MUSIC, MIND, AND SCIENCE

Edited by
SUK WON YI

1999

XVI. Individual Differences in the Expressive Shaping of a Musical Phrase: The Opening of Chopin's Etude in E major

Bruno H. Repp

There is great variety in the performance of the standard repertoire of Western classical music, especially in solo playing where individuality of expression can be given free rein. No two performances of the same work are exactly alike, and this is often true even for repeated renditions by the same artist. A musician must exert control over a number of expressive parameters, each of which is continuously variable, and this results in a combinatorial explosion of possibilities. Yet there are significant constraints on this variety, deriving both from the musical structure of a given work and from performance conventions that define what expressive actions are aesthetically pleasing within that structure.

Diversity in performance is made possible by the indeterminacy of the musical score with regard to expressive nuances. Diversity is important because it offers listeners different perspectives of the same work and helps sustain the concert and recording industries, which are based in part on music lovers' interest in individual artists. How do individual differences among artists arise? This is surely a complex question, but in principle one may distinguish between unintentional and intentional differences. The former are due to the different biomechanical and psychological characteristics of individual musicians, as well as their different training and musical experiences. Even if two musicians intended to play the same work in exactly the same way (in terms of their expressive goals, however they may be defined), their performances probably would not sound alike.

Intentional differences among performances arise from diverging structural and expressive understandings of the music as well as from planned spontaneity in performance. Thus, one and the same artist may produce different interpretations on different occasions.

Differences among performances of the same work may be thought of as arising from a dynamic system governed by two opposing forces: conventionality and individuality. On one hand, artists have a strong tendency to follow generally accepted norms; on the other hand, they have a desire to distinguish themselves from fellow musicians and say something new. Each individual artist needs to find a personal balance between these two forces. In recent years, many observers of the musical scene have deplored an increasing uniformity of performance, brought about by factors such as the wide availability of recordings, the textual fidelity instilled by musicologists, and the demise of national and local schools of performance practice. Yet, this is only a matter of degree, and individual differences certainly will never disappear from music performance.

The goal of the present study was to provide an objective characterization of the nature and range of individual differences in the expressive shaping of a single phrase, drawing on a large sample of commercially recorded piano performances. The study had three parts: analyses of (1) expressive timing and (2) expressive dynamics, and (3) aesthetic evaluation of the performances.

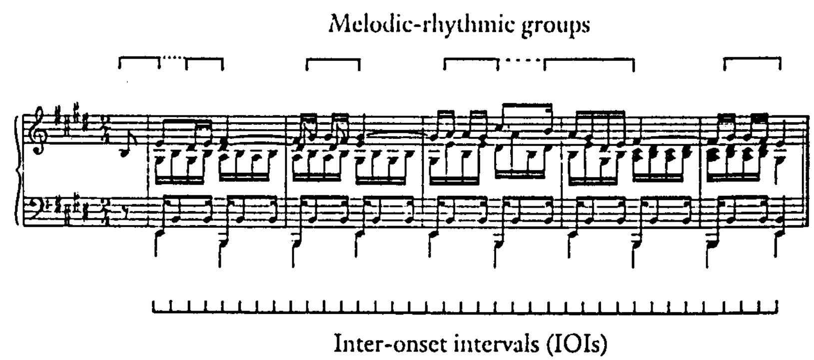
There were three main questions: (1) How many truly different expressive shapes (of timing or dynamics) are there for the phrase chosen, and are these shapes categorical alternatives (such as might result from different structural interpretations) or do they rather span a continuum of possibilities? (2) What is the relationship between expressive timing and dynamics? Are they correlated or independent? (3) To what extent do aesthetic preferences among performances rest on differences in expressive timing and dynamics?

Previous investigations of expressive timing (e.g., Repp, 1992a) have suggested that there is an inverse relationship between the length of a musical passage and the relative diversity of individual performances, as assessed with correlational statistics. This is so because all artists tend to respond similarly to major structural features of the music, and the longer a piece is, the more such major features it will contain. However, within a short passage such as a single phrase, considerable individual differences may be observed, presumably due to fewer structural constraints at such a local level. It is here that statistical analysis of performance measurements can reveal radically different expressive strategies.

1. Analysis of expressive timing and dynamics

Method

The musical passage chosen was the opening of Chopin's Etude in E major, op. 10, No. 3. A somewhat simplified, computer-generated score is shown below. The second beat of bar 5 (which is notated as a chord here, to save space) defines the end of the excerpt. As indicated above the score, the principal melody in the soprano voice is divided into a number of segments or gestures, each ending in a long note. The accompanying alto voice moves in sixteenth notes throughout, and the lower voices form a repetitive rhythmic accompaniment. As indicated below the score, the note onsets in all voices combined define 36 inter-onset intervals (IOIs) of nominally equal duration.



There were several reasons for selecting this particular excerpt. First, it is a well-known piece of which many recordings exist. Second, it is characteristically performed with large variations in expressive parameters such as timing and dynamics. Third, it has been used in studies of timing perception (Repp, 1998a, 1998b, 1998c, 1999a) which suggest a perceptual basis for the most typical expressive timing pattern. Finally, a preliminary analysis of 15 performances (Repp, 1997) has revealed three very different patterns of expressive timing whose generality is of interest.

The present analyses were performed on 115 recordings by 108 different artists of many nationalities, spanning 68 years. They included the 15 recordings analyzed previously (Repp, 1997).

Measurements of ("horizontal") expressive timing were conducted on the digitized sound files with the help of a digital waveform editor. Tone (chord) onsets were located and labeled, relying on both visual and auditory cues. If there were detectable asynchronies within a chord (due to "vertical" timing), the onset of the highest tone was marked. Inter-onset interval (IOI) durations were obtained by calculating the differences between successive onset times. The sequence of 36 sixteenth-note IOIs constituted the *timing profile* of a performance. The initial eighth-note upbeat IOI was not included in the analyses reported here (but see Repp, 1999b).

Measurements of ("horizontal") expressive dynamics were obtained by computing the root-mean-square amplitude envelope of each digitized waveform and determining the peak envelope amplitude following each note (chord) onset. The amplitudes were then converted into peak sound levels (PSLs) in decibels (dB). Although each PSL represented a combination of all tones that were sounding at that moment, it was assumed that the main contribution came from the highest and loudest tone. This was confirmed by measurements on synthesized performances (Repp, 1999b). Differences among simultaneous tones ("vertical" dynamics) could not be assessed. Each performance yielded a series of 38 PSLs that constituted its *dynamic profile*.

To determine how many different types of timing and dynamic profiles were represented in the sample of performances, each data set was subjected to *principal components analysis* (PCA). This technique decomposed the 115 individual profiles, which exhibited various degrees of pairwise similarity, into a number of completely unrelated profiles (the principal components or PCs), so that each individual timing profile could be expressed as a weighted sum of the PCs. Since successive PCs account for less and less variance in the data, only the first few PCs were considered significant and interpretable. The criterion was that a significant PC had to account for at least 1/m of the variance, where m was the number of data points in the profile (36 or 38). Weighted combinations of these PCs then provide an approximation to the original data, with the remaining variance unaccounted for. After deciding on the number of significant PCs, a *Varimax rotation* was carried out. This procedure modified the PCs so that their correlations with the performance profiles (the PC "loadings") exhibited a maximal range. The rotation also distributed the variance accounted for (VAF) more equally among the PCs. Each rotated PC could then be interpreted as a particular expressive strategy.

It should be noted that PCs are expressed in standard scores (mean of 0, standard deviation of 1) and thus are independent of the mean and standard deviation of the expressive deviations in the original performances. This report focuses solely on the *patterns* of timing and dynamics. Analyses of other aspects of the data may be found in Repp (1998d, 1999b).

Results: Timing profiles

The PCA of the timing profiles yielded four significant PCs that accounted for 76% of the variance in the data. The first unrotated PC (TUPC-I, where T stands for timing) represents the average of all timing profiles in standardized form. This grand average timing profile is shown in Figure 1a. Filled circles represent IOIs initiated by melody (soprano) tones, whereas open circles represent IOIs initiated by accompaniment tones during sustained melody tones. The TUPC-I profile represents the average magnitudes of various expressive lengthening tendencies in the sample of performances. The initial downbeat in bar 1 clearly is elongated most. A ritard occurs also at the end of each of the melodic segments, that is in sixteenth-note positions 4 and 5 of each bar. The melodic segment in bar 4 starts earlier than the others (in position 8 of bar 3) and begins with an acceleration; a small initial lengthening can also be seen in other melodic gestures. Finally, there is also a tendency towards ritards in the accompaniment preceding melodic segments, at the beginnings of bars 2, 3, and especially 5.

The TUPC-I profile alone accounted for 61% of the variance in the data and was representative of many individual performances. Its correlations with the individual timing profiles (the TUPC-I loadings) ranged from 0.94 to 0.31, with only 22 values falling below 0.70. The TUPC-I pattern thus may be regarded as a common, typical, or conventional timing profile for this music, and the TUPC-I loadings may be interpreted as indices of the typicality or conventionality of individual timing profiles. By that criterion, the most conventionally timed performance in the sample (not a value judgment!) was that by Yukio Yokoyama (Figure 1b). Other examples of typical timing were the performances by Paul Badura-Skoda and Alexis Weissenberg, while the most unconventionally timed performances were by Géza Anda, Vladimir Horowitz, and Samson François.

The other three unrotated PCs accounted for only small amounts of variance. After Varimax rotation, however, the VAF was more evenly distributed, and the four rotated PCs (TPC-I, ..., TPC-IV) accounted for 31%, 17%, 17%, and 11% of the variance, respectively.

TPC-I (Figure 2a) represents the most frequently employed timing strategy. It retains a significant similarity to TUPC-I and differs mainly in that it de-emphasizes ritards between melodic segments and also the lengthening at the end of bar 3, which shows up strongly in TPC-IV instead (Figure 5a). TPC-I also has a long initial downbeat and a ritard during the final melodic gesture in bar 5. Loadings on TPC-I, which ranged from 0.85 to -0.19, may be considered an alternative measure of typicality. However, whereas TUPC-I loadings express the degree to which a performance represents the *most typical mixture* of timing strategies, TPC-I loadings express the degree to which a performance exhibits the *single most typical* timing strategy. In terms of this measure, the most typically timed performance was the one by Dezsö Ranki (Figure 2b). Other examples were the performances by Alicia de Larrocha and Cecile Licad.

The timing strategy represented by TPC-II (Figure 3a) is very different. It dwells on the *beginnings* of melodic segments, especially in bars 2 and 5, and it completely suppresses the ritards at the ends of melodic gestures. There is no lengthening of the initial downbeat either. In bars 1 and 2 (and probably 5 as well), the pace accelerates

during the melodic gesture and continues smoothly into the accompaniment. In bars 3 and 4, the melodic timing is fairly steady, but the two accompaniment notes in bar 3 (positions 6 and 7) are taken very fast. There were quite a few timing profiles that resembled TPC-II, with loadings as high as 0.84. The pianists most representative of this pattern were Robert Lortat (Figure 3b), Alfred Cortot, and Isador Goodman.

The timing profile associated with TPC-III (Figure 4a) has a single salient feature, the extreme lengthening of the initial downbeat, and is almost flat elsewhere. Nevertheless, a group of performances showed loadings on TPC-III as high as 0.79, even though they were rarely as flat as the TPC-III profile. These pianists included Wilhelm Backhaus, Rena Kyriakou, and Dinorah Varsi (Figure 4b). Varsi's performance was the fastest in the set, which may account for its relative lack of timing modulation.

The timing profile associated with TPC-IV (Figure 5a) is rapidly and systematically modulated. It shows strong ritards in the accompaniment preceding the onsets of melodic gestures (position 1 in bars 2, 3, and 5), as well as smaller ritards at the ends of segments, as in TPC-I. There is no lengthening of the initial downbeat and no final ritard, but a lengthening in position 8 of bar 3, which is inconsistent with a purely metrical explanation of the timing pattern. Loadings on TPC-IV reached only a maximum of 0.72. The highest loadings were exhibited by Louis Lortie, Samson François (Figure 5b), and Istvan Székely.

Although the Varimax rotation maximized the number of performances that closely resembled one or another PC, there were many profiles that had non-negligible loadings on two or more PCs. It can easily be imagined how TPC-III combines with the other PCs to enhance the lengthening of the initial downbeat, and how combinations of TPC-I and TPC-IV lead to variations in the relative degree of ritards within and between melodic segments. Examples of two more interesting combinations are provided in the next two figures. Figure 6a shows the average (i.e., the standardized sum) of the TPC-I and TPC-II profiles, while Figure 6b shows the timing profile of the performance by Malcolm Binns, which had nearly equal loadings on TPC-I and TPC-II. Figure 7a shows the average of the

TPC-II and TPC-IV profiles, while Figure 7b shows the timing profile of the performance by Liberace, which had nearly equal loadings on TPC-II and TPC-IV. Even though these two timing strategies seem incompatible, they were observed in various combinations.

Whether pianists showing such hybrid timing patterns really entertain several independent expressive strategies simultaneously remains an open question. What the PCA demonstrates is that *across different pianists* certain timing patterns (the different PCs or strategies) are independent of each other while others (the timing of individual gestures within each PC) tend to go together. Thus, for example, the degree of lengthening of the initial downbeat (TPC-III) seems to be largely independent of the timing of later events, and the within-gesture ritards (TPC-I) seem to be at least partially independent of the between-gesture ritards (TPC-IV), but within these patterns each type of ritard tends to be applied consistently. However, these are only overall tendencies, and there were numerous individual variations and exceptions. Moreover, the different PCs occurred in mixtures of various proportions. Two-dimensional scattergrams of the PC loadings for the 115 performances suggested no evidence of either clusters or gaps. The "space" of possible PC combinations seemed to be filled fairly evenly by the individual performances. This argues against the hypothesis that categorically distinct structural interpretations of the Chopin excerpt underly the individual variability. Rather, the different individual timing patterns seem to represent different expressive shapings of the musical surface, selected from a continuum of possibilities.

Results: Dynamic profiles

The PCA of the dynamic profiles yielded five significant PCs that accounted for 77% of the variance in the data. (A separate PCA was conducted only on the 23 PSLs representing melody note onsets, with roughly similar results; see Repp, 1999b.) The first unrotated PC (DUPC-I, where D stands for dynamics) represents the standardized grand average dynamic profile (Figure 8a). It shows very clearly the dynamic distinction between melody (peaks) and accompaniment (troughs). The only melody note that, on average, is as

soft as the accompaniment is the initial upbeat. The accompaniment stays at a fairly constant dynamic level in bars 1–3 but increases somewhat in intensity in bar 4, which is probably due to the doubling of the notes in the right hand. The melody starts out softly, though with a clear dynamic accent on the initial downbeat, and stays at a fairly constant level in bars 1, 2, and 4. The melodic peak in bar 3 is marked by a *crescendo* and a dynamic peak which, however, is already reached on the preceding note. A slight *decrescendo* occurs in bar 5.

DUPC-I alone accounted for 61% of the variance in the dynamic profiles. Ninety-four of the 115 performances showed correlations above 0.7 with the DUPC-I profile. The performances by Louis Kentner (Figure 8b), Maurizio Pollini, and Cecile Licad were the ones with the most typical dynamic profiles, whereas those by Vladimir Horowitz, Witold Malcuzinsky, and Stanislaw Niedzielski had the least typical profiles.

The other unrotated PCs accounted for only little variance. After Varimax rotation, however, the VAF was divided more evenly, and the rotated PCs (DPC-I, ..., DPC-V) accounted for 17%, 13%, 13%, 20%, and 14%, respectively. (The numbering of the rotated PCs reflects the output of the statistical program and is maintained here to avoid confusion.) In contrast to the results of the timing analysis, there seemed to be no single predominant dynamic strategy. Also, the maximal PC loadings tended to be somewhat lower, perhaps due to the lower accuracy of the dynamic measurements.

The DPC-I pattern (Figure 9a) is characterized by *crescendi* during all melodic gestures. There is an early dynamic peak, with little increase thereafter except in bar 4, and a small final *crescendo*. The accompaniment is particularly soft in the second half of bar 3 but almost as strong as the melody in the second half of bar 4. The most representative performances were those by Lubov Timofeyeva (Figure 9b; its limited dynamic range should not detract from the pattern similarity), Erika Haase, and Witold Malcuzinsky.

The DPC-II profile (Figure 10a) shows a consistent differentiation of melody and accompaniment and a marked *decrescendo* through bars 4 and 5. Melodic gestures show little dynamic variation and no *crescendi*. The most representative performances were those by Vlado Perlemuter (Figure 10b), Raoul Koczalski, and John Crown.

The DPC-III pattern (Figure 11a) is characterized by a lack of differentiation between melody and accompaniment throughout, and by a pronounced dynamic arch that reaches its emphatic peak on the highest melody note. The most representative performances were those of Ruth Slenczynska (1956 version, Figure 11b), Peter Donohoe, and Roger Woodward.

The DPC-IV profile (the most frequent dynamic strategy, Figure 12a) has a rather soft beginning in bar 1 but makes a clear distinction between melody and accompaniment in the following bars. The melodic gestures in bars 3, 4, and 5, show an abrupt drop in energy on or before the final long note, down to the level of the accompaniment. In particular, the melodic peak in bar 3 is conspicuously de-emphasized, in contrast to the tendency seen in the grand average profile, in DPC-I, and in DPC-III. There is a parallel between the soft-spoken three-note melodic gesture in bar 1 and the suddenly attenuated second half of the melodic gesture in bar 4. The performances most representative of this interesting strategy were the ones by François-René Duchâble (Figure 12b), William Aide, and Barbara Hesse-Bukowska.

The DPC-V profile (Figure 13a) is characterized by a strong initial upbeat, a de-emphasis of bar 2, a high dynamic level in bars 3 and 4 with little differentiation of melody and accompaniment, and a final *decrescendo*. The individual performances most representative of this pattern were those by Géza Anda (Figure 13b), Alfred Cortot, and Louis Lortie.

As with timing, performances which loaded primarily on one of the five PCs were in the minority. Most performances had modest loadings on two or more of the PCs, which implied that their dynamic profiles were a combination of several strategies. Examples are provided in the next two figures. Figure 14a shows the average of the DPC-I and DPC-V profiles, while Figure 14b shows the dynamic profile of the performance by Ronald Smith, which had nearly equal loadings on DPC-I and DPC-V. Figure 15a shows the average of the DPC-III, DPC-IV, and DPC-V profiles, while Figure 15b shows the dynamic profile of the performance by Monique Haas, which had nearly equal loadings on these three PCs. As in the analysis of the timing data, two-dimensional plots of the dynamic PC loadings did not reveal any obvious clusters or gaps in the distributions. It may be concluded that the dynamic PC profiles do not represent alternative structural interpretations but samples from a continuous range of possible expressive shapes.

Correlational analyses revealed few significant relationships between individual timing profiles and dynamic profiles. In particular, none of the 20 cross-correlations between the loadings of the 115 performances on the four timing PCs and on the five dynamic PCs exceeded 0.3. That is, there were no timing and dynamic strategies that tended to go hand in hand. Moreover, only 18 of the 115 correlations between the individual timing and dynamic profiles (computed here for the melody only) reached significance, and those were in large part due to the initial downbeat being both long and soft. For all practical purposes, therefore, expressive timing and dynamics seem to be independently controlled in this musical passage. This, too, argues against discrete structural interpretations to which both expressive parameters are subordinated.

2. Aesthetic judgments

Method

Four judges participated: BR (the author, amateur pianist, age 53), MC (pianist and music scientist, age 71), NN (pianist and musicologist, age 56), and OS (music critic, amateur pianist, age 30). The judgments were made on a 10-point scale of overall quality ranging from 1 (poor) to 10 (outstanding). Recorded sound quality was to be ignored, as much as possible. BR rated all 115 performances 10 times in different random orders on different days spread out over three weeks, with the identity of the pianists concealed (though he could not help recognizing a few). MC, NN, and OS rated 100 of the performances twice on different days at least one week apart, in slightly different orders, without knowing the identity of the pianists.

BR rated in addition a set of 115 synthesized performances *varying in timing only* 5 times in different random orders, on successive days. These performances were generated by substituting the measured timing patterns for the timing of a good MIDI-recorded performance by a young pianist and resynthesizing all performances on a digital piano. (For details of method, see Repp, 1999c.)

Results

The judges' ratings were moderately reliable. The correlations among sessions were 0.64 for BR (averaged over 45 intercorrelations), 0.76 for MC, 0.50 for NN, 0.56 for OS, and 0.69 for BR's ratings of the synthesized performances (averaged over 10 intercorrelations).

The intercorrelations among the four judges' average ratings are shown in Table 1. They all reached significance but were not very high, especially between OS and the others. This suggests that the judges employed different aesthetic criteria, which was quite welcome in this study, because it increased the generality of the results.

Each judge's average ratings were subsequently entered into a stepwise multiple regression analysis with 16 independent variables: basic tempo (TEMPO), initial upbeat duration (UPBEAT), relative modulation depth of the timing profile (RELMOD), the loadings on TUPC-I and TPC-I through TPC-IV, the standard deviation of the dynamic variation in the melody (MELSD), the average dynamic difference between melody and accompaniment (MELACC), and the loadings on DUPC-I and DPC-I through DPC-V. The results of this analysis are presented in Table 2. Surprisingly, the many variables accounted for only 10 to 18% of the variance (R^2) in each judge's ratings of the original excerpts. Two judges (BR, MC) showed a slight preferences for slower performances, one (NN) for performances with typical timing, and one (OS) for performances with long upbeats and modest timing variation. With one small exception (BR), none of the timing and dynamic profiles explained any significant amount of

Table 1. Intercorrelations among the four judges' average ratings of 100 original excerpts.

	MC	NN	OS
BR	0.56***	0.52***	0.30**
MC	–	0.37***	0.21*
NN	–	–	0.29**

$^{***}p < .001$, $^{**}p < .01$, $^{*}p < .05$

Table 2. Results of stepwise multiple regression analyses on the ratings

Judge	Performance variable	(partial) r	R
BR	TEMPO	–0.36	
	DPC-IV	–0.20	0.39
MC	TEMPO	–0.42	0.42
NN	TUPC-I	0.31	0.31
OS	UPBEAT	0.30	
	RELMOD	–0.25	0.38
BR: synthesized	TEMPO	–0.46	
	TUPC-I	0.41	
	RELMOD	–0.21	0.73

variance. This means either that all four judges were insensitive to timing and dynamics (which seems highly unlikely), or that they found all patterns aesthetically viable to the same degree. Only BR showed a slight dislike for the DPC-IV profile.

By contrast, three temporal variables accounted for more than 50% of the variance in BR's judgments of the synthesized performances varying in timing only, although again these variables did not include any of the specific timing strategies. BR's preference for typically timed synthesized performances (reflected in the positive correlation of his ratings with TUPC-I) replicates an earlier finding reported in Repp (1997): Absence of realistic piano sound seems to induce an aesthetic preference for conventional timing patterns.

3. Conclusions

A mere five bars of music can give rise to a rich diversity of expressive actions, and the present large sample of performances made it possible to map out a representative "space" of acceptable timing and dynamic patterns for a single musical phrase. It seems unlikely (though not inconceivable) that patterns completely outside the possibilities delineated here will be aesthetically viable, especially since the space seems to be shrinking rather than expanding in contemporary performance practice.

The space of possible timing and dynamic profiles is defined by a small number of basic underlying patterns. Although these patterns can be described and perhaps even rationalized in terms of the musical structure they are applied to, most individual profiles do not seem to correspond to different structural interpretations. If that were the case, stronger clustering of performances representing the same structural interpretation should have been observed. Unless structural interpretation is reconceptualized as the adjustment of continuous parameters rather than the making of discrete choices, it seems appropriate to distinguish such continuous adjustments from structural interpretation by regarding them as expressive shapings of the musical surface. The musical structure exerts constraints on these shapings (perhaps more so on timing than on dynamics), just as a complex physical object permits or resists various patterns of deformation. Small deformations do not seriously alter the structure; rather, they present it in a certain light and thus give it a particular aesthetic quality, often difficult to characterize in words.

The psychological status of the PC patterns remains uncertain. Although they appear in many combinations, each combination is presumably conceived and perceived as a unitary expressive strategy. The PC profiles, therefore, are best regarded as abstractions that make possible an economical description of individual variability in performance. They are not totally abstract, however, because they correspond rather closely to particular individual performances, usually located at the periphery of the space of expressive possibilities. These performances, then, exemplify different ways of deviating from the most typical expressive profile, which is a weighted average of all possibilities and which, at least in the case of timing, seems to have a basis in the perception of rhythmic groups and their temporal implications (Repp, 1992b, 1998a).

One surprising finding was that timing and dynamics were essentially unrelated. Todd's (1992) observation that timing and dynamics are often linked ("the faster the louder") across longer stretches of music does not seem to hold at this within-phrase level of detail. Pianists' independent control over these two important expressive parameters makes possible a very large variety of expressive shapes.

Another surprising finding was that the measured aspects of timing and dynamics (including some not discussed here in detail) accounted for little systematic variability in aesthetic judgments. It is possible that there are aesthetically important aspects of timing and dynamics that were not adequately captured by the analyses performed, for example their relative smoothness or continuity. A more likely reason, however, is that other expressive dimensions that are much more difficult to measure and quantify played an important role in this Chopin Etude excerpt. Foremost among these are beauty of tone and texture, which the E-major Etude is really a study of. Excellent control over these more elusive aspects of the pianist's art seems to give artists the freedom to explore less conventional patterns of timing and dynamics. Tone and texture are less satisfying in synthesized performances, which is why listeners seem to prefer more conventional timing (and perhaps also dynamic) patterns in such performances.

Acknowledgments

This research was supported by NIH grant MH-51230. The author is grateful to Suk Won Yi for inviting him to present this work in a plenary session at the Fifth International Conference on Music Perception and Cognition in Seoul. The present chapter summarizes findings described in detail in a series of three articles in the *Journal of the Acoustical Society of America* (Repp, 1998d, 1999b, 1999c).

References

Repp, B. H. (1992a). Diversity and commonality in music performance: An analysis of timing microstructure in Schumann's "Träumerei". *Journal of the Acoustical Society of America, 92*, 2546–2568.

Repp, B. H. (1992b). Probing the cognitive representation of musical time: Structural contraints on the perception of timing perturbations. *Cognition, 44*, 241-281.

Repp. B. H. (1997). The aesthetic quality of a quantitatively average music performance: Two preliminary experiments. *Music Perception, 14*, 419-444.

Repp, B. H. (1998a). Variations on a theme by Chopin: Relations between perception and production of timing in music. *Journal of Experimental Psychology: Human Perception and Performance, 24*, 791–811.

Repp, B. H. (1998b). Obligatory "expectations" of expressive timing induced by perception of musical structure. *Psychological Research, 61*, 33–43.

Repp, B. H. (1998c). The detectability of local deviations from a typical expressive timing pattern. *Music Perception, 15*, 265–290.

Repp, B. H. (1998d). A microcosm of musical expression: I. Quantitative analysis of pianists' timing in the initial measures of Chopin's Etude in E major. *Journal of the Acoustical Society of America, 104*, 1085–1100.

Repp, B. H. (1999a). Detecting deviations from metronomic timing in music: Effects of perceptual structure on the mental timekeeper. *Perception & Psychophysics, 61*, 529-548.

Repp, B. H. (1999b). A microcosm of musical expression: II. Quantitative analysis of pianists' dynamics in the initial measures of Chopin's Etude in E major. *Journal of the Acoustical Society of America, 105*, 1972-1988.

Repp, B. H. (1999c). A microcosm of musical expression: III. Contributions of expressive timing and dynamics to the aesthetic impression of the initial measures of Chopin's Etude in E Major. *Journal of Acoustical Society of America, 106*, 469-478.

Todd, N. P. McA. (1992). The dynamics of dynamics: A model of musical expression. *Journal of the Acoustical Society of America, 91*, 3540-3550.

Recordings mentioned in this article

(For a complete listing of all 115 recordings, see Repp, 1998d.)

Pianist	Label	Year (~ = estimated)
Aide, William	Musica Viva 1017	1987
Anda, Géza	Fonit Cetra CDE 1018	1965
Backhaus, Wilhelm	Pearl GEMM CD 9902	1927
Badura-Skoda, Paul	Westminster XWN-18811	~1960
Binns, Malcolm	Pearl 9641	1995
Cortot, Alfred	EMI Classics 2905401	1933
	Pathé FJLP 5050	1942
Crown, John	Co-Art 5047	~1947
Donohoe, Peter	EMI 54416	1993
Duchâble, François-René	Erato 45178	1981
François, Samson	EMI C 163-5323/7	1959
Goodman, Isador	Austral. Philips 6508 004	1979
Haas, Monique	Erato STU 70941	1977
Haase, Erika	Thorofon CTH 2195	1992
Hesse-Bukowska, Barbara	Muza SXL 0611	~1970
Hobson, Ian	EMI CFP 4392	1982
Horowitz, Vladimir	RCA Victor 60376-2-RG	1951
	Sony 53468	1972
Kentner, Louis	Capitol GBR 7162	1957
Koczalski, Raoul	Polydor 67262	1938
Kyriakou, Rena	Vox GBY 12710	1964
Larrocha, Alicia de	MHS 1761	~1969
Liberace	Columbia ML 4900	~1955
Licad, Cecile	MusicMasters MM 67124	~1994
Lortat, Robert	Dante 025	~1931
Lortie, Louis	Chandos CHAN 8482	1986
Malcuzinsky, Witold	British Columbia LX 1203	~1948
Niedzielski, Stanislaw	Westminster WL 5340	1955
Perlemuter, Vlado	Nimbus NI 5095	1983
Pollini, Maurizio	DGG 413 794-2	~1971
Ranki, Dezsö	Hungaroton 11555	~1975
Slenczynska, Ruth	Decca DL 9890	1956
Smith, Ronald	Nimbus 5224	1990
Székely, István	Naxos 8.550083	1987
Timofeyeva, Lyubov	Melodiya 10-00071	1985
Varsi, Dinorah	Intercord 160.842	1981
Weissenberg, Alexis	EMI 69114	1979
Woodward, Roger	Austral. EMI OASD 7560	~1975
Yokoyama, Yukio	Sony SK 62605	1995

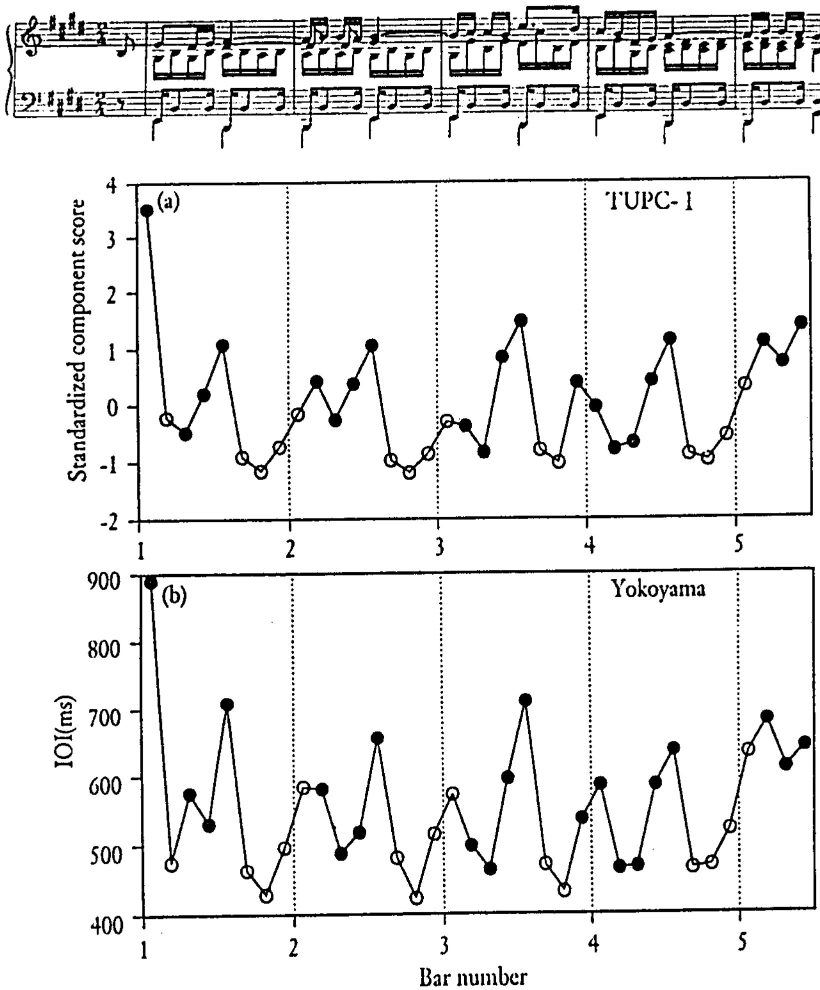


Figure 1. (1) The unrotated first principal component timing profile (TUPC-I) and (b) the timing profile of the performance by Yukio Yokoyama ($r = 0.94$).

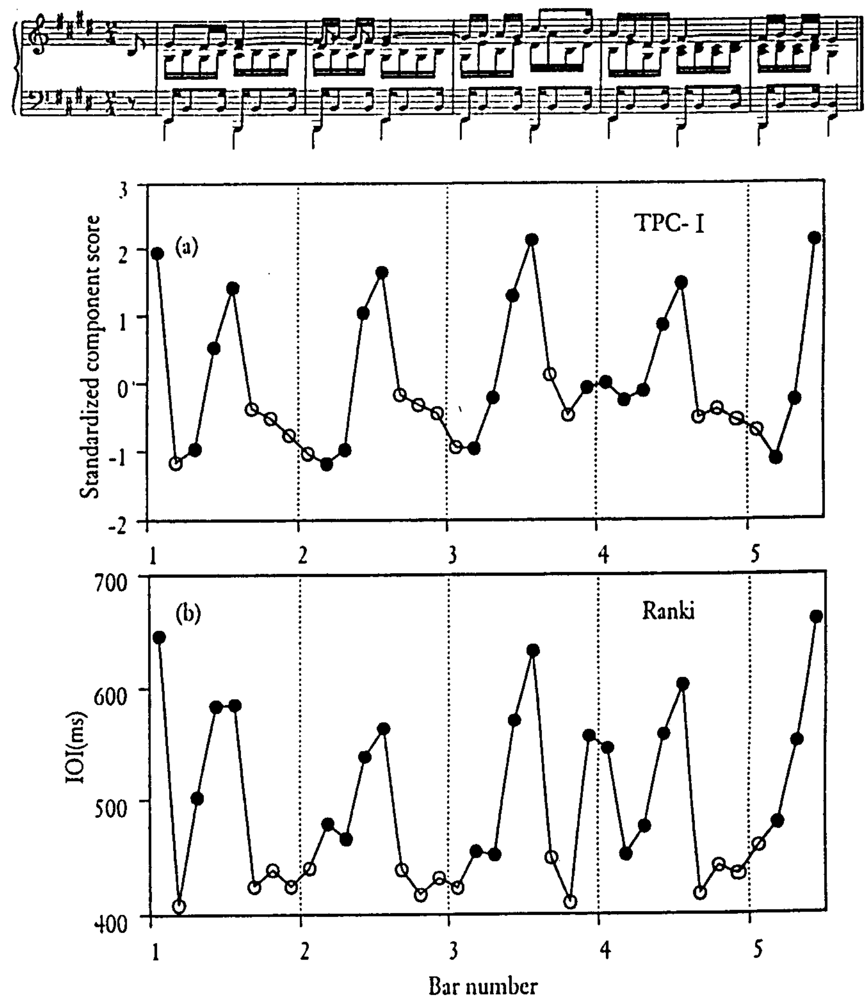


Figure 2. (a) The rotated first principal component timing profile (TPC-I) and (b) the timing profile of the performance by Dezsö Ranki ($r = 0.85$).

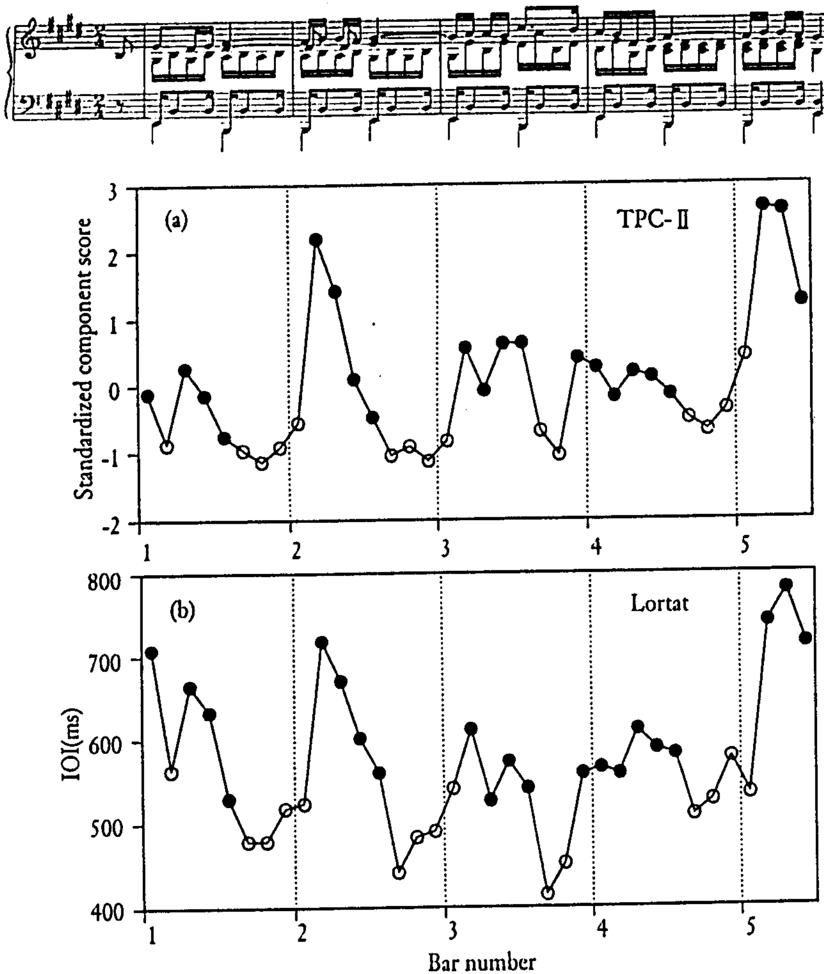


Figure 3. (a) The rotated second principal component timing profile (TPC-II) and (b) the timing profile of the performance by Robert Lortat ($r = 0.84$).

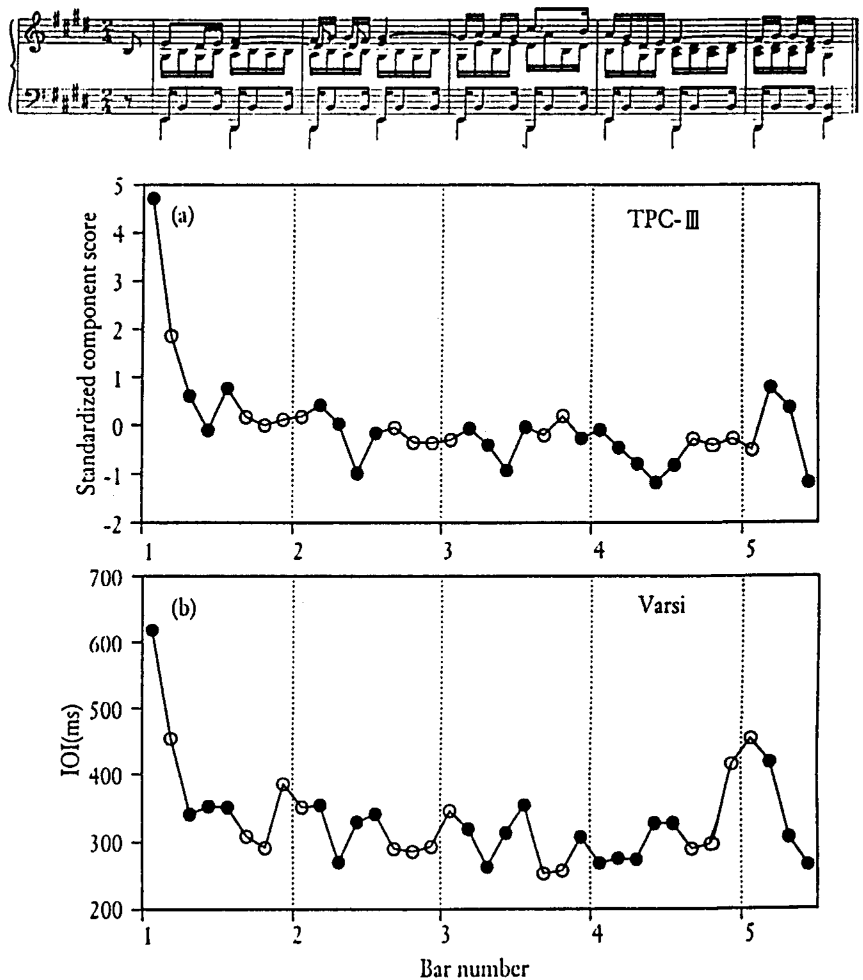


Figure 4. (a) The rotated third principal component timing profile (TPC-III) and (b) the timing profile of the performance by Dinorah Varsi ($r = 0.74$).

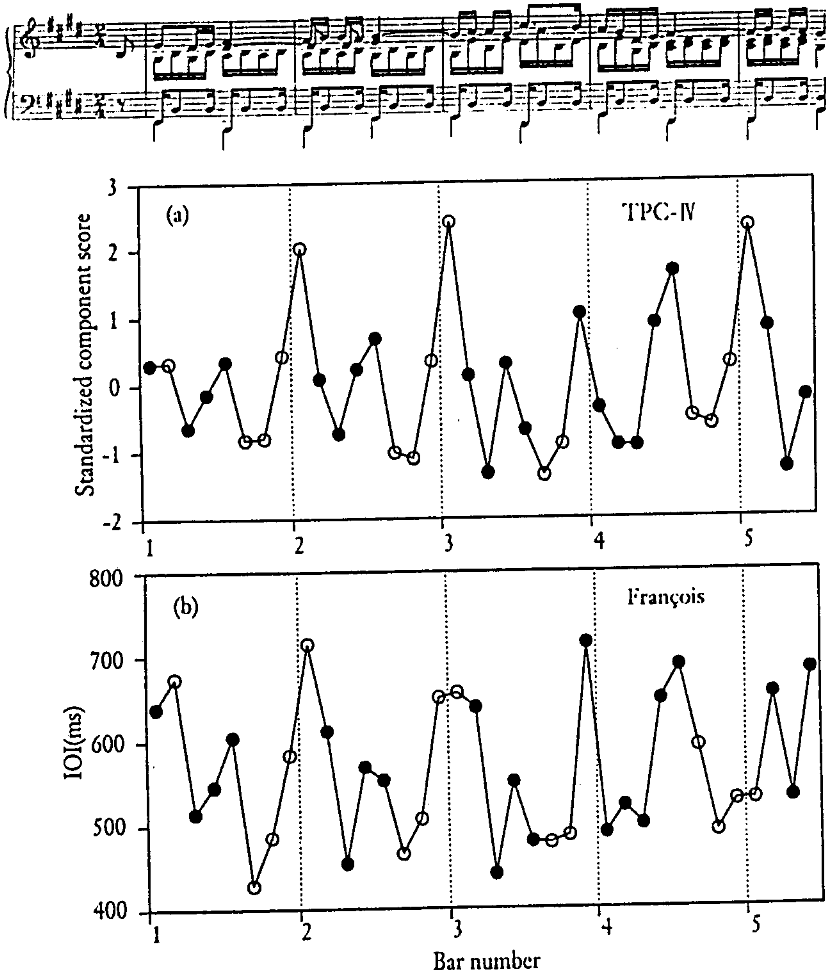


Figure 5. (a) The rotated fourth principal component timing profile (TPC-IV) and (b) the timing profile of the performance by Samson François (r = 0.71).

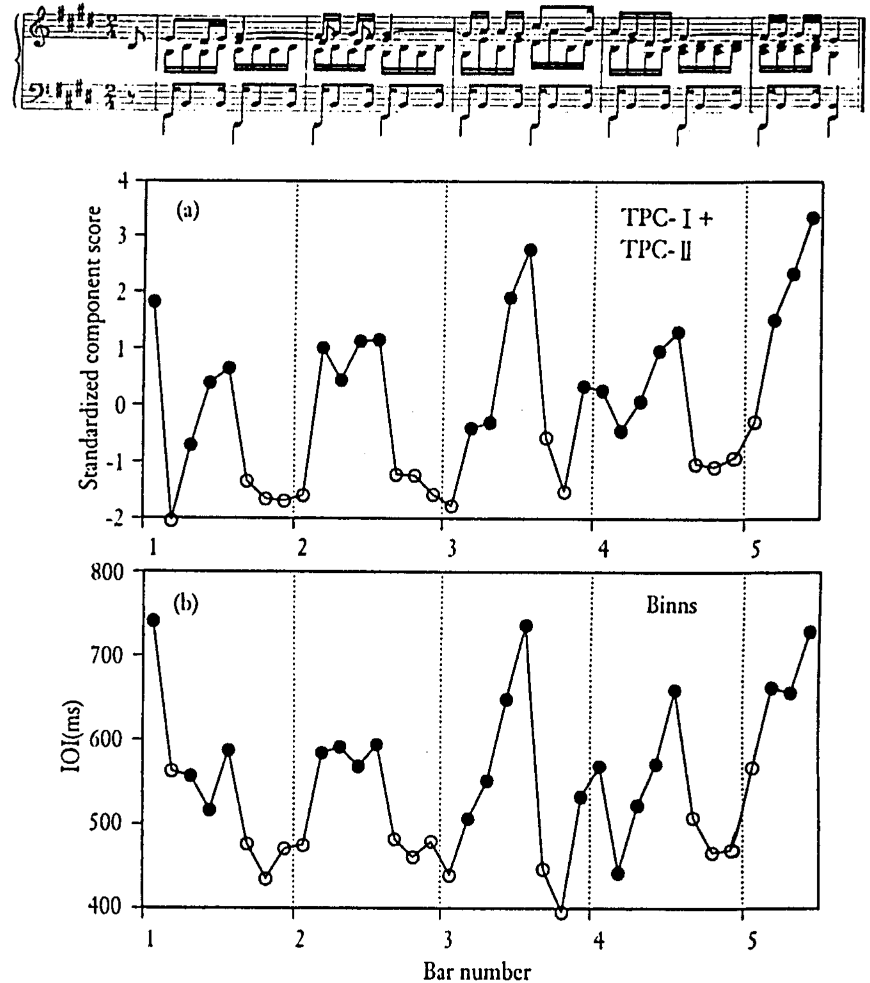


Figure 6. (a) The average (standardized sum) of TPC-I and TPC-II and (b) the timing profile of the performance by Malcolm Binns (r = 0.88).

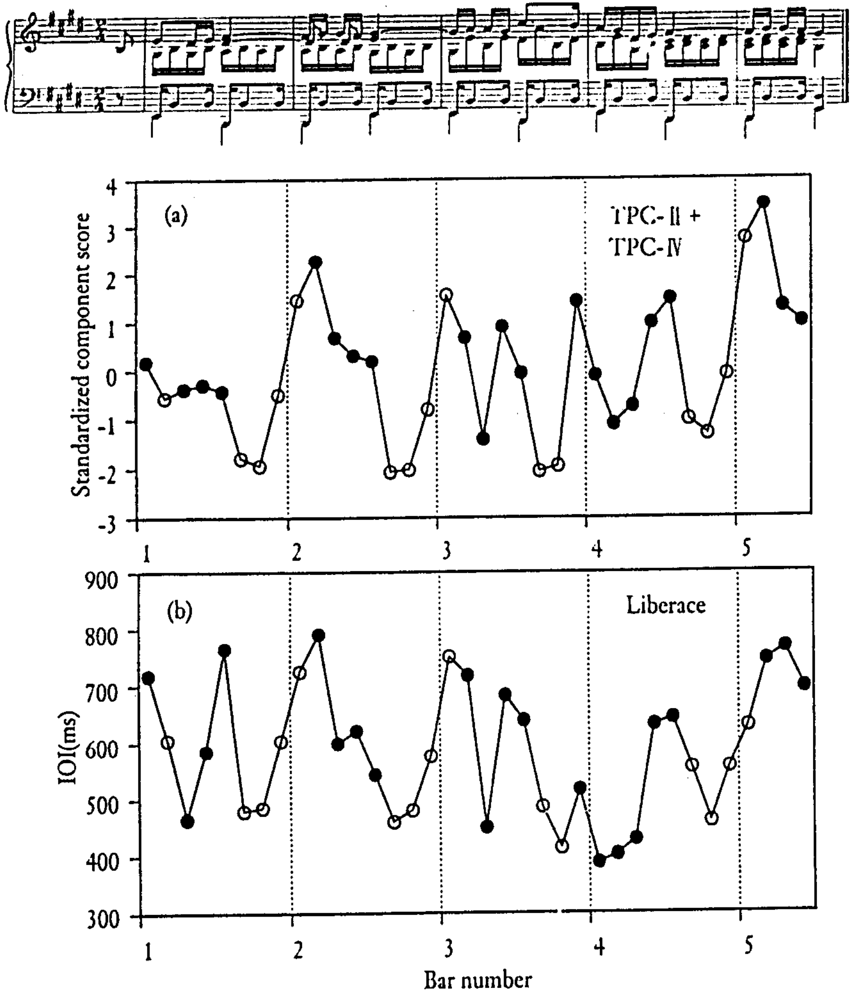


Figure 7. (a) The average (standardized sum) of TPC-II and TPC-IV and (b) the timing profile of the performance by Liberace ($r = 0.73$).

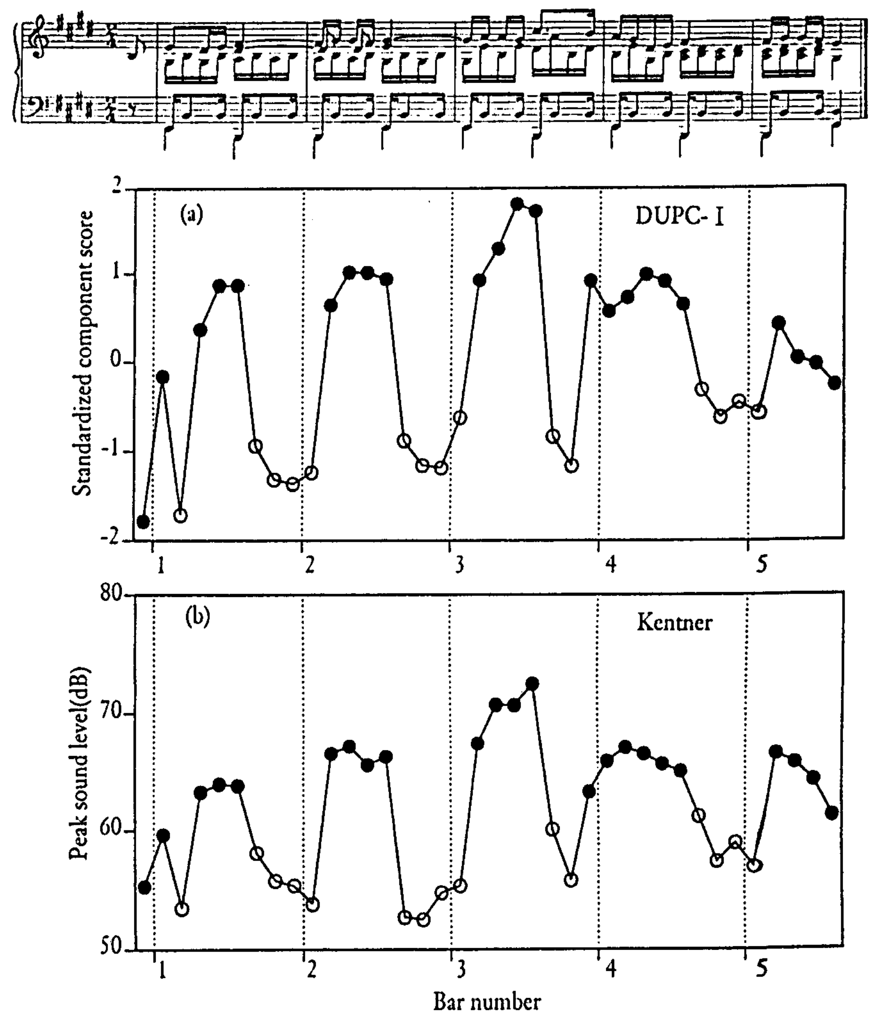


Figure 8. (a) The unrotated first principal component dynamic profile (DUPC-I) and (b) the dynamic profile of the performance by Louis Kentner ($r = 0.94$).

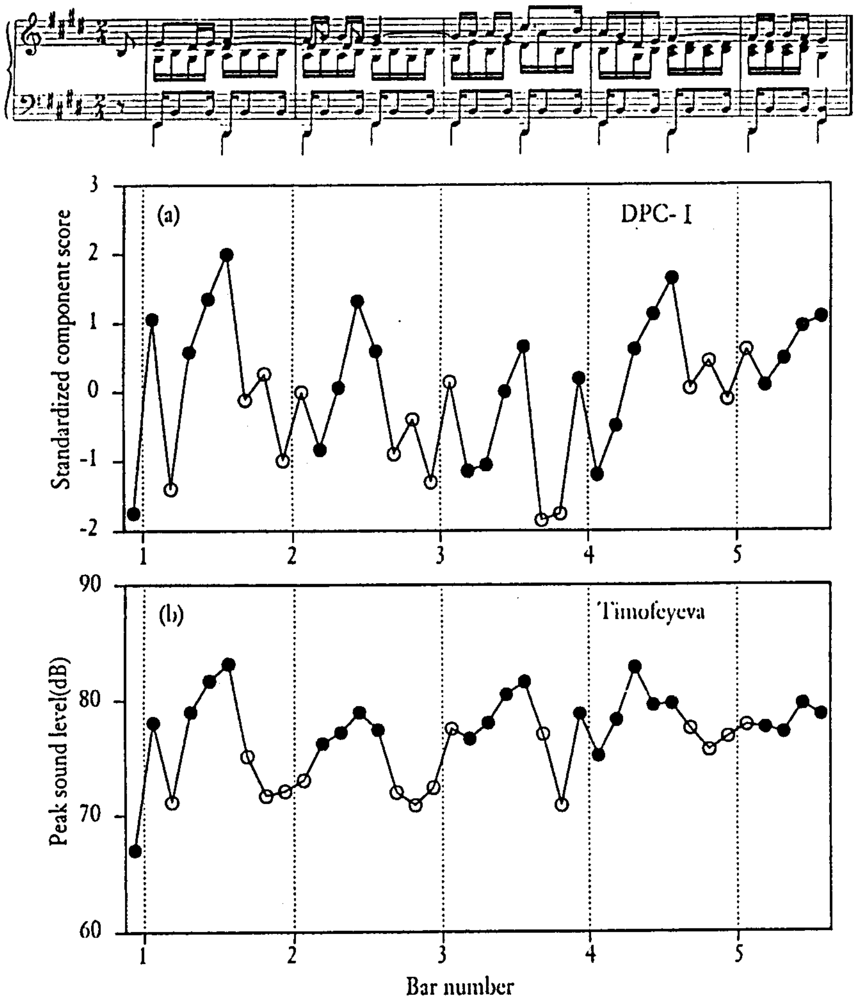


Figure 9. (a) The rotated first principal component dynamic profile (DPC-I) and (b) the dynamic profile of the performance by Lubov Timofeyeva ($r = 0.72$).

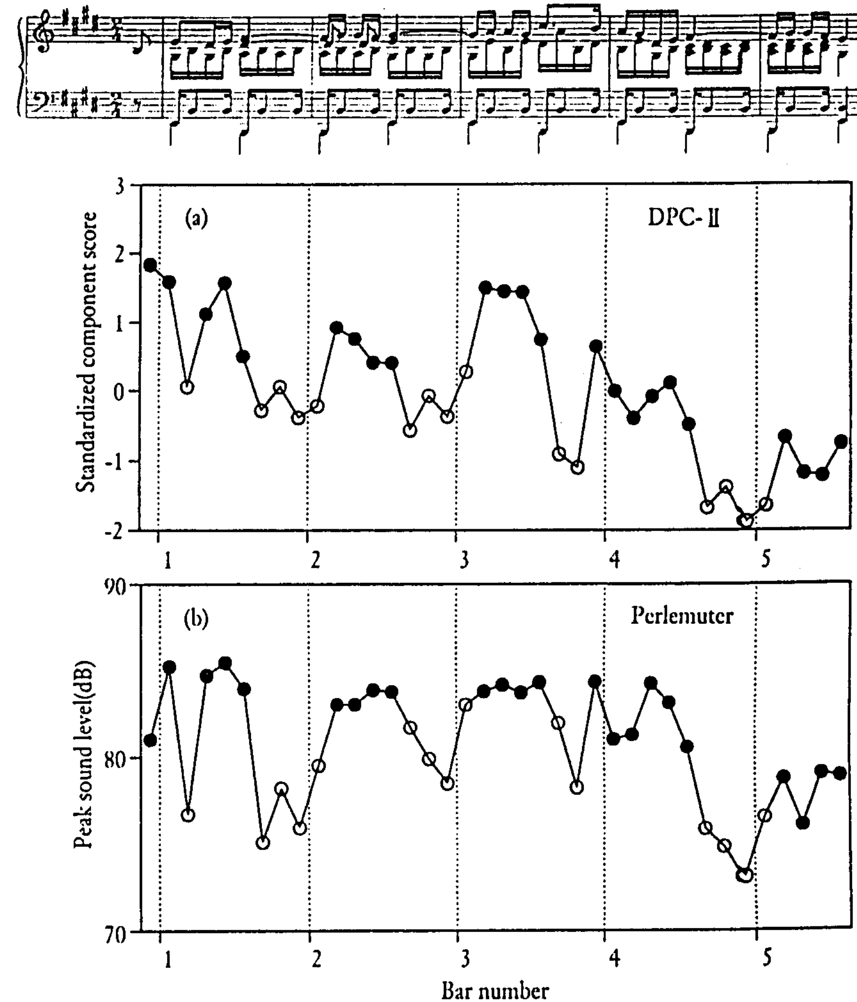


Figure 10. (a) The rotated second principal component dynamic profile (DPC-II) and (b) the dynamic profile of the performance by Vlado Perlemuter ($r = 0.78$).

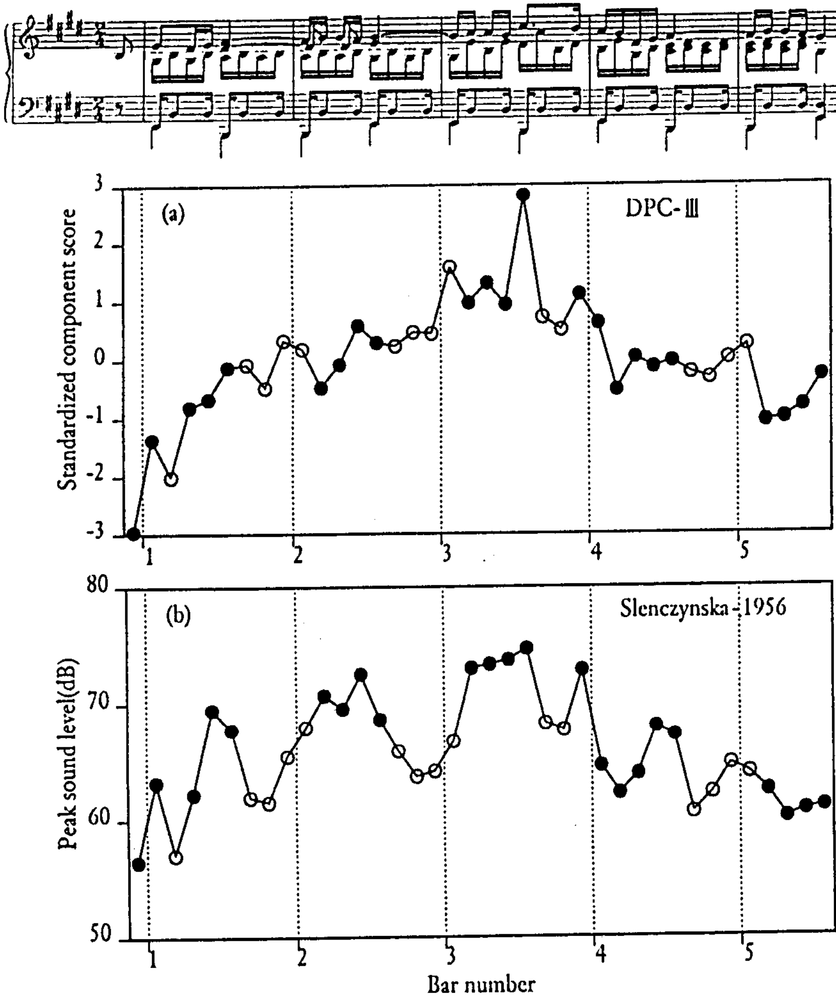


Figure 11. (a) The third principal component dynamic profile (DPC-III) and (b) the dynamic profile of the performance by Ruth Slenczynska (1956) ($r = 0.75$).

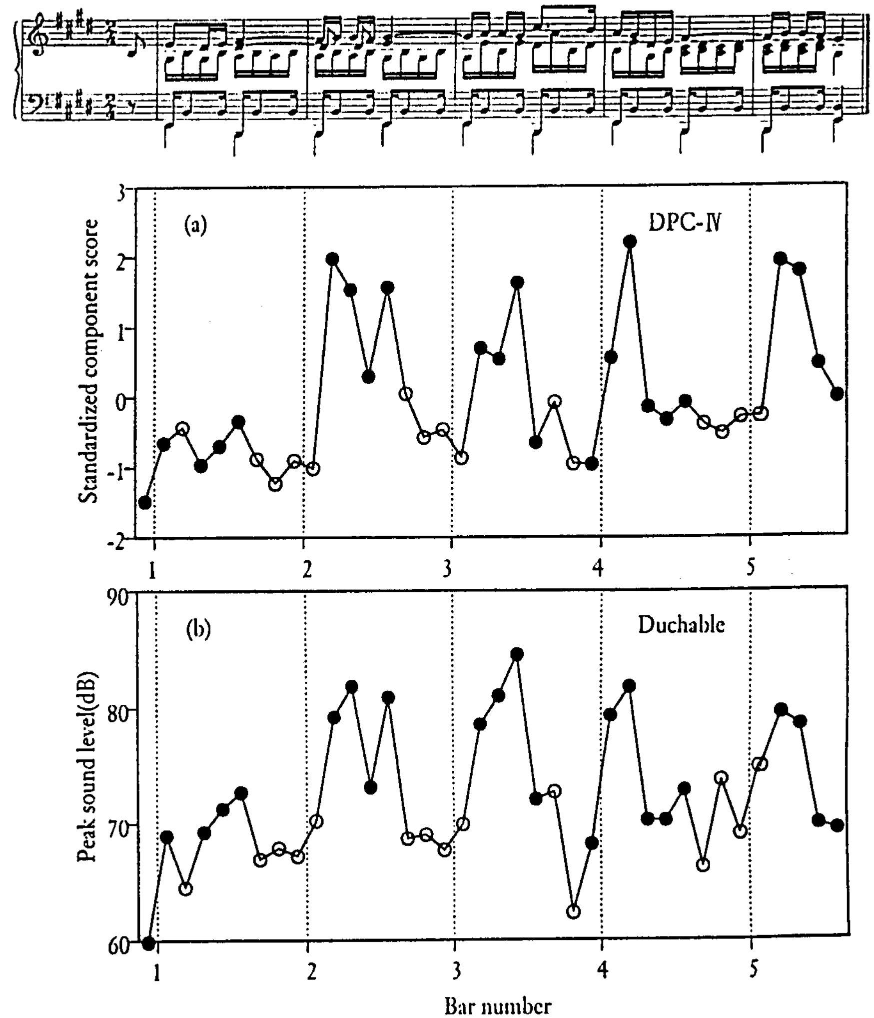


Figure 12. (a) The rotated fourth principal component dynamic profile (DPC-IV) and (b) the dynamic profile of the performance by François-René Duchâble ($r = 0.86$).

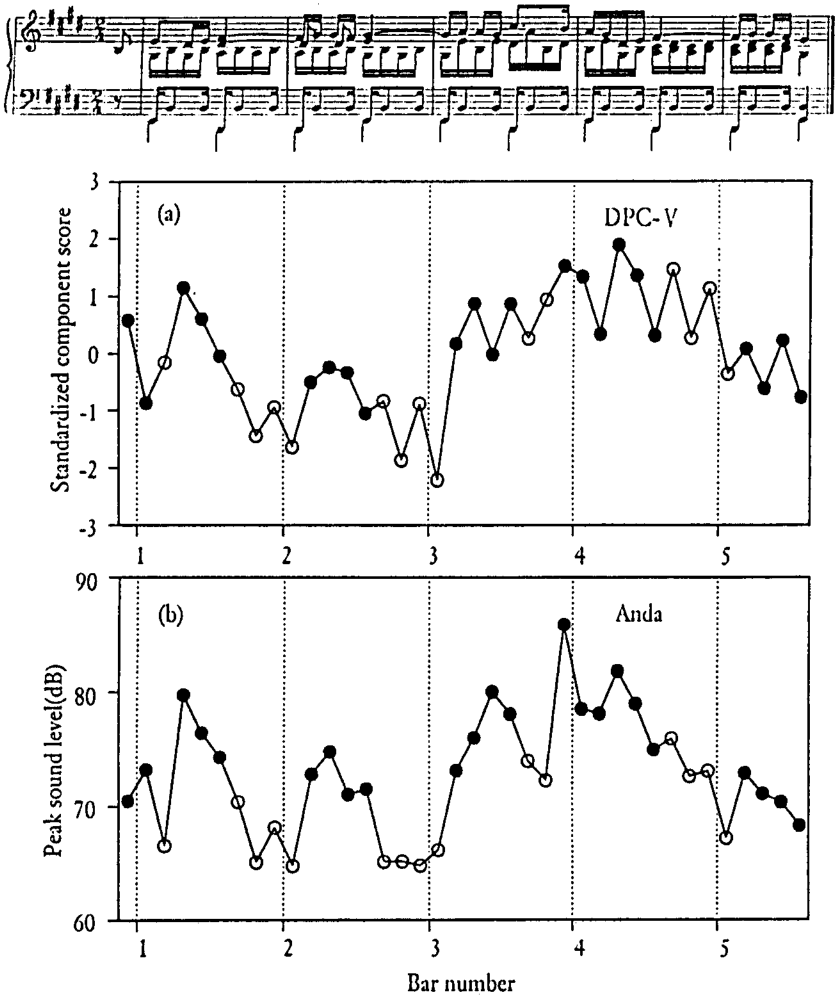


Figure 13. (a) The rotated fifth principal component dynamic profile (DPC-V) and (b) the dynamic profile of the performance by Géza Anda ($r = 0.81$).

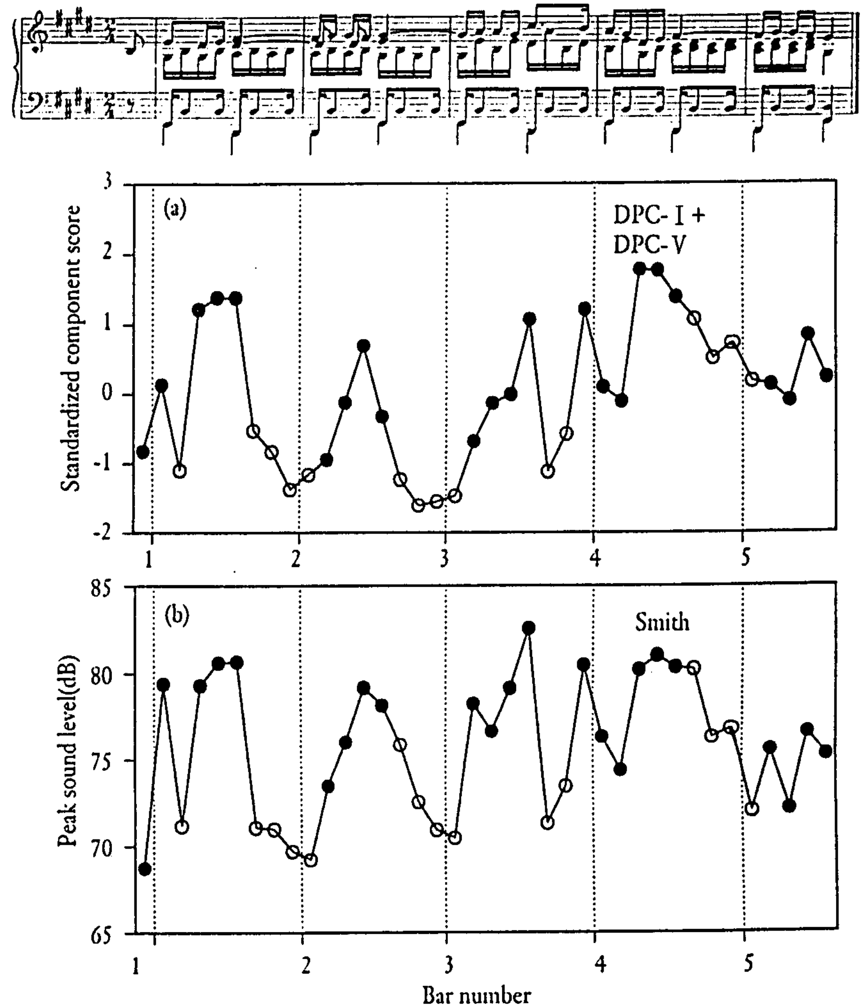


Figure 14. (a) The average (standardized sum) of DPC-I and DPC-V, and (b) the dynamic profile of the performance by Ronald Smith ($r = 0.83$).

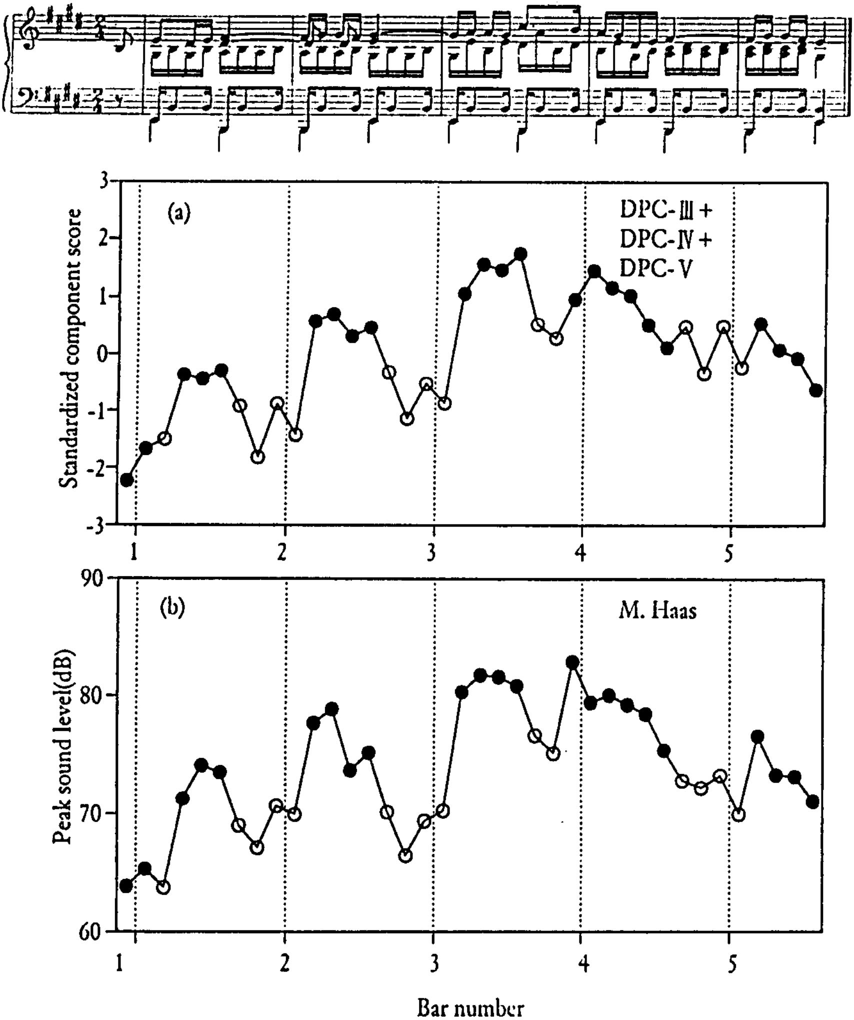


Figure 15. (a) The average (standardized sum) of DPC-III, DPC-IV, and DPC-V, and (b) the dynamic profile of the performance by Monique Haas ($r = 0.94$).