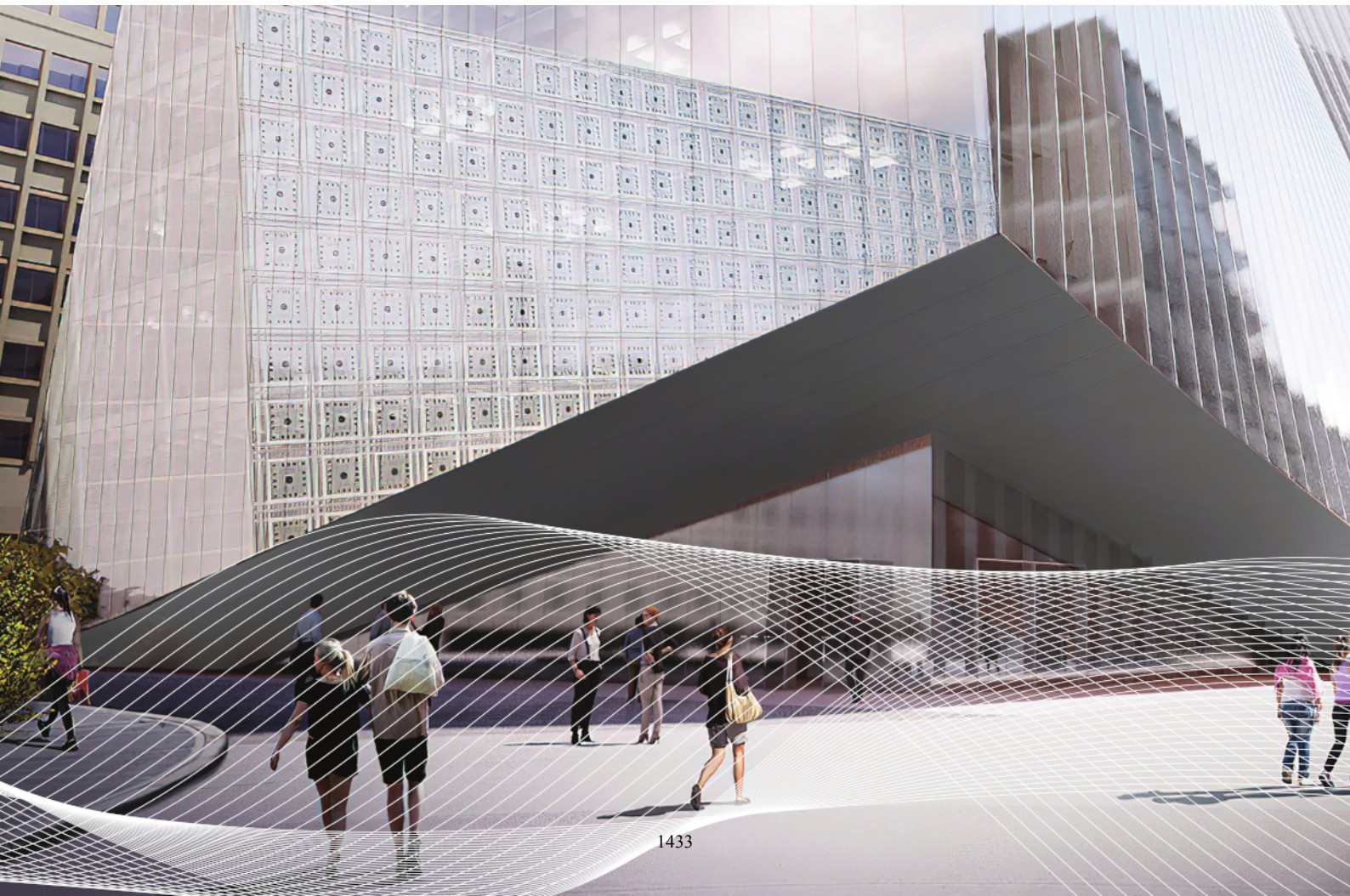
A. Somma ^{a,b}, J. Roudet ^c et B. Fabre ^d

^a École Polytechnique, CNRS, Laboratoire de Mécanique des Solides, 91128 Palaiseau Cedex

^b Sorbonne Université, Institut Collegium Musicae, F-75013, Paris, France

^c Sorbonne Université, CNRS, Institut de Recherche en Musicologie, F-75013, Paris, France

^d Sorbonne Université, CNRS, Institut Jean Le Rond d'Alembert, F-75005 Paris, France



The physical function of a musician's movement is to exert mechanical work on the instrument, thereby controlling sound production. Different movement profiles can result in the same displacement at the musician-instrument interface, producing an identical sound. Additionally, movement has a cognitive function, embodying the meaning the musician attributes to the sound—that is, its expressivity. Each musician thus develops a personal movement strategy that combines these two functions. Research on instrumental performance often focuses on shared movement features rather than individual-specific ones, typically examining their relationship to sound control physiology or to the formal structure of the score. Our study adopts a complementary approach, linking movement specificities to interpretive singularities. Two pianists, engaged in a historically informed approach, were interviewed about their technique. Thematic analysis shed light on the pianists' verbalized gesture strategies as embodiment of their individual aesthetic frameworks. Specificities in their gesture strategies were highlighted. The same pianists then performed the same piece on a historical piano. Upper-limb movements and audio recordings were analyzed to determine their interpretive choices as well as movement idiosyncrasies. Verbalized gesture strategies, interpretive choices, and movement idiosyncrasies were compared, revealing the inherently expressive nature of the movements performed.

1 Introduction

Historically, the quantitative analysis of pianistic diversity and commonalities relied solely on audio recordings [1]. The accessibility of extended instruments like the Yamaha Disklavier and Bösendorfer CEUS, which capture note timing and volume, has since made MIDI-based analysis widespread [2].

In parallel, the analysis of pianists' movements has a long-standing tradition [3], particularly focusing on the link between finger, hand, and upper-limb kinematics and the physiological mechanisms of tone production [4, 5]. Since the 2000s, growing interest in the expressive nature of musicians' movements [6] has led to increased attention to performers' physical gestures. It is now widely acknowledged that bodily movement is integral to expressing artistic intention and interpreting musical structure. Embodied music cognition theory [7] offers a valuable framework for understanding the connection between a musician's mental image of music and the gestures that give it form. Li and Timmers [8] investigated this by interviewing pianists about their timbre conceptualizations, showing that these are holistic, shaped by individual, stylistic, and composer-related factors, and deeply tied to corporeal intentionality. Pianists view their movements as more than tone production or communication tools; conceived as musical gestures, they are central to expressivity and essential for conveying artistry, especially in pedagogical contexts.

While the aforementioned study included pianists' demonstrations during interviews, it did not involve direct observation of their performances. Conversely, most research on pianistic gestures in performance has focused on identifying shared patterns across pianists [9], overlooking individual uniqueness. Analyzing musical gesture can provide insight into how pianists construct and communicate their personal aesthetic frameworks and musical ideals. Capturing this individuality requires a complementary analytical approach.

This study adopts a mixed qualitative-quantitative approach to identify individual performers' idiosyncrasies

and link them to their personal aesthetic frameworks. Can these frameworks be traced through how pianists describe the shaping of their technique? Can we connect the aesthetic conceptions they express offstage with the interpretive choices they make in gesture and sound during performance? This work forms part of a broader project aimed at recontextualizing instrument craftsmanship within the historical development of piano technique [10]. As a case study, it draws on the genuinely artistic approach of Historically Informed Performance (HIP) in revisiting musical execution on historical instruments. Accordingly, two contrasting instruments were used in the experiments: a Kawai grand piano (RX-2, 1995) and a historical pianoforte by William Stodart (London, ca. 1820–26). This paper focuses on the data collected from the Stodart, as its scope is limited to exploring inter-individual diversity.

Section 2 presents the qualitative analysis of interviews with participating pianists, from which characteristic verbalized gesture strategies emerged. This is followed by an observation of the same pianists in performance (Section 3), where their movement and audio recordings were analyzed under controlled conditions. The interpretive choices – drawn from audio analysis – and observed movement idiosyncrasies are discussed in Section 4. Finally, Section 5 links these findings to the gesture strategies verbalized during the interviews and concludes with perspectives for future research.

2 Interviews

Three concert-level pianists, deeply involved in HIP practice and experienced in pedagogy, were interviewed on aspects of their artistic research. In semi-structured interviews, they reflected on the development of pianistic gesture and its transmission. This phase of the study had two main goals: to understand the significance the pianists assign to their gestures while playing, and to identify verbal references to idiosyncratic gesture strategies.

Verbatim transcripts were analyzed thematically [12]. Theme identification was partly data-driven – emerging through coding of the pianists' discourse – and partly

theory-driven, shaped by the core research questions behind the interview design. A central inquiry concerned how these pianists' artistic research engages with historical sources in developing a historically informed technique. Notably, all three pianists frequently and spontaneously reflected on their teaching, emphasizing that it is through the challenge of transmitting their artistry to students that the value of verbalizing their expertise becomes most apparent.

From this analysis, we identified and coded several gesture-related themes [10]: *Against a literal reading of historical sources*; *The musical image and playing aesthetics precede the gesture*; *The right gesture enhances the perception of touch*; *Gesture exploration involves bodily sensation*; and *Pianistic gesture affects sound*. These themes support our hypothesis that each pianist's aesthetic framework is embodied. Consequently, their technique should be understood as guided by expressive intent.

Distinct gesture strategies clearly emerge in the accounts of two pianists. Pianist 1 (P1) emphasizes "hygiene of movement" as a way to free the pathway from mind to fingertips. His approach aligns with historical sources – such as Czerny [13] – in advocating a simple, steady posture, but expands on them by assigning a unique role to the wrist in shaping phrasing. Wrist neutrality, he claims, enhances the sensation that the fingers themselves "speak," akin to how the lips and tongue articulate speech in relation to the whole mouth. His approach reflects a rhetorical aesthetic grounded in fine-grained articulation. Conversely, Pianist 2 (P2) argues that the expressive richness of early nineteenth-century music cannot be captured through the reductive gestures suggested by a literal reading of historical sources. Humans, he contends, do not function so rigidly. P2 seeks circular motion while pressing the keys, as if "massaging" the keyboard. His conception of touch is profoundly vocal, aiming for a *belcanto* aesthetic inspired by the expressive legacy of figures like French pianist and pedagogue Hélène de Montgeroult (1764–1836) [11].

In conclusion, both the thematic analysis and the description of gesture strategies confirm that the pianists' verbalized gestures are embodied expressions of their individual aesthetic frameworks. These strategies are closely tied to each pianist's unique musical conception and serve as a means of shaping and conveying it.

3 Observations of piano performances

The same pianists were invited to take part in an experiment involving motion capture while playing the Stodart pianoforte. The selected repertoire was drawn from Montgeroult's *Cours complet pour l'enseignement du forte-piano* (ca. 1820) [11]. This section analyzes data collected specifically for Etude No. 36 in F major ("*pour apprendre à lier le chant*", to learn how to connect the singing line),

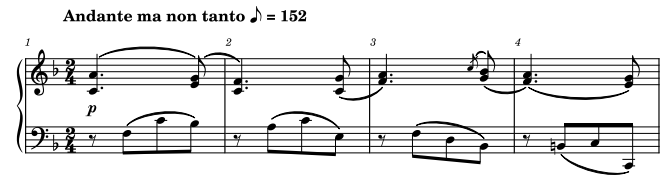


Figure 1: Hélène de Montgeroult, Etude No. 36 in F major from the *Cours complet pour l'enseignement du forte-piano* (ca. 1820), bars 1-4.

whose first four bars are reported in Figure 1¹. The Etude is accompanied by a detailed explanatory note written by Montgeroult herself. It indicates that the performer must create the illusion of a continuous singing line by connecting each note through the intermediate voice – typically played by the right thumb – and by subtly enhancing melody notes through dynamic reinforcement of certain bass notes.

Subsection 3.1 outlines the protocol used for performance observations, while Subsection 3.2 details the processing of audio and video data and the extracted features, aimed at analyzing interpretive singularities and identifying movement idiosyncrasies.

3.1 Materials and methods

The pianists received the sheet music two weeks prior to the recordings to allow adequate preparation. On the day of the experiment, each was brought to the observation room – a space at the Institut d'Alembert on Sorbonne University's science faculty campus, comparable in size to a typical music school classroom. They were given about twenty minutes to familiarize themselves with the instrument. After this phase, each pianist was invited to perform the selected pieces freely, with the suggestion to play as if demonstrating to a class. A mobile camera recorded the session for qualitative analysis. Initial observations showed that the pianists made no significant lateral flexion or trunk rotation movements, that the upper arm generally stayed aligned with the sagittal plane, and that hand axes remained perpendicular to the keyboard. These findings support the underlying assumption of the protocol that two lateral views, though limited, provide sufficiently informative data.

Before the final part of the experiment, each pianist was brought to a separate location, where the purpose of the observations was explained in detail. They were then invited to sign a consent form for voluntary participation and data use. Each pianist changed into a black sleeveless shirt to allow placement of motion-capture markers at predefined anatomical points, including the shoulders (coracoid processes), elbows (radial heads), wrists (ulnar styloid processes), and knuckles of the little fingers (metacarpals) (see Figure 2). The markers measured 1 cm × 2 cm and were green. In this setup, two performances of the piece were recorded using two fixed side-view cameras and a pair of omnidirectional microphones. The cameras (GoPro Hero 4) were positioned approximately one meter from

¹The full score is available as an appendix to [10].

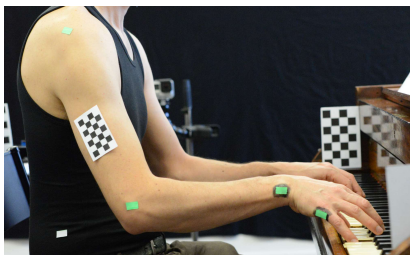


Figure 2: View of one of the two pianists’ right upper limb while playing the Stodart piano during the last phase of the performance experiment, with the markers in place. The white marker on the hip and the chessboards are not exploited in this paper.

the seat center, to the right and left of the keyboard, at a height of 90 cm – above the Stodart’s keyboard height of 68 cm. This arrangement captured the pianists from head to hips. Video was recorded at 60 fps with a resolution of 1080 px × 1920 px (height × width). Audio was captured in stereo using DPA 4006A omnidirectional microphones placed in the instrument’s near field and recorded via an audio interface at a sampling rate of 48 kHz.

3.2 Analysis and feature extraction

The Python OpenCV packages² were used to track the green markers frame-by-frame. The algorithm, though simple, proved effective: an HSV filter mask was applied to each frame to isolate contours of the five largest areas, corresponding to the markers. These were then labeled using positional constraints based on typical pianist posture (e.g., the elbow marker cannot be higher than the shoulder). If fewer than five areas remained, labels were assigned based on proximity to previously identified markers. The process is fully automated, and occasional brief tracking losses – never exceeding one tenth of a second – represented an acceptable trade-off for automation.

In parallel, the music synchronization pipeline SyncToolbox [14], based on dynamic time warping (DTW), was used to align the averaged microphone audio signal with the reference score (in .musicxml format) at 40 features/second. A simple correlation was then used to determine the time offset between the microphone audio and the video audio, enabling indirect synchronization of the marker positions with the score metrics.

After the signal treatment, the following features were extracted:

Bar-averaged beats-per-minute (BPM). The warping path aligning score metrics (in bars) with performance time (in seconds) was used to estimate local tempo. This yielded bar-averaged BPM values, expressed in eighth notes per minute, in line with the score’s tempo marking (Figure 1).

²<https://pypi.org/project/opencv-python/#description>.

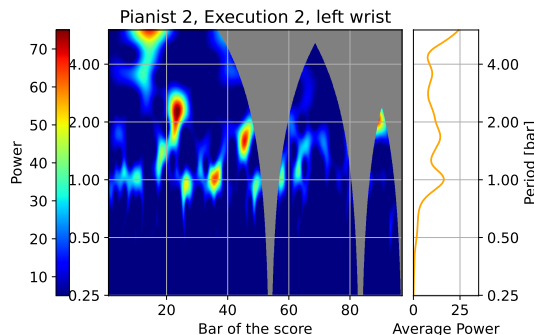


Figure 3: Squared CWT coefficients of P2’s left wrist apparent flexion angle during the second execution. The gray zones indicate invalid regions due to tracking loss. On the right, the squared CWT coefficients averaged across score periods are shown.

Table 1: Mean and standard deviation of the bar-averaged BPM of each execution by each pianist.

	BPM [eights per minute]			
	Execution 1		Execution 2	
	mean	std	mean	std
P1	142	29	146	30
P2	176	42	171	42

Bar-averaged audio envelope amplitude. The audio envelope was computed using an RMS filter with a 100 ms window. After alignment to the score via interpolation, its logarithm was averaged over each bar. Values are expressed in decibels relative to the maximum bar-averaged envelope amplitude in each recording.

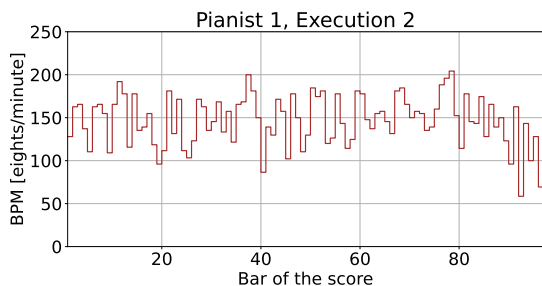
Continuous Wavelet Transform (CWT) of apparent angles. Wrist flexion and elbow extension angles were derived from camera-tracked marker positions. Each angle was aligned to score metrics, then normalized (zero mean, unit variance). Following [15], a Continuous Wavelet Transform using the complex Morlet wavelet was applied. Each wavelet scale corresponds to a period relative to score metrics (e.g., half-bar, one bar, two bars). High CWT coefficients indicate periodic movement patterns matching those metric periods. An example is shown in Figure 3.

4 Results

The mean of the bar-averaged BPM indicates how much faster one pianist played compared to the other, while the standard deviation provides a rough measure of tempo fluctuations. These values are reported in Table 1. The pianists perform at noticeably different tempos, both deviating from the notated 152 eighth notes per minute: P1 plays slower, while P2 plays faster. Consequently, P2’s

Table 2: Mean and standard deviation of the bar-averaged audio envelope of each execution by each pianist.

	Envelope amplitude [dB re max across acquisitions]			
	Execution 1		Execution 2	
	mean	std	mean	std
P1	-11.5	5.1	-11.5	6.0
P2	-8.9	5.3	-9.4	5.5



(a)



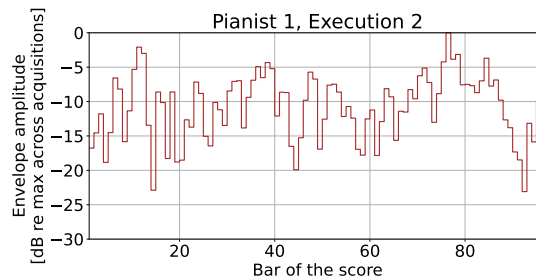
(b)

Figure 4: Bar-averaged beats-per-minute for the second execution by each of the two pianists.

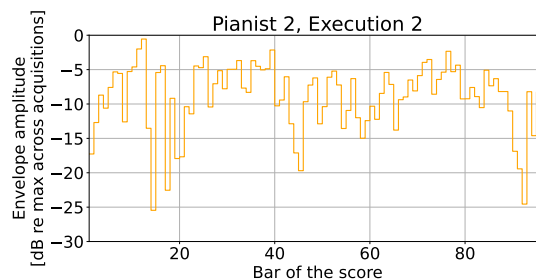
performance feels more fluid, despite P1 maintaining a more consistent overall tempo. A faster tempo also indirectly affects dynamics, as it promotes blending between the naturally decaying tones of successive notes.

The mean of the bar-averaged audio envelope reflects overall loudness, while its standard deviation provides a rough measure of dynamic variation throughout the performance. These values are presented in Table 2. The data show that P2 plays louder than P1, indicating a preference of the first for a more projecting tone. Overall dynamic fluctuation remains consistent across pianists and performances.

The results in Tables 1 and 2 suggest greater intra-pianist consistency in global tempo and dynamics than inter-pianist variation. This supports the comparison of bar-averaged BPMs (Figures 4a and 4b) and of the bar-averaged audio envelopes (Figures 5a and 5b) from the pianists’ final takes to explore interpretive choices. Visual inspection of these curves reveals that local minima (valleys) reflect how each pianist used tempo and dynamics to shape phrasing. P1 articulates more frequently, with four-bar groupings often



(a)



(b)

Figure 5: Bar-averaged audio envelope for the second execution by each of the two pianists.

Table 3: Standard deviations of elbow and wrist apparent angles.

	Pianist 1		Pianist 2	
	E. 1	E. 2	E. 1	E. 2
Left wrist std [°]	6.8	7.0	15.5	15.9
Right wrist std [°]	6.2	6.8	12.9	13.5
Left elbow std [°]	7.1	6.3	15.4	14.1
Right elbow std [°]	7.5	7.5	14.5	13.6

enclosed within pronounced valleys, indicating a higher articulation pace than P2.

Table 3 reports the standard deviations of the elbow and wrist apparent angles, reflecting overall movement variability. P2’s values are roughly twice those of P1, indicating significantly greater movement.

Table 4 presents the squared CWT coefficients averaged across three relevant score periods: one, two, and four bars. These values, computed from the apparent angles squared CWT coefficients, averaged across each execution, reflect the salience of periodic movement patterns at each score metric scale.

P2’s left-hand wrist angles show clear bar-scale periodicity, absent in P1. In contrast, right-hand wrist and elbow angles display greater consistency across pianists, with less bar-scale and more large-scale periodicity. This reflects the right hand’s role in creating legato through carefully sustained intermediate notes (see Section 3.1). Overall, elbow angles show less bar-scale periodicity than the wrist, while two- and four-bar periodicities are

Table 4: Average squared CWT coefficients of apparent angles, at specific score periods: one bar, two bars, four bars.

	Pianist 1					
	Execution 1			Execution 2		
Period [bar]	1	2	4	1	2	4
Left wrist	5.4	13.7	10.5	3.1	10.5	9.7
Right wrist	7.0	10.5	34.0	1.4	1.4	5.3
Left elbow	2.1	6.8	16.0	2.8	8.4	25.6
Right elbow	2.1	5.5	16.9	1.5	3.5	13.6
	Pianist 2					
	Execution 1			Execution 2		
Period [bar]	1	2	4	1	2	4
Left wrist	17.3	13.0	8.7	16.3	12.0	8.7
Right wrist	5.6	12.8	29.1	5.7	15.5	26.6
Left elbow	6.1	6.7	23.8	7.2	10.9	17.9
Right elbow	1.4	4.0	13.9	1.3	6.8	14.0

comparable across all angles.

Notably, P1’s right wrist periodicity differs between the two executions, suggesting a shift in interpretive conception. This highlights the evolving nature of musical interpretation and cautions against over-reliance on averaged data, even within the same performer under similar conditions.

5 Conclusion

Based on the audio analysis (Section 4), Pianist 1 favors fine-grained articulation, while Pianist 2 seeks a broad, singing tone. These choices align with their respective aesthetic frameworks, as inferred from their verbalized gesture strategies (Section 2). The observed movements further reflect these strategies: P1, committed to a simple, stable posture, displays a more restrained bodily attitude (Table 3), whereas P2, with a freer conception of gesture, expresses musical intent through broader movements. The physical realization of these strategies confirms that movement is inherently expressive and reveals their artistic individuality.

Given the wrist’s closer proximity to the keyboard, its generally higher bar-scale periodicity compared to the elbow (Table 4) suggests that both pianists attribute a greater role in tone production via the fingers, while the elbow is freer to support larger-scale articulations. Wrist angles thus emerge as a key site for the fine-grained enactment of the embodied musical image, where idiosyncratic actions may be linked to expressive demands in specific score excerpts. As an illustrative example, bars 34–37 contain *sforzando* accents at each barline in the right hand (Figure 6a). P1 (Figure 6b) displays flexion spikes at the right wrist aligned with these accents, and also at the left wrist, marking the onset of each bass group. In contrast, P2 (Figure 6c) shows a characteristic oscillating pattern in both wrists, more

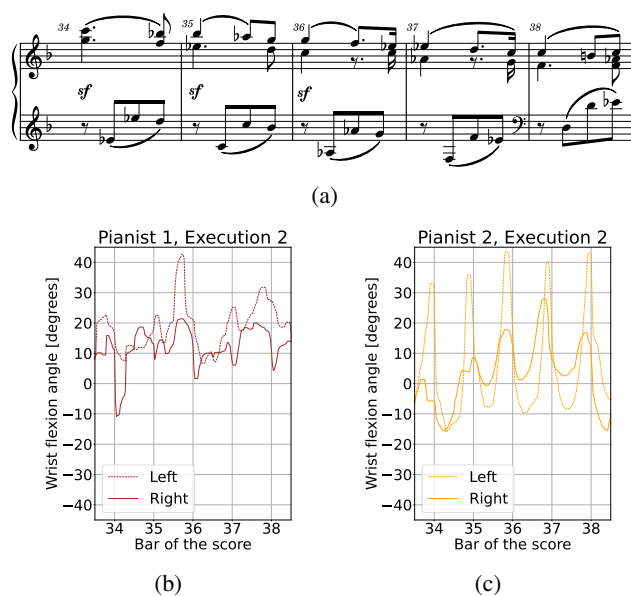


Figure 6: (a) Hélène de Montgeroult, Etude No. 36 in F major from the *Cours complet pour l’enseignement du forte-piano* (ca. 1820), bars 34–38. (b-c) Left and right wrist flexion angles for the same bars in the second executions by Pianist 1 and Pianist 2, respectively.

pronounced on the left. These idiosyncratic movements align with the interpretive choices identified through prior analysis.

The relationship between movement and sound reveals some counterintuitive results. P2’s steady left-wrist oscillation at the bar scale (Table 4) does not align with fine-grained tempo or dynamic fluctuations – features present in P1’s performances (Figures 4a and 5a) – but corresponds instead to broader, large-scale articulation (Figures 4b and 5b). This challenges the common belief that the so-called “digital school” of piano playing [16] – to which P1 explicitly refers – lacked tonal nuance, a trait often credited only to more recent pianistic schools.

In line with a long-term goal of accessibility for the broader research community in musical performance, the experimental work was guided by an economy of means and a critical assessment of its strengths and limitations. The proposed method enables analysis of piano playing without MIDI-based sensing. While the DTW-based approach using score metrics is effective, it should be complemented by NMF-based methods [17], which can capture single note-level dynamics, articulation, and timing shifts when multiple notes occur within a single beat – features essential for interpreting the selected Etude.

References

[1] Repp, B. H. Diversity and commonality in music performance: An analysis of timing microstructure in

- Schumann's 'Träumerei'. The Journal of the Acoustical Society of America 92, 2546–2568 (1992).
- [2] Clarke, E. Empirical Methods in the Study of Performance. in Empirical musicology: aims, methods, prospects (ed. Clarke, E.) 77–102 (Oxford Univ. Press, Oxford, 2004).
- [3] Ortmann, O. The Physical Basis of Piano Touch and Tone: An Experimental Investigation of the Effect of the Player's Touch Upon the Tone of the Piano. (London: K. Paul, Trench, Trubner & Company Limited, J. Curwen & Sons Limited, New York: E. P. Dutton & Company, 1925).
- [4] Furuya, S., Altenmüller, E., Katayose, H. & Kinoshita, H. Control of multi-joint arm movements for the manipulation of touch in keystroke by expert pianists. BMC Neuroscience 11, 82 (2010).
- [5] Goebel, W. & Palmer, C. Temporal Control and Hand Movement Efficiency in Skilled Music Performance. PLoS ONE 8, e50901 (2013).
- [6] Wanderley, M. M., Vines, B. W., Middleton, N., McKay, C. & Hatch, W. The Musical Significance of Clarinetists' Ancillary Gestures: An Exploration of the Field. Journal of New Music Research 34, 97–113 (2005).
- [7] Leman, M., Maes, P.-J., Nijs, L. & Van Dyck, E. What Is Embodied Music Cognition? in Springer Handbook of Systematic Musicology (ed. Bader, R.) 747–760 (Springer Berlin Heidelberg, Berlin, Heidelberg, 2018).
- [8] Li, S. & Timmers, R. Exploring pianists' embodied concepts of piano timbre: An interview study. Journal of New Music Research 49, 477–492 (2020).
- [9] MacRitchie, J., Buck, B. & Bailey, N. J. Inferring musical structure through bodily gestures. Musicae Scientiae 17, 86–108 (2013).
- [10] Somma, A. Acoustique de la pratique sur instruments historiques. Étude transdisciplinaire de l'interprétation historiquement informée au piano. PhD thesis. (Sorbonne Université, Paris, 2024).
- [11] Montgeroult, H. de. *Cours Complet Pour l'enseignement Du Forte-Piano, Conduisant Progressivement Des Premiers Éléments Aux plus Grandes Difficultés* (Janet et Cotelle, Paris, ca. 1820).
- [12] Braun, V. & Clarke, V. Thematic analysis. in Research designs: Quantitative, qualitative, neuropsychological, and biological vol. 2 57–71 (American Psychological Association, 2012).
- [13] Czerny, C. *Vollständige theoretisch-practische Pianoforte-Schule von dem ersten Anfange bis zum höchsten Ausbildung fortschreitend, Op. 500.* (A. Diabelli u. Comp., Wien, 1839).
- [14] Müller, M., Özer, Y., Krause, M., Prätzlich, T. & Driedger, J. Sync Toolbox: A Python Package for Efficient, Robust, and Accurate Music Synchronization. JOSS 6, 3434 (2021).
- [15] D'Amario, S. et al. Interperformer coordination in piano-singing duo performances: phrase structure and empathy impact. Psychological Research 87, 2559–2582 (2023).
- [16] Somma, A., Roudet, J. & Fabre, B. A Multidisciplinary Study of Pianoforte Touch and Tone Qualities. in Proceedings of the 10th Convention of the European Acoustics Association, Forum Acusticum 2023 2765–2772 (European Acoustics Association, Turin, Italy, 2023).
- [17] Ewert, S. & Muller, M. Using score-informed constraints for NMF-based source separation. in 2012 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP) 129–132 (IEEE, Kyoto, Japan, 2012).