Expressive timing in Schumann's "Träumerei:" An analysis of performances by graduate student pianists

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(Received 15 March 1995; revised 22 May 1995; accepted 24 May 1995)

Statistical analyses were conducted on the expressive timing patterns of performances of Schumann's "Träumerei" by ten graduate student pianists who played from the score on a Yamaha Disclavier after a brief rehearsal. A previous study of acoustic recordings of "Träumerei" by 24 famous pianists [B. H. Repp, J. Acoust. Soc. Am. 92, 2546–2568 (1992)] provided "expert" timing data for comparison. In terms of group average timing pattern, individual shaping of *ritardandi*, and within-performance consistency, the students turned out to be quite comparable to the experts. This demonstrates that precision in expressive timing does not require extensive study and practice of the music at hand, only general musical and technical competence. Subsequent principal components analyses on the students' timing patterns revealed that they were much more homogeneous than the experts'. Individual differences among student pianists seemed to represent mainly variations around a common performance standard (the first principal component), whereas expert performances exhibited a variety of underlying timing patterns, especially at a detailed level of analysis. Experienced concert artists evidently feel less constrained by a performance norm, which makes their performances more interesting and original, hence less typical. Since the norm may represent the most natural or prototypical timing pattern, relatively spontaneous performances by young professionals may be a better starting point for modeling expressive timing than distinguished artists' performances. © *1995 Acoustical Society of America.*

PACS numbers: 43.75.St, 43.75.Cd

INTRODUCTION

Musical performance is one of the most intricate and highly developed skills humans are capable of. It requires hundreds of hours of instruction and thousands of hours of practice to reach a high level of competence. This competence includes not only technical mastery of the instrument of choice, but also a thorough acquaintance with stylistic and expressive norms. That is, musicians must not only know how to play the right notes, in tune, in tempo, with the correct rhythm, and at an appropriate dynamic level, but also how to continuously *vary* tempo and dynamics (and on some instruments, intonation and timbre as well) so as to produce an expression that captures listeners' attention and emotions. This is particularly true of Western art music of the Romantic period, which often calls for extreme modulations in tempo and dynamics which, for the most part, are not notated.

On the piano, expressive timing and dynamics are the two principal dimensions that make a performance interesting and appealing. The present study focuses on expressive timing only. This term denotes continuous modulations of the basic tempo which can be measured and described in terms of the temporal intervals between successive tone onsets (tone interonset intervals or IOIs).[1] The pattern of IOIs, normalized to a fixed nominal note value and plotted as a function of metrical score position defines the expressive *timing profile* of a performance.[2] A number of earlier studies have analyzed the expressive timing of pianists' performances; for a summary of this literature, see Repp (1992a). In most of these studies, as in the present one, technical difficulty or fingering were not important factors; the music was relatively slow and easy to play, so that the timing profile was a relatively pure measure of expressive intention (though the precise realization of that intention does require fine motor control!). The most extensive analysis of this kind included 28 recorded performances of Robert Schumann's well-known piano piece, "Träumerei" (Repp, 1992a). Various statistical techniques were applied to assess within-performance consistency, commonalities and differences among individual timing patterns, relationships of timing to musical structure, and the precise shaping of temporal detail (such as *ritardandi*).

The present investigation was modeled closely after this earlier analysis. It was based on a new set of 29 performances by ten advanced student pianists ("students" henceforth), which had been recorded on a Yamaha Disclavier in MIDI format after only a brief rehearsal. These recordings satisfied the minimal requirements of a professional performance in that they were fluent and expressive. Whereas the "expert" performances studied by Repp (1992a) represent the pinnacle of artistic achievement and insight (in many instances at least), the student performances analyzed here represent expressive performance in a more pristine state, as it were. They result from the relatively spontaneous application of acquired technical and musical skills to a score, albeit one familiar from listening and, in some cases, from past study. Such performances are of interest in their own right because they may be more representative of a standard or norm that guides the expressive shaping of timing (and dynamics) than are the highly individual and refined interpretations of famous concert artists. Whether that is the case, however, is an empirical question that the present study

meant to address. In principle, it could well be that student performances are as diverse or more diverse than expert performances, due to large variation in students' competence and degree of musical understanding. Considering the minimal preparation preceding the present recordings, the students' expressive timing might also be more variable than the experts' finely honed profiles, and it might show lapses of control or taste in the shaping of temporal detail. If so, the student performances would probably not be a good basis for studying principles of expressive timing. It will be argued below, on the contrary, that these performances in fact reveal a high level of competence and may actually provide a better starting point for modeling expressive microstructure than the performances of the most famous artists.

The aspects of expressive timing that will be considered may be grouped under four headings: (1) consistency, (2) commonalities, (3) execution of local details, and (4) individual differences.

The pianists' consistency was assessed by comparing their timing profiles across repeated performances and across identical or similar musical passages in the same performance. Consistency may be regarded as a measure of technical precision, provided that the pianist did not intend to play the music differently when it was repeated. A low correlation may indicate a change of interpretation, but since the students had been asked to provide three similar performances, their between-performance consistency was taken as an indication of their ability to reproduce the same expressive intention. A comparison of between- with within-performance consistency was expected to reveal the extent to which the students intended to play repeated sections the same way. High within-performance consistency would also indicate precision of expressive intent and execution.

The group average timing profile gives a picture of what most performances have in common. The relative similarity of the average student and expert profiles was of interest. The students might be expected to show a less differentiated or less varied profile, due to a less thorough structural understanding of the music and a less developed ability to convey that interpretation through expressive timing. As Todd (1985), Palmer (1989), and others have demonstrated, the peaks and valleys in the timing profile are an index of the hierarchical phrase structure of the music, as understood by the performer.

In the execution of local details, the temporal shape of *ritardandi* was of special interest. Several studies have found evidence that the sequence of IOIs during well-executed *ritardandi* tends to follow a parabolic or possibly cubic curve (Kronman and Sundberg, 1987; Repp, 1992a, b; Feldman *et al.*, 1992; Epstein, 1995), and Todd's (1995) recent characterization of expressive timing in terms of linear changes in tempo is consistent with that finding also (Todd, submitted). The extent to which *ritardando* timing fits such a curve may thus serve as an index of the individual performer's skill or taste, and the question was whether the students would live up to the examples set by the experts.

Last, but certainly not least, was the issue of individual differences. The experts exhibited varied timing strategies, but they were also a very heterogeneous group, representing a wide range of ages, nationalities, and recording dates. Would the students show similar diversity, or would they be more homogeneous and hark closer to a common norm? This was perhaps the most interesting question of this study, and it was addressed primarily by means of principal components analysis, which gives an indication of the number of statistically independent timing patterns underlying a set of performances.

Although the expert data will be summarized and occasionally reproduced here in a new format, frequent reference will be made to Repp (1992a), particularly its figures and tables. The reader should have a copy of that article available.

I. METHOD

A. The music

The score of "Träumerei" is reproduced in Repp (1992a; Fig. 1), and a brief analysis is presented there also. The piece consists of six 4-bar phrases, the first two of which are repeated. Phrases 1 and 5 are identical and similar to the (abbreviated) final phrase, whereas phrases 2–4 are structurally similar to each other. Positions in the music will be referred to by using the convention "bar-beat-halfbeat;" thus "15-3-2" refers to the second eighth note of the third beat in bar 15.[3]

B. The pianists

Nine of the participating pianists were graduate students of piano performance at the Yale School of Music; the tenth was about to enter the same program. Five students were in their first year, one in her second year, and three were third-year students. Their age range was 21–29, and they had started to play the piano between the ages of 4 and 8. Seven were female, three male. They will be referred to here by numbers prefaced by the letter P (for pianist).

C. Procedure

The pianists were sent a copy of the music prior to the recording session. Given their extremely busy schedules, however, most of them came to the recording session without advance preparation. The recording took place in a room housing an upright Yamaha MX100A Disclavier connected to a Macintosh computer which recorded the keyboard and pedal actions in MIDI format. The pianist was given the music and asked to rehearse it at the Yamaha for 1 h. There were three other pieces to be played in addition to "Träumerei," about 13 min of music altogether. After the rehearsal hour, the pieces were recorded one at a time, in whichever order the pianist preferred, and then the cycle was repeated twice. If something went seriously wrong in a performance, it was repeated immediately. One pianist, P4, as a result of multiple retakes and a computer problem, was able to record only two performances of each piece; all others recorded three, as planned. At the end of the session, each pianist filled out a questionnaire and was paid $50.

The responses to the questionnaire revealed that Schumann's "Träumerei" had been previously studied by three

pianists (P5, P7, P8) and played informally by two; the rest knew it well from listening only. The pianists were also asked to indicate how satisfied they were with their performances, choosing from the categories "best effort," "good effort," "average," "below average," and "poor." For "Träumerei," the distribution of choices was 0, 4, 5, 1, 0.

D. Data analysis

The MIDI data were imported as text files into a Macintosh spreadsheet and graphics program (DELTAGRAPH PROFESSIONAL), where the note onsets were separated from the other events (note offsets and pedal actions) and labeled with reference to a numerical (MIDI pitch) transcription of the score. Only the highest note in each chord received a label, and grace notes were excluded.[4] The labeled note onsets were subsequently extracted, and the IOIs between them were computed. Those IOIs which represented intervals longer than a nominal eighth note were divided into equal eighth-note parts, so that all IOIs represented nominal eighth-note intervals. While this subdivision of longer IOIs is useful for graphic purposes, it may be debated whether they should enter statistical procedures as single or multiple data points. Repp (1992a) used the single data point format in some analyses and also applied a logarithmic transformation to the IOIs. The present analyses instead used the multiple data point format without transformation. Analyses of the expert data were redone in the present format, with minimal differences.

II. RESULTS AND DISCUSSION

A. Basic tempo

To begin with, the tempo choices of the students were compared with those of the experts, which provided an opportunity to correct faulty tempo estimates reported in Repp (1992a). Estimating the basic tempo of a performance whose tempo is continuously modulated is not straightforward in view of the asymmetric distribution of IOI durations caused by *ritardandi* at major structural boundaries. Repp (1994a) demonstrated, however, that listeners' subjective tempo estimates for music *not* containing extreme *ritardandi* (in fact, for the initial 8 bars of "Träumerei") are very close to the reciprocal of the average beat duration (expressed in fractions of a minute). The tempo estimates (beats per minute, or bpm) employed here are therefore based on the average beat duration of bars 1–8 of each performance (including the repeat). The estimates given in Table III of Repp (1992a), which were derived by a different method, are almost certainly too high and are superseded by the present estimates. Figure 1 shows these estimated tempi for all expert and student performances, rank-ordered according to average tempo in the case of multiple performances.[5] They span a wide range (from 42 to 67 bpm) but are much slower than the 80 bpm recommended by Clara Schumann in her edition of the music, not to mention the 100 bpm attributed to the composer himself.

The tempo choices of the student pianists cover as wide a range as those of the experts. Most students, however, turned in relatively fast performances. Those of P4 were

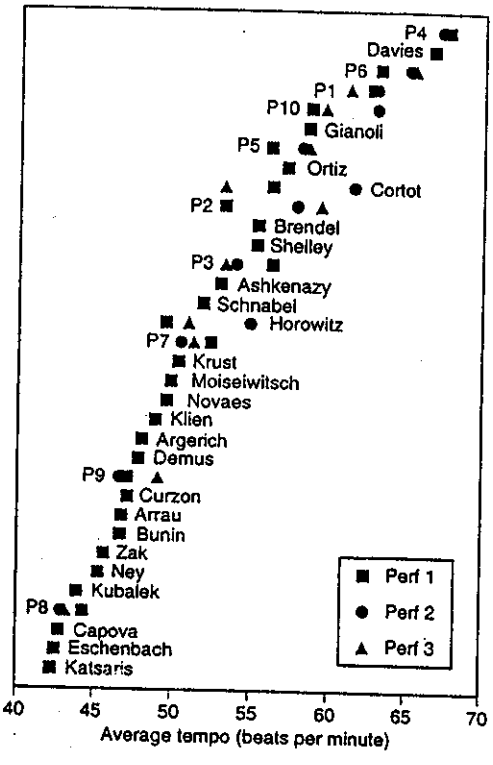

FIG. 1. Average tempi of the various performances, based on bars 1–8.

slightly faster than the fastest expert performance, which was by Clara Schumann's one-time pupil, Fanny Davies. P6, P1, and P10 played faster than the next-fastest expert, French pianist Reine Gianoli, and P5, P2, and P3 were still in the faster half of the distribution. P7 was near the center, P9 was somewhat on the slow side, and only P8 was near the slow end of the distribution. It can also be seen that no student played all three performances at exactly the same tempo, though P4 (who played only two performances) came close. The two experts who provided three performances each (Cortot, Horowitz) varied more than most student pianists, but their recordings were separated by years whereas the students' performances were only about 20 min apart.

One reason for the students' faster tempo choices could have been that they performed the piece in isolation, whereas most of the experts played it in the context of the complete "Kinderszenen" suite. Four of the expert recordings, however, represent performances of "Träumerei" by itself (Katsaris, Capova, Klien, Horowitz-3), and none of them is very fast. Another possible explanation is that the students, especially those who had not studied the piece, were somewhat tense in the recording situation and therefore tended toward faster tempi. The three who had studied "Träumerei" previously (P5, P7, P8) indeed produced some of the slower performances.[6]

B. Stability of timing patterns across repetitions

High stability of a pianist's expressive timing across repeated performances of the same music seems to be the rule. Although it is often said that artists rarely play the same

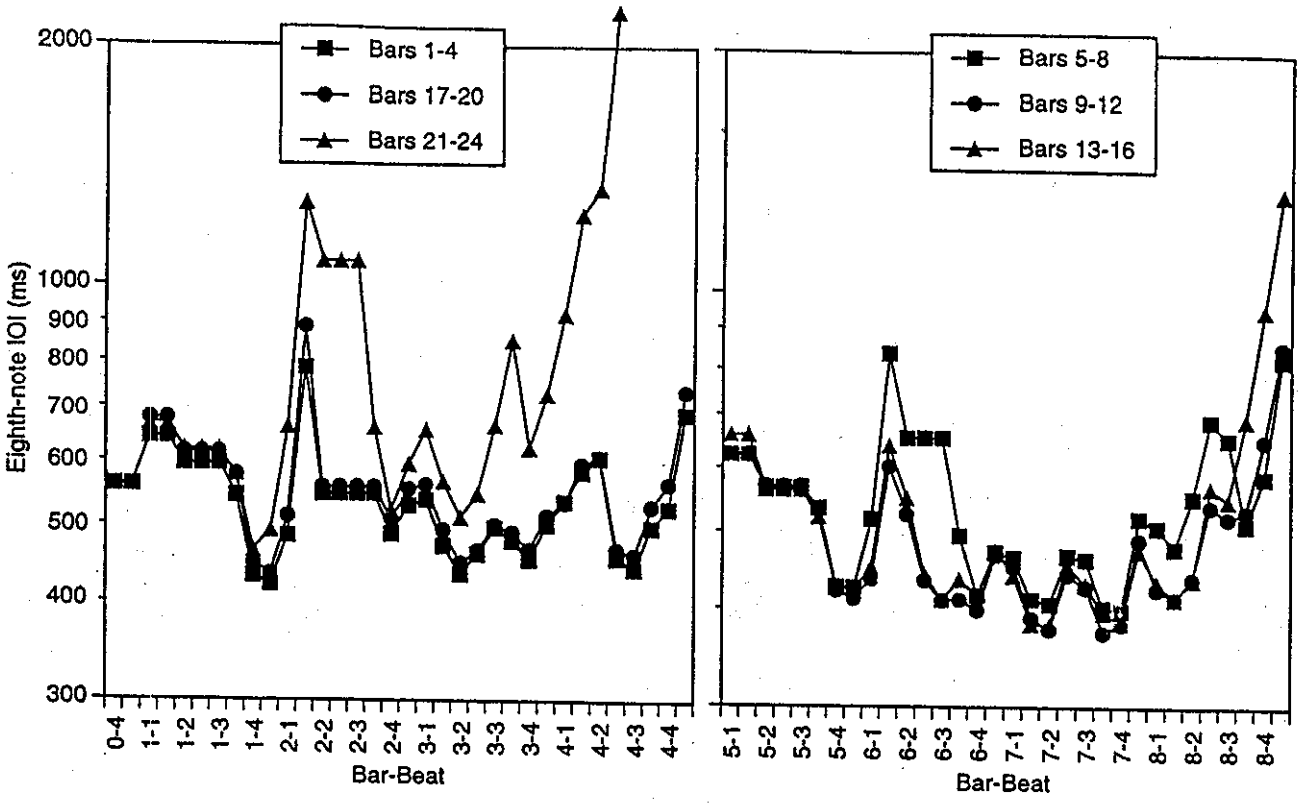

FIG. 2. Grand average timing profile of the ten student pianists. Structurally similar phrases are superimposed.

music the same way twice, or that repeats within a piece should be played differently, such differences seem to be more the exception than the rule with regard to timing. For the student pianists, the stability of timing profiles could be assessed both across repeated performances and across repeats within performances, whereas for the experts (with the exception of Cortot and Horowitz, whose three performances were years apart) only within-performance stability could be assessed.

Within-performance stability can be assessed in three ways in "Träumerei:" (a) between bars 1–8 and their repeat, (b) between bars 1–4 and their literal repeat in bars 17–20, and (c) between bars 9–12 and their almost literal transposition in bars 13–16. The focus will be on the first comparison here; the others can be made informally in Fig. 2. Between-performance stability may be determined for complete performances, but in that case the long IOIs associated with major *ritardandi* will have a dominant influence on the correlations; a better choice are bars 1–8, which do not end with an extreme *ritardando*. The comparison of within- and between-performance stability can then also be carried out for bars 1–8.

The between-performance timing profile correlations, averaged over the three pairwise correlations among each pianist's three performances, are shown in Table I (columns a and b). Evidently, the student pianists had a high degree of control over their expressive timing patterns. Computed over the whole piece, the correlation was 0.947 on the average. For bars 1–8 alone, the correlations were somewhat lower, due to the absence of very long IOIs, but still quite high (average of 0.907). There is little doubt from these correlations that all students intended to play the piece the same way each time, as they were asked to do. They succeeded in controlling up to 90% of the timing variance, which represents impressive evidence of a cognitive plan that guides rhythmic microstructure.[7]

The average within-performance correlations for bars 1–8 (Table I, column c) are as high as the between-performance correlations for the same bars (average of 0.899), indicating that the student pianists did not vary the repeat. The expert pianists' analogous correlations ranged from 0.51 to 0.95 (Repp, 1992a: Table IV, second column).[8]

TABLE I. Average correlations of timing profiles in Schumann's "Träumerei" (a) between entire performances ($n=214$), (b) between performances of bars 1–8 only, including the repeat ($n=107$), and (c) within performances, between the two renditions of bars 1–8 ($n=53$).

Pianist	(a)	(b)	(c)
P1	0.928	0.871	0.857
P2	0.961	0.924	0.931
P3	0.936	0.916	0.892
P4	0.963	0.925	0.928
P5	0.958	0.913	0.907
P6	0.974	0.917	0.908
P7	0.965	0.903	0.906
P8	0.974	0.953	0.958
P9	0.942	0.877	0.849
P10	0.868	0.867	0.858

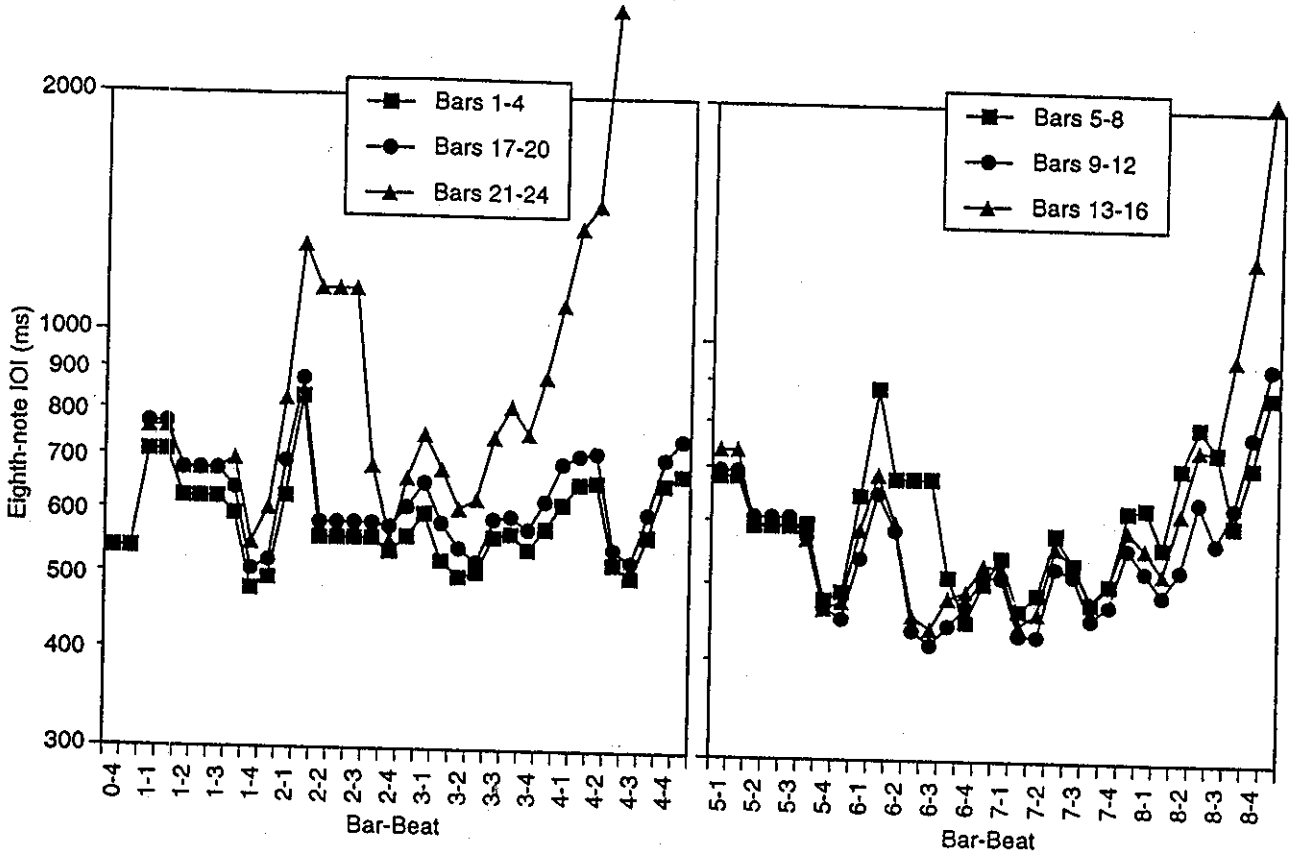

FIG. 3. Grand average timing profile of the expert pianists.

They may have been underestimated slightly, due to human measurement error in the data. Nevertheless, it is clear that the students as a group were as consistent as the most consistent experts. Of course, the experts were free to play the repeat differently, and the lower correlations of some probably reflect such a strategy.[9] Others, however, clearly intended to maintain their original timing pattern; they included such outstanding artists as Arrau, Ashkenazy, and Brendel. P8's correlation of 0.96 may well represent the upper limit of timing accuracy achievable in this portion of the music.

C. The grand average timing profile

A grand average timing profile was obtained by first averaging the timing profiles (sequences of IOIs) of each student pianist's three performances (two in the case of P4) and then averaging across all ten students. Subsequently, the profiles for the two renditions of bars 1–8 were averaged, as they were extremely similar and did not differ in average tempo. The resulting timing patterns are shown in Fig. 2, which uses the format established in Repp (1992a: Fig. 3). Eighth-note IOI durations are plotted on a logarithmic scale to reduce the graphic excursions of the large *ritardandi* and make the detailed variation of the shorter IOIs more visible. The abscissa shows bar and beat numbers for bars 1–4 and 5–8 (left and right panels), corresponding to the initial two 4-bar phrases. The patterns for the remaining four phrases are overlaid on those of bars 1–4 and 5–8; the bar numbers of the abscissa need to be incremented accordingly. IOIs longer than a nominal eighth note are represented as multiple data points or "plateaus."

The left panel of the figure shows that the average timing profiles of bars 1–4 and 17–20 virtually coincide. Since they represent identical music, this is another illustration of the student pianists' high consistency. Bars 21–24, which start out similarly, soon deviate because of the approach to the *fermata* in bar 22; then, from the middle of bar 23 onward, the final *ritardando* holds sway. In the right panel of the figure, the close timing similarity of bars 9–12 and 13–16 may be observed; these phrases are notationally almost identical but in different keys. Their profiles deviate only during the second half of the last bar, where bar 16 exhibits a greater *ritardando* than bar 12, due to the "deeper" structural boundary following bar 16. The profile for bars 5–8 partially coincides with those of bars 9–12 and 13–16, precisely where the musical material is highly similar. It deviates at points of structural difference, particularly in the second and fourth bars of the phrase, where its local tempo is slower. The final *ritardando* is highly similar in bars 8 and 12.

The students' average timing profile may be compared with that of the experts, which is reproduced in Fig. 3.[10] The similarity is quite remarkable; in fact, there is not a single qualitative difference between the two profiles. One must

look carefully to detect some small quantitative differences: Apart from playing somewhat slower overall than the students, the experts tended to play bars 17–20 a little slower than bars 1–4 whereas the students did not; their initial upbeat was a little shorter relative to the following chords than the students'; they lengthened the IOIs less in positions 4-4-2, 20-4-2, and 23-3-2; and they slowed down a little earlier and made a more pronounced *ritardando* in bar 16 compared to bar 12. The correlation between the student and expert grand average profiles was 0.964, and that between their profiles for bars 1–8 only was 0.922. These correlations show that, *on the average*, the students played with almost exactly the same expressive timing as the experts. This is especially remarkable in view of the fact that most of the students had practiced the piece only for a few minutes.

D. Intercorrelations among performances

The timing similarities among all individual pianists' performances were assessed by computing the correlations between their timing profiles. As already mentioned, when such correlations are computed over all IOIs, the very long IOIs associated with major *ritardandi* dominate and lead to high correlations of restricted range, since all pianists mark major phrase boundaries in this manner. It was more informative, therefore, to examine the intercorrelations for bars 1–8 only (including the initial upbeat), where very long IOIs are absent.

Inspection of the intercorrelation matrix for experts and students combined ($n=38$) revealed that all students showed high correlations with all other pianists' performances, except with Argerich, Bunin, Horowitz, Moiseiwitsch, and especially Cortot. These highly individual artists in turn showed lower correlations with other experts' performances. For each pianist's performance, the three most highly correlated performances were determined.[11] This tally revealed that the students' performances were more similar to each other than to the experts' performances. Twenty-two of the 30 correlations (73%) represented other students, even though they constituted only 9/37=24% of the possible candidates. Of the eight expert performances in this set, four were by one pianist (Capova) and two by another (Ashkenazy). In fact, for five students the most similar expert performance was that of Capova, and for three that of Ashkenazy. All ten students showed relatively high correlations with Capova, eight with Ashkenazy, and nine with Zak, another Russian pianist.[12]

Conversely, and perhaps more surprisingly, the experts' timing profiles tended to correlate more highly with the students' profiles than with those of other recording artists. Fifteen of the 28 expert performances correlated most highly with a student performance. Forty-two (50%) of the 84 "highest three" correlations were with students, even though they constituted only 10/37=27% of the candidates. Nine student pianists were represented among those correlations; the one absent was P8, who had conspicuously lower correlations with most experts' performances. Two factors may account for the experts' higher correlations with students than with other experts: First, it is possible that the students' profiles were more representative of the grand average timing profile, so that they were closer, on the average, to most other performances than were the more eccentric expert performances. This will be investigated further below. Second, the absence of measurement error and the reduction of random variation by averaging over three performances made the student profiles statistically more reliable than the expert profiles, which contained some random error; this may have enhanced the correlations with the student performances. It should also be noted that the expert performances' correlations with other performances were generally lower than the students' correlations with other performances.

Finally, it was evident that each student's own three performances were more similar to each other (Table I) than their average was to any other pianist's performance. Likewise, as already noted by Repp (1992a), Cortot's and Horowitz's respective three performances, even though they had been recorded years apart, were more similar to each other than to any other pianist's performance. Thus each pianist, whether expert or student, seems to have a replicable "timing signature," part of his or her individuality. However, the similarity to other pianists' performances may be nearly as great.

E. Extent of timing variation

Correlations are sensitive only to differences in shape among the timing profiles, not to the magnitude of the expressive tempo modulation (a scale factor). A measure of the range of individual timing variation is the standard deviation of the IOIs, or even better, the coefficient of variation, which is the standard deviation divided by the mean. This measure corrects for the natural tendency of absolute timing variation to increase at a slower tempo (cf. Repp, 1994b); thus it is a measure of relative timing variation. Individual coefficients of variation for bars 1–8 ranged from 0.14 to 0.31 across the 38 performances. Both the least modulated (Schnabel, Klien, Eschenbach) and the most highly modulated performances (Argerich, Demus, Horowitz-3, Cortot-1, Arrau) were by experts; the students' values extended over a narrower range from 0.17 (P7) to 0.24 (P3).

F. Principal components analysis

Following Repp's (1992a) procedures, principal components analysis (PCA) with Varimax rotation was employed to determine whether more than one shared pattern of variation underlies the individual pianists' timing profiles.[13] The analyses were conducted on expert and student profiles combined as well as separately.[14] Analyses conducted on the complete performances yielded single-component solutions, which basically showed that all pianists marked the major phrase boundaries with *ritardandi*, even though there were individual differences in their extent. It was again more informative to restrict the analyses to bars 1–8 (including the initial upbeat), which did not contain any extreme *ritardandi* and thus permitted the performance intercorrelations to vary over a wider range.

The PCA on the experts yielded results similar to those reported in Repp (1992a: Table V, Fig. 4), except that the fourth component fell just short of significance. Three sig-

nificant components (i.e., with eigenvalues greater than 1) accounted for 72% of the variance. Before rotation, the first principal component (a kind of grand mean) accounted for most of this variance, but Varimax rotation redistributed this variance among the components so as to maximize discrepancies among component loadings, which usually facilitates interpretation. The first rotated component still represented the most common timing pattern, with Schnabel showing the highest loading (profile-component correlation) by far and many other pianists showing substantial loadings. The second component was the "Horowitz component," with several other pianists (especially Argerich) showing moderate loadings, and the third component was virtually unique to Cortot.

The separate analysis on the students, by contrast, yielded only a single significant component that accounted for 80% of the variance. Component loadings ranged from 0.94 (P2) to 0.82 (P8). Thus it is evident that the students showed much less individual variability than the experts.

In the combined analysis of experts and students, five significant components emerged which together accounted for 80% of the variance. Before Varimax rotation, the first principal component explained 62%, and the others 7%, 5%, 3%, and 3%, respectively. Clearly, the first component was again a sort of grand mean, and all individual performances loaded on it with values of 0.51 or higher. The student pianists in particular had high loadings (0.73–0.91), and among the experts Capova (0.93) and Ashkenazy (0.86) had the highest loadings. This confirms that these pianists' timing profiles were all close to the grand average timing pattern. The five rotated components accounted for 25%, 20%, 14%, 11%, and 10% of the variance, respectively. The rotated component loadings of the 38 performances are shown in Table II. Values of less than 0.4 are omitted.

The first of these rotated components was similar to the grand average, but there was a much wider range of component loadings now. Still, eight of the ten student pianists had their highest loading on this component, and even the remaining two (P3, P10) showed a modest correlation with it. Interestingly, P8, who seemed least typical in the separate analysis on the students, had the highest loading of all. Expert pianists represented most strongly by the first component were Kubalek, Schnabel, Zak, Capova, and Davies. The second component was the Horowitz component. Other moderately high loadings were all by experts; only three students showed small correlations (between 0.4 and 0.5) with this component. The third component was new (compared to the analysis on the experts alone), and six experts as well as two students had their highest loadings on it, with three additional students showing small correlations. The highest expert loadings were by Katsaris, Demus, Ashkenazy, and Shelley. The fourth component was the idiosyncratic Cortot component, with no students and only two other experts minimally represented. The fifth component, defined by Novaes and Brendel, among others, also showed little student representation.

These results confirm the general impression that the students were relatively conservative in their timing patterns and stayed close to the most representative timing profile,

TABLE II. Component loadings of the Varimax-rotated five-component solution for bars 1–8. Only correlations above 0.4 are listed; the highest loading of each performance is in boldface.

Pianist	Comp I	Comp II	Comp III	Comp IV	Comp V
P8	**0.831**				
Kubalek	**0.751**				
P7	**0.750**				
Schnabel	**0.710**				
P2	**0.690**				0.436
Zak	**0.677**	0.442			0.462
P9	**0.672**	0.431			
Capova	**0.665**	0.409			
P5	**0.664**		0.499		
Davies	**0.656**				
P6	**0.630**				
P4	**0.603**		0.522		0.406
P1	**0.572**	0.464	0.411		
Ortiz	**0.532**	0.400			
Horowitz-2		**0.858**			
Horowitz-3		**0.850**			
Horowitz-1		**0.834**			
Argerich		**0.727**			
Eschenbach		**0.658**			
Klien	0.514	**0.641**			
Gianoli	0.413	**0.575**			
Ney		**0.563**			0.551
Katsaris			**0.697**		
P3	0.423		**0.670**		
Demus		0.434	**0.669**		
P10	0.445	0.495	**0.575**		
Ashkenazy	0.455		**0.559**		
Shelley			**0.557**		0.496
Bunin		0.496	**0.529**		
Cortot-3				**0.873**	
Cortot-1				**0.873**	
Cortot-2				**0.868**	
Novaes		0.509			**0.619**
Brendel	0.463	0.457			**0.564**
Moiseiwitsch	0.491				**0.539**
Krust	0.444			0.481	**0.536**
Arrau	0.421	0.406	**0.474**		
Curzon	**0.432**			0.422	

though the combined analysis revealed some influence from Katsaris- and Horowitz-type patterns (components III and II, respectively). Several student pianists actually mentioned that they had been impressed and possibly influenced by Horowitz's famous performances of "Träumerei" (his favorite encore). On the whole, however, the students were decidedly "mainstream" in their timing strategies.

The components just discussed represent abstractions from the data. Each rotated component represents a particular "underlying" timing profile that is only similar to, but not identical with, certain individual performances. Each individual performance can be represented as a linear combination of these underlying (orthogonal) profiles, plus variation unique to the performer (i.e., variance not accounted for). Rather than focusing on these abstract patterns (see Repp, 1992a: Fig. 4), we will now examine individual differences in the execution of detailed timing maneuvers.

G. Upbeats

Each phrase in "Träumerei" begins with an upbeat, which appears in the score as an unaccompanied quarter note

TABLE III. Ratios $5A/(2B+3C)$ and B/C of the three normalized IOIs between the first four events in each phrase. The B/C ratios are averaged over all eight occurrences, the first two $5A/(2B+3C)$ ratios over the two renditions of bars 1–8. The grace note in bar 16 is considered a nominal eighth note.

	$5A/(2B+3C)$						
Bars:	0–1	4–5	8–9	12–13	16–17	20–21	B/C
P1	0.92	1.17	1.49	1.18	0.63	1.10	1.34
P2	0.93	1.06	1.42	1.73	1.31	0.98	1.07
P3	1.05	1.14	1.99	2.20	1.62	1.22	1.22
P4	0.89	1.14	1.55	1.52	1.66	1.07	1.29
P5	0.83	0.90	1.15	1.09	0.52	0.89	1.04
P6	0.91	1.03	1.47	1.31	0.92	1.02	1.19
P7	0.87	0.98	1.09	1.19	1.14	0.91	1.01
P8	0.83	0.92	1.27	1.16	0.98	0.97	0.95
P9	0.98	0.99	1.34	1.42	1.18	0.99	0.96
P10	0.95	1.14	1.47	1.59	1.30	1.14	1.31

(bar 0), an accompanied quarter note (bars 4 and 20), an accompanied eighth note (bars 8 and 12), or a grace note (bar 16). It is followed by a melody note an interval of a fourth higher (accompanied by a bass note) and, on the next beat, by a four-note chord, which is in turn followed after one beat and a half by a melody note that initiates the next melodic gesture. In Repp (1992a: Fig. 5), the expert pianists' timing behavior was portrayed in terms of two ratios among the three normalized IOIs (A,B,C) defined by these four events.[15] The first ratio, $5A/(2B+3C)$, describes the timing of the upbeat relative to the five-eighth-note IOI between the two subsequent melody notes, whereas the second ratio, B/C, describes the relative placement of the chord in this long IOI. In each case, a ratio of 1 implies that the local tempo (the underlying beat) remained constant. The students' ratios are shown in Table III.

The expert pianists had a strong tendency to shorten the initial unaccompanied upbeat (bars 0–1) by various degrees; their ratios ranged from about 0.4 to 1.1. The student pianists showed a similar tendency, but their range of ratios was much more restricted (0.83–1.05) and thus closer to the nominal value of the quarter-note upbeat. The experts' relative timing of the accompanied quarter-note upbeats in bars 4–5 and 20–21 also showed a wide range (ratios from about 0.7 to 1.4), with a slight tendency toward lengthening the upbeat, due to its overlap with the end of the preceding phrase. The students were again more conservative, with ratios between 0.90 and 1.22. The eighth-note upbeats in bars 8–9 and 12–13 were almost always lengthened by the experts, again due to their straddling a phrase boundary; the ratios ranged from 0.7 to 1.8 in bars 8–9, and from 0.8 to 2.4 in bars 12–13. The students also exhibited lengthening and considerable variation here, with ratios from 1.09 to 1.99 in bars 8–9, and from 1.09 to 2.20 in bars 12–13. The most interesting upbeat is the grace note in bar 16 (considered nominally an eighth note here), which in expert interpretations ranged from the equivalent of a sixteenth note (0.4) to that of a quarter note (2.2), with many gradations in between. The students, too, showed a variety of ratios ranging from 0.52 to 1.66. P1 and P5 played the grace note effectively as a sixteenth note, P6 and P8 as a literal eighth note, and the others as an eighth note lengthened by various degrees.

As to the relative placement of the following four-note chord, expert pianists showed an overwhelming tendency to lengthen the preceding (two-eighth-note) IOI relative to the following (three-eighth-note) IOI in all positions in the music, though there were some exceptions, most notably Cortot (Repp, 1992a: Fig. 5). Their B/C ratios were generally between 0.8 and 1.6. Here the students show again a more restricted range, from 0.95 to 1.34 in terms of average ratios (from 0.88 to 1.49 in terms of ratios for individual instances). It should be acknowledged that previous averaging over the students' three performances may have contributed to a relative narrowing of their range of ratios in these comparisons. However, the students never exhibited the rather eccentric upbeat timing of some of the famous pianists (such as Cortot or Argerich).

H. The ascent to the melodic peak

The apex of each phrase is reached by an ascending melodic gesture composed of five eighth notes and a long note, thus comprising five IOIs. The gesture recurs eight times in the music, or six times after averaging over the two renditions of bars 1–8. Repp (1992a) showed that, for most expert pianists, the sequence of IOI durations in this gesture can be described by a quadratic (parabolic) function that first descends and then ascends to the pitch peak. As Todd (1992, 1995) has shown, this time course corresponds to physical motion with a constant deceleration and acceleration. Thus pianists' ability to follow such a timing curve may be taken as an index of their ability to shape a phrase, as long as it can be assumed that no atypical timing pattern was intended. In the case of Cortot, who consistently shortened the last IOI (except in bars 21–22), this assumption was clearly not warranted, and a few other pianists (Argerich, Bunin, Curzon) occasionally showed a pattern similar to Cortot's. The large majority of experts, however, showed good to excellent fits to a parabolic curve, with individual variations in its elevation and degree of curvature.[16]

The students' average timing functions for the six instances of the melodic gesture are shown in Fig. 4. They are quite similar in pattern to the averages of the expert pianists (Repp, 1992a: Fig. 6), and the quadratic fits are satisfactory (r^2 ranged from 0.970 to 0.985, versus 0.949 to 0.999 for the experts), though it may be noted that the fourth IOI tends to be too short. This was mainly due to one pianist's atypical functions, just as a tendency for the fifth IOI to be too short in the average expert data was mainly due to Cortot and a few others.

The student pianists' individual fits to parabolic timing curves were good to excellent. Only P4 repeatedly showed a tendency to shorten the fourth IOI, resulting in fits (r^2 values) between 0.851 and 0.922. P7 also showed relatively poor fits in the middle section ($r^2=0.916$, 0.804). All other goodness-of-fit indices ranged from 0.924 to 0.999. By comparison, the experts' performances included some much poorer fits, ranging from 0.027 to 0.694 for Cortot (except in bars 21–22), for example, and from 0.073 to 0.779 for Curzon in the same positions. These distinguished pianists apparently had some unconventional ideas about how the me-

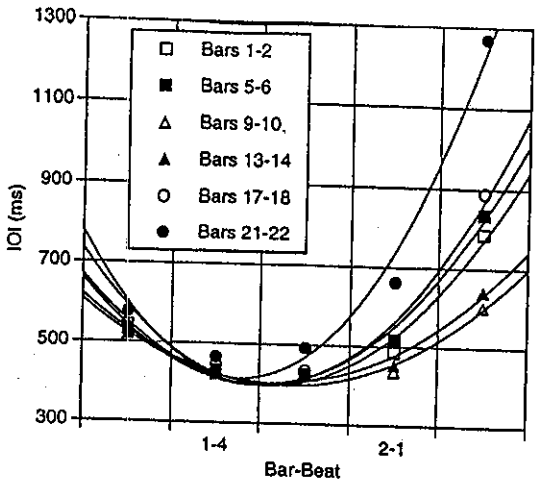

FIG. 4. Parabolic curve fits to the students' average timing patterns in the "ascent to the melodic peak" in six different positions in the music.

lodic gesture should be shaped. However, most of the experts' fits were in the same range as the students', suggesting that the students (with the possible exception of P4) had mastered the art of shaping a phrase in the conventional manner.

The ranges of curvatures of the parabolic functions may also be compared. Repp (1992a: Fig. 9) plotted average curvatures in bars 1–2, 5–6, and 12–18 against those in bars 21–22 for those cases that yielded a good parabolic fit; the respective ranges (the values represent the coefficients of quadratic equations, with the five IOIs numbered serially) were 30–160 and 20–150, respectively. The comparable ranges for the students were 33–90 and 70–168, respectively. These ranges were more restricted, but this difference was mainly due to Demus's extremely high curvatures, and to Horowitz's abnormally flat functions in bars 21–22. For the most part, experts and students showed similar degrees of curvature, or temporal inflection.

The average relative timing of the long IOI at the melodic peak, even though it varied with context, was extremely similar for experts and students, as can be seen in Figs. 2 and 3.

I. Grace notes

The final long note of the melodic gesture just discussed (the peak of the phrase) is preceded by two grace notes in the left hand, basically a written-out *arpeggio*, in bars 2, 6, and 18. The conventional way of playing this passage, suggested by the notation, is to fit the two grace notes into the preceding IOI, so that the third and final left-hand note coincides with the melody note (and its lower octave) in the right hand. Thus the IOI can be divided into three portions, A, B, and C, and ratios can be calculated which reflect the relative placement of the first grace note in the IOI, $A/(B+C)$, and the relative "durations" of the two grace notes, B/C.[17] Repp (1992a: Fig. 10) discovered that only about half of the experts played this passage the conventional way. At least five variants were observed, some of which made it impossible to calculate the ratios just described. For those instances where the ratios could be determined, they varied widely but tended to cluster around modal values of 0.4 and 0.5, respectively (Repp, 1992a: Fig. 11). In other words, the first grace note tended to occur after about 30% of the IOI had elapsed, and the second grace note shortly after the middle of the IOI.

The students, too, did not all play the passage the conventional way. P7 played the first grace note at the same time as the preceding melody note (as did Schnabel), so that the $A/(B+C)$ ratio was close to zero. P10, on the other hand, played the second grace note very close to the following melody note (as did Bunin and Kubalek), so that the B/C ratio became very large. Both P8 and P10 delayed the top note in the left hand and P9 advanced it, but this did not affect the ratios, since the IOI was measured to the onset of the melody note in the right hand. With P7 and P10 omitted, the student pianists' average ratios ranged from 0.22 to 0.57 for $A/(B+C)$, and from 0.33 to 0.77 for B/C.[18] These ranges coincide precisely with the main cluster of expert values (Repp, 1992a: Fig. 11). Again, the students can be seen to be similar to the experts in their microtiming but more conservative on the whole, as a larger number of deviant ratios and strategies was observed among the experts.

The music contains two other, isolated grace notes. One of these, the upbeat in bar 16, has already been discussed. The other one is the melodic grace note in bar 8, whose onset falls within the fourth eighth-note IOI (position 8-2-2) in that measure. Most expert pianists played it near the middle of the IOI; its relative position ranged from 33% to 70%. Two pianists (Cortot-3, Davies) omitted the grace note, and in other performances Cortot played E instead of C. (One must be a very great pianist to take that kind of liberty!) Two student pianists also were deviant: P10 consistently omitted the grace note, whereas P9 sustained the grace note and thus omitted (or effectively advanced) the following melody note. For the other eight student pianists, the average relative timing of the grace note ranged from 33% to 42% (from 27% to 46% across individual instances). Here, at last, is a clear difference between experts and students: The students tended to play the grace note earlier. Only four expert pianists (Capova, Cortot-2, Gianoli, Krust) fell within the students' range of timing.

J. The descent from the melodic peak

The second half of each phrase consists of a series of falling melodic gestures or "phraselets." There are two versions of this descent, one instantiated in bars 2–4, 18–20, and 22–24, and the other in bars 6–8, 10–12, and 14–16. They will be referred to as type A and type B, respectively. The average timing patterns for the three occurrences of each type were very similar, except for varying extents of the phrase-final *ritardandi* (see Figs. 2 and 3). To obtain a more detailed picture of individual variability in the temporal shaping of these complex passages, they were subjected to separate principal component analyses.

The analysis of the type-A phrases did not include bars 22–24 because the very long IOIs of the final *ritardando* would have dominated the intercorrelation structure. The relevant IOIs thus ranged from position 2-4-1 to 4-4-2, and

TABLE IV. Component loadings of the Varimax-rotated seven-component solution for bars 2-4-1 to 4-4-2 and 18-4-1 to 20-4-2. Only correlations above 0.4 are listed; the highest loading of each performance is in boldface.

Pianist	I	II	III	IV	V	VI	VII
P7	**0.874**						
Capova	**0.823**						
P8	**0.798**						
P6	**0.759**		0.464				
P5	**0.738**						
Bunin	**0.683**						
P2	**0.681**		0.533				
P9	**0.646**	0.535					
P3	**0.645**		0.622				
P5	**0.634**		0.504	0.420			
Shelley	**0.594**		0.426		0.563		
P1	**0.589**		0.435				
P10	**0.507**	0.427	0.443				
Horowitz-2		**0.912**					
Horowitz-1		**0.859**					
Horowitz-3		**0.783**					
Klien		**0.767**					
Zak	0.503	**0.625**					
Demus		**0.592**					
Ney			**0.775**				
Eschenbach		0.443	**0.684**				
Ashkenazy			**0.681**				
Brendel			**0.651**				
Katsaris	0.472		**0.638**				
Arrau	0.551		**0.626**				
Cortot-1				**0.851**			
Cortot-2				**0.810**			
Cortot-3				**0.683**			0.462
Ortiz		0.471		**−0.659**			
Moiseiwitsch					**0.876**		
Davies					**0.578**		
Gianoli	0.462			0.417	**0.559**		
Krust					**0.510**	0.428	
Novaes						**0.837**	
Schnabel						**0.829**	
Kubalek	0.560					**0.686**	
Curzon					0.554	**0.596**	
Argerich	0.463	0.445					**0.608**

from 18-4-1 to 20-4-2. The PCA on the experts yielded six significant components which accounted for 82% of the variance. The analysis on the students, however, yielded only a single component, accounting for 76% of the variance. This provides a particularly striking demonstration of the greater homogeneity of the students' timing patterns. The combined analysis yielded seven components, accounting for 86% of the variance. After Varimax rotation, the variance was distributed among the components as follows: 23%, 15%, 15%, 10%, 9%, 9%, and 4%. The component loadings are shown in Table IV. Six of the components resembled those obtained for the experts alone (cf. Repp, 1992a: Table VI), though their order had changed somewhat. The new component, remarkably, was the first and most important one. All ten student pianists, but only three experts (Capova, Bunin, Shelley), had their highest loading on this component. This suggests that the students as a group represented a particular style of timing in this musical passage. Two students showed modest loadings on the second component (the Horowitz component), six showed affinities with the third component

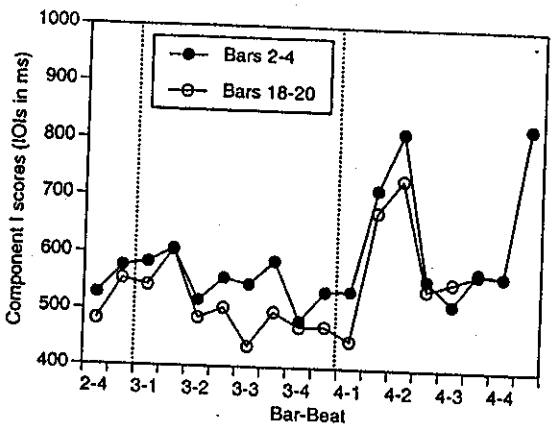

FIG. 5. Timing pattern of component I for the descent from the melodic peak" in type-A phrases in the combined analysis of students and experts.

(defined by Ney and others), and one with the fourth component (the Cortot component). The remaining three components, though they showed high loadings by some expert pianists (Moiseiwitsch, Novaes and Schnabel, Argerich) had no significant student representation.

The timing profiles corresponding to components II–VI, reconstructed from the standardized component scores, can be seen in Repp (1992a: Fig. 12).[19] The new component I pattern is shown in Fig. 5. This underlying timing profile is characterized by relatively even timing through bar 3, with only slight *ritardandi* during the first two phraselets, followed by a huge *ritardando* toward the end of the third phraselet (positions 4-1-2 and 4-2-1), and a pronounced lengthening of the last IOI, which marks the end of the fourth phraselet in the bass voice and accompanies the upbeat to the following phrase.[20]

All students exhibited high within-performance consistency by playing bars 2–4 and bars 18–20 very similarly. Most experts, on the other hand, played bars 18–20 more slowly than bars 2–4, and their timing profiles for these two musically identical passages also often diverged considerably, especially in Horowitz's and Cortot's renditions. There were some experts, however, who, like the students, played the two passages almost identically (most notably Arrau, Capova, Kubalek, and—surprisingly—Horowitz-3).

The PCA of the type-B phrases included positions 6-4-1 to 8-1-2, 10-4-1 to 12-1-2, and 14-4-1 to 16-1-2. The final six IOIs of each phrase had to be excluded because of the large *ritardandi* they carried, which will be analyzed separately below. The analysis of the expert performances again yielded six components, accounting for 80% of the variance, whereas the student analysis once again gave rise to only a single significant component, accounting for 65% of the variance. Eight components emerged in the combined analysis, accounting for 84% of the variance. The component loadings for the first seven components are shown in Table V. Again, the addition of the students to the experts resulted in a new first component. The five highest loadings on that component represent student pianists; four additional students had loadings above 0.4. No expert loaded very highly on this com-

TABLE V. Component loadings of the Varimax-rotated eight-component solution for bars 6-4-1 to 8-1-2, 10-4-1 to 12-1-2, and 14-4-1 to 16-1-2. Only correlations above 0.4 are listed; the highest loading of each performance is in boldface. Component VIII is not shown.

Pianist	I	II	III	IV	V	VI	VII
P4	**0.833**						
P8	**0.823**						
P9	**0.777**						
P2	**0.765**	0.434					
P10	0.587			0.511			
Capova	**0.585**					0.438	0.408
Argerich	0.527		0.470				
Krust		**0.827**					
Cortot-1		**0.775**					
Cortot-2		**0.742**		0.460			
P3	0.437	**0.630**			0.401		
Brendel		**0.593**			0.407		
Kubalek		**0.586**					
Novaes	0.455	**0.568**					
P6	0.509	**0.530**		0.521			
Klien			**0.777**				
Moiseiwitsch			**0.732**				
Arrau	0.629		**0.678**				
Horowitz-2			**0.677**				
Horowitz-3	0.435		**0.665**	0.400			
Gianoli		0.427	**0.568**				
Zak				**0.727**			
Ney				**0.716**	0.469		
Davies				**0.656**			
Curzon		0.411			**0.732**		
Schnabel					**0.726**		
Katsaris				0.574	**0.598**		
Ortiz						**0.889**	
Eschenbach	0.412					**0.509**	
Bunin							**0.691**
Shelley		0.411			0.537		**0.548**
Cortot-3							
Horowitz-1				0.407			0.426
P5	0.422			0.456			
Demus			0.403	0.457			
Ashkenazy			0,490				
P1					0.495	0.408	
P7	0.407			0.425			

ponent; Arrau, Capova, and Argerich showed moderate correlations with it. The other novel component was component V, defined by Curzon and Schnabel. Two students had small loadings on this component, though for one of them (P1) it was the highest on any component.[21] The remaining six components resembled those obtained in the analysis on the experts alone, with the order of the first two components reversed (see also Repp, 1992a: Table VII). Two students (P3, P6) had their highest loadings on component II, defined by Krust and two of Cortot's performances; P2 loaded weakly. No student was represented on component III, associated most strongly with Klien and Moiseiwitsch, as well as with two of Horowitz's performances. Four students were represented on component IV, defined by Zak, Ney, and Davies. Only P1 was marginally associated with component VI, which was almost unique to Ortiz. Component VII, defined by Bunin and Shelley, and component VIII, unique to Cortot-3 (with a loading of 0.818), showed no student affiliation.

The diversity of patterns in this part of the music is

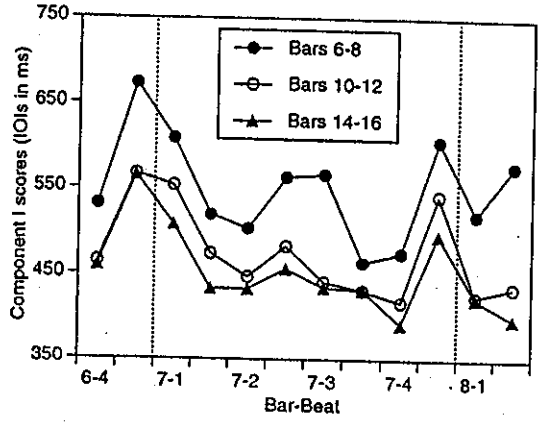

FIG. 6. Timing pattern of component I for the descent from the melodic peak in type-B phrases in the combined component analysis of students and experts.

noteworthy, with even Horowitz's and Cortot's performances varying significantly amongst themselves. Most pianists were not strongly associated with any single component but showed contributions from several; this was true for the students as well as the experts. Nevertheless, the students did tend to cluster on component I. It should also be noted that the similarity structure captured by the component loadings is entirely different from that for the type-A phrases; there are hardly any expert pianists that "stayed together" in terms of their primary component affiliations (exceptions are Klien and Horowitz; and Capova, who stayed with the students). The distribution of the variance accounted for among the rotated components was also less skewed than in the Type-A analysis, which indicates that there were no strongly dominant patterns.

The timing pattern associated with component I is shown in Fig. 6. It shows a clear (and representative) tendency for the phrases in the middle section (bars 10–12, 14–16) to be played faster than bars 6–8. Otherwise, the timing profiles are fairly parallel, showing a tendency to accelerate during the phrase (before the final *ritardando*) and a pronounced lengthening of the IOIs preceding downbeats (positions 6-4-2 and 7-4-2), which also precede salient harmonic changes.

Again, the students showed considerable similarity among each other, while the expert profiles were much more diverse. Most students played the three instances of the type-B phrase similarly, whereas experts more often varied their timing. The secondary components which influenced the students most, II and IV, differed from component I more in overall trend than in qualitative detail, hence the apparent homogeneity of the student group. Component III, which showed a pronounced lengthening of downbeat rather than predownbeat IOIs, was peculiar to a small group of experts (including two of Horowitz's performances), as were components V and VI.

K. Phrase-final *ritardandi*

There are three major *ritardandi* in the piece, in bars 12, 16, and 23–24, respectively. The ones in bars 12 and 16

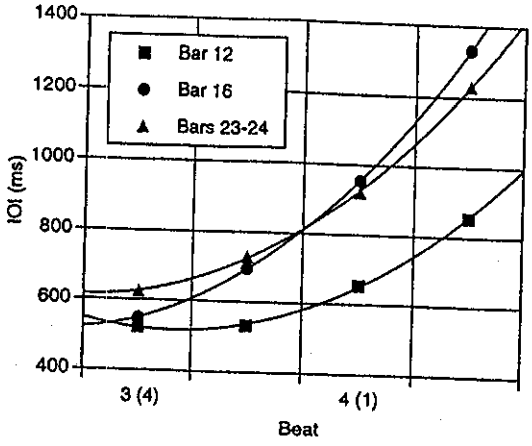

FIG. 7. Parabolic curve fits to the students' average timing patterns in the major phrase-final *ritardandi*. The beat numbers in parentheses refer to bars 23–24.

comprise four IOIs each, whereas the final *ritardando* exhibits a structural and agogic break (a "comma" in the score) that sets the final two IOIs apart from the four preceding ones (cf. Figs. 2 and 3). Repp (1992a: Fig. 14) found that each of the 4-IOI progressions was fit very well by a parabolic function, at least when the average across all expert pianists was considered. Individual fits were not always so close, especially in bar 12, but satisfactory on the whole. These fits were reexamined quantitatively here, to compare them to those for the students.

Figure 7 shows the parabolic fits to the students' average *ritardando* curves. All three fits were remarkably close, with r^2 greater than 0.999 in each case. The curvature of the functions was greater than that of the experts' average functions in bars 12 and 23–24, but less in bar 16.

To compare the individual fits, the following classification of r^2 values was made: excellent (>0.999), very good (0.99–0.999), good (0.95–0.99), moderate (0.90–0.95), poor (0.80–0.90), and unacceptable (<0.80). Table VI shows for each of the three *ritardandi* the distribution of fits among these categories for experts and students. They are quite comparable. Both groups showed poorer fits in bar 12 than in the other locations. Instances of unacceptable fits were observed only among the experts, as were excellent fits in bar 12; thus the experts again exhibited somewhat greater diversity. The range of curvatures (considering only fits of better than 0.90) was also greater for the experts than for the students in bars 12 and 16. Among students and experts alike, there were instances of negative curvature, i.e., *ritardandi* about to change into *accelerandi*. However, no pianist exhibited such a function in all three positions.

Finally, the last two IOIs (positions 24-2-1 and 24-2-2) were examined in terms of their ratio. Among the experts, the ratios varied from 1.22 to 2.24, among the students from 1.33 to 1.93—again a somewhat smaller range.

TABLE VI. Comparison of r^2 values of parabolic fits to *ritardando* functions.

	Bar 12		Bar 16		Bars 23–24	
Quality of fit	experts	students	experts	students	experts	students
r^2>0.999	6	0	5	2	3	2
0.99–0.999	4	4	11	5	10	5
0.95–0.99	6	2	10	1	8	3
0.90–0.95	4	1	2	2	4	0
0.80–0.90	5	3	0	0	1	0
r^2<0.80	3	0	0	0	1	0
Min. curvature	−98	−15	7	−80	−27	−21
Max. curvature	117	76	447	183	239	236

III. GENERAL DISCUSSION

The performances of Schumann's "Träumerei" examined here were obtained under conditions that—some might argue—make a comparison with commercially recorded expert performances futile. Not only were the student pianists younger, less experienced, and probably less talented than the famous pianists, but they also were less prepared, played from the score on a mediocre piano, and even committed some errors (though none that affected timing). It is the more remarkable, therefore, that the students were fully the equal of the experts in terms of measures of timing precision and consistency. If anything, they were *more* consistent than the experts, since the least consistent artists were all from the expert camp. What this demonstrates is that even a minimally prepared performance by a competent pianist has a precisely defined underlying plan that governs its expressive timing pattern. This plan presumably derives from tacit knowledge of general rules of expressive timing that can be implemented quickly and accurately, perhaps even in a first reading. Since application of these rules is contingent on a structural analysis of the score into phrases and their gestural substructure, the present results also imply that the student pianists carried out an appropriate structural analysis, efficiently but presumably without explicit awareness. The expressive timing profile is evidence of their structural analysis.

The consistency of the students relative to the experts may has been overestimated slightly because the expert timing profiles contained human measurement error whereas the students' MIDI data did not; moreover, in most subsequent comparisons the student timing data were further stabilized by averaging over three performances, which reduced random "motor error" and brought out more clearly the pianists' intentions. While this may have tilted the comparison in favor of the students at the "high end" of the continuum, it cannot account for the large differences in consistency at the "low end." They can only be explained by assuming that some expert pianists did not wish to be highly consistent. Their intention must have been to vary their timing of repeated or similar material, and this is quite in line with what many artists say about their performance strategies. The students were much less prone to such strategies, presumably because their limited preparation (or possibly their limited experience or smaller artistic imagination) did not allow them to include multiple strategies in their performance plans. Their plans were more rigid and circumscribed; they were also safer. The experts' greater intraindividual variability carried a certain risk with it: The more different timing

patterns are tried out, the more likely it is that one or the other will strike the listener as odd or mannered (see Repp, 1992a).

The students were not only as consistent as the more consistent experts in their timing, but they were equally matched in their ability to shape a *ritardando*. This ability was assessed at four different places in the music (one phrase-internal, three phrase-final), and no student consistently failed the litmus test of the parabolic curve fit. Only one pianist (P4) produced a somewhat awkward ascent to the melodic peak, though her phrase-final *ritardandi* were quite normal. Again, it was the experts who sometimes had different ideas about the shaping of these local gestures, not all of them convincing to this listener. It may still be controversial to take a curve fit to a sequence of IOIs as a measure of temporal shaping skill, but there is increasing evidence that a certain manner of changing local tempo is generally adhered to by performers and is also perceived as optimal by listeners (Sundberg and Verrillo, 1980; Repp, 1992b). This manner seems best characterized by a quadratic (or possibly cubic) function of score position (in terms of IOIs), or equivalently by a linear change in velocity (position as a function of time), all being allusions to biological motion in space (Truslit, 1938; Kronman and Sundberg, 1987; Todd, 1985, 1992, 1995, submitted; Feldman *et al.*, 1992; Repp, 1992a, 1993; Epstein, 1995). Although an artist always has the option of deliberately deviating from such a "natural" form, (s)he does it at the (perhaps well-considered) risk of being perceived as anomalous.

The results discussed so far demonstrate that the student pianists, despite the unfavorable circumstances in which they had to play, exhibited considerable agogic skill and taste. It would not have been surprising, however, to find that their performance plans—and the structural analysis they reflect—were less detailed and somewhat impoverished compared to the experts'. It was impressive, therefore, to find that, *on the average*, the students' and experts' timing profiles were virtually the same. While some small quantitative differences existed, together with some average differences in basic tempo choices, there were no qualitative differences at all between the shapes of the respective average timing profiles. Even though the average profile is a statistical construct and not a real performance, it is a representation of significant commonality among performances and hence of a common standard or norm.[22] From this perspective, it is significant that the average profiles of students and experts were so highly similar. The finding points to a shared standard of expressive timing for this particular music, and hence also to a shared structural analysis. While there may be innumerable ways of deviating from the norm—in fact, the norm may never be realized in any particular performance—it nevertheless serves as a guiding force that "pulls" performers toward some center. This center is not predefined but probably has evolved through the history of performance, both of Romantic pieces in general and of "Träumerei" in particular, and it may keep changing. Precisely such an "evolutionary" theory of performance standards was recently proposed by Bowen (1993). What the present results demonstrate is that, despite differences in age, generation, and year of recording, today's student pianists seem to share the same performance standard as the very heterogeneous group of older expert pianists. This may indicate that the performance standard for "Träumerei," at least, has not changed much in recent decades. Analysis of the expert data has not revealed any obvious historical trends (Repp, 1992a).

The most important and convincing result of the present study concerns the one way in which the students differed from the experts: By several measures, but particularly in terms of the temporal organization of the intricate descent from the melodic peak in each phrase, the students' timing profiles were much more homogeneous than the experts'. The experts, even though they seemed to adhere to the same abstract standard as the students, felt much more free to deviate from it and, in doing so, showed greater individuality (and, occasionally, eccentricity) than the students. The students' individuality was a more limited and cautious one; the students seemed more strongly constrained by their common standard than many of the experts. Again, it is Bowen (1993) who has formulated a pertinent model which he in turn credits to the Russian literary critic Bakhtin (1981). Bakhtin spoke of "centripetal" and "centrifugal" forces in the everyday and artistic use of language; in Bowen's paraphrase, "the one [tends] toward unity and the need to understand each other, and the other toward the specific and the desire to express our uniqueness. ... This dichotomy can also be expressed as the tension between individual expression and communication or between innovation and tradition" (Bowen, 1993, p. 143). The expert pianists, therefore, were more innovative than the students or, more precisely, they included a number of innovative artists, for some of them were quite traditional in outlook (as far as "Träumerei" is concerned), perhaps deliberately so. Music performance thus seems to be comparable to composition: It is generally agreed that the greatest composers, of past centuries at least, deviated in many ways from the then current compositional standards, which may have been followed religiously by lesser contemporaries and particularly by composition students.

This difference between experts and students does not come as a surprise, of course. It is its rigorous demonstration by means of objective performance analysis that is novel and deserves attention. It may be asked, however, whether the students would have produced more diverse performances if they had had the opportunity to study and rehearse the piece more carefully before the recording was made. We enter the realm of speculation here, but a negative answer seems likely. Music critics and other observers of the contemporary classical music scene often comment on the relative loss of diversity in performance, and the author can confirm this impression on the basis of having heard the present student pianists (as well as many others) in recital, playing carefully prepared programmes. One component that may contribute to the reduced originality of young artists is the competitive nature of the music business today. Music competitions, by their very nature, discourage deviation from the norm because the jury decides by consensus, and the consensus most often *is* the norm.[23] The training of today's young pianists, whether or not they have the talent to capture a top prize, is oriented toward making them successful competitors, not

unique individuals. Their teachers probably assume that individuality will emerge spontaneously, and indeed it does; however, the range of the resulting individual variety is relatively restricted.

There are many other components that contribute to this phenomenon of relative uniformity among young performing artists today: The universal availability of many note-perfect recordings of the standard repertoire, which has raised expectations of technical accuracy enormously, to the detriment of interpretive originality; the increasing uniformity of these recordings as more and more young artists enter the Schwann catalog while historical recordings fade into the background; the lack of originality in popular classical mainstream artists who serve as role models; the disappearance of national and regional performance traditions; the enormous influx of highly competent musicians from countries without any performance traditions in Western music; the increasing remoteness of the cultural and historical contexts that gave rise to the masterpieces that constitute the standard repertoire; and the lack of incisive life experiences in an increasingly uniform and commercialized world. It must also be remembered, however, that student pianists obviously differ from expert pianists in age and experience. It is possible that individuality increases with age and experience, and if so, there is little reason for concern. Did the great individualistic pianists of the past, such as Cortot and Horowitz, play more conventionally when they were young? This would be an interesting topic for further investigation, as would be a longitudinal follow up study of the student pianists of today.

While the students' relatively conservative interpretations may lack the aesthetic refinement of great artists' renditions, they are interesting in their own right. Precisely because they do *not* stray too far from a common standard—because they are played as "correctly" as possible—they define that standard more precisely. Efforts to understand and model the basic principles of expressive timing would best start with prototypical profiles, leaving the modeling of originality to a later stage. Student performances are also much easier to obtain than performances of famous concert pianists in MIDI format. Furthermore, student performances may provide important information about the nature and origin of individuality in expression. For despite their relative homogeneity, the student pianists each had their own individual timing pattern, replicable (within the limits of motor control) only by themselves. These timing patterns may represent the interaction of a common structural interpretation and a common set of implicit performance rules with an individual organism whose cognitive and kinematic parameters determine the precise surface pattern of a performance. In the students' case, this interaction may be relatively uncontaminated by explicit desires to differ from the norm; the individual differences may be obligatory, as it were. Perhaps there is a relatively small set of parameters that, once determined, can predict individual variations in timing patterns and can serve as a characterization of an artist's personality. Such a parameterization of individuality—an explanation of the unexplained variance among performances—remains a project for the distant future.

ACKNOWLEDGMENTS

This research was supported by NIH Grant No. MH-51230. I am grateful to Charles Nichols and Ilan Berman for assistance, to Jonathan Berger (Director, Center for Research in Music Technology, Yale University) for permission to use the Yamaha Disclavier, to José Bowen, Nigel Nettheim, and two anonymous reviewers for helpful comments on an earlier version of the manuscript, and to the pianists for lending their skills to this project.

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[1]As the term is used here, expressive ("horizontal") timing does not include the asynchronies among nominally simultaneous tone onsets ("vertical" timing), which are an order of magnitude smaller than the IOIs considered here. In any chord, the onset of the highest tone (usually part of the principal melody and played by the pianist's right hand) is taken as the reference for computing IOIs.

[2]There are other ways of representing timing information—as tempo curves (see Desain and Honing, 1992), as cumulative functions of real time (Todd, 1992, 1995), or as percentage deviations from the average IOI (Gabrielsson, 1987; Palmer, 1989)—but normalized IOIs as a function of score position remain this author's preference.

[3]This is a departure from Repp (1992a), where only bar numbers and eighth-note numbers were used: "15-3-2" was "15-6" there.

[4]The performances did contain some inaccuracies—a few wrong notes and a larger number of missing and extra notes—nearly all of which were in secondary voices. (See Repp, submitted, for an error analysis.) There was no evidence that errors affected expressive timing; all performances were fluent and without hesitations.

[5]Two experts, Alfred Cortot and Vladimir Horowitz, were each represented by three performances. See Repp (1992a: Table I) for a detailed listing of the recordings.

[6]There was no evidence for a historical trend toward faster tempi in the expert data (the oldest recordings, by Davies and Cortot, were among the fastest), nor did the age at which the experts were recorded seem to be related to their tempo choices.

[7]Such high precision should not be equated with performance quality, however; the quality of a timing profile is probably unrelated to its replicability.

[8]These correlations, like the present statistics, were computed on the subdivided, untransformed IOIs.

[9]Interestingly, the less consistent experts (Argerich, Bunin, Cortot, Ortiz, Schnabel) were those who had somewhat unusual timing patterns to begin with (see Repp, 1992a, and below). Of course, it is not known whether their inconsistency was deliberate or happenstance. It could be that less typical timing patterns are less replicable in principle (see Clarke, 1993).

[10]This figure is similar to Fig. 3 in Repp (1992a), but the average profile here represents arithmetic rather than geometric means, and the abscissa has been relabeled in terms of beats rather than eighth notes.

[11]Only one of Cortot's and Horowitz's three performances was allowed among the three.

[12]While Vladimir Ashkenazy is world famous and the late Yakov Zak was a well-known teacher in the USSR, the author has no information at all about Sylvia Capova.

[13]Repp (1992a), following the terminology of the BMDP statistical software manual, considered PCA a species of factor analysis and referred to components as "factors." The author now prefers to talk about "components," in accord with the SYSTAT software manual, but the technique is the same.

[14]Each student was represented by the average timing profile of his or her three (or two) performances, but the three performances of Cortot and Horowitz were kept separate. In each performance, the IOIs of the two renditions of bars 1–8 were averaged, and long IOIs were represented as multiple eighth-note IOIs. Thus each complete performance contained 190 IOIs. No transformation was applied. Because of the different data format, the analysis of the expert data yielded results that differed in some details from those reported in Repp (1992a).

[15]The first ratio was described somewhat awkwardly as $A/(B+C)$ with subsequent normalization; it is equivalent to the $5A/(2B+3C)$ ratio reported here.

[16]Goodness of fit values (r^2) were not reported in Repp (1992a) but were computed for the present comparison.

[17]Unlike the normalized IOIs (A,B,C) used in the ratios of Table III, these fractions of a single IOI are not normalized.

[18]The ratios for the five instances of the grace note passage in the music (the two renditions of bars 1–8 were treated individually here) were averaged. Individual pianists were fairly consistent across the five instances, and they all differed from each other in their precise grace note timing patterns, which is additional evidence for stable individual differences, despite relative homogeneity overall.

[19]The present components II–VI correspond to factors II, I, III, V, and IV there, and the resemblance is close. Only the marginally significant component VII differs from the previous factor VI.

[20]Component I also indicates a tendency for bars 18–20 to have a faster tempo than bars 2–4, though this was observed in only one of the student performances (P8) and was even more atypical of expert performances, most of which showed just the opposite, as did all the other component scores. Therefore, this trend in component I seems to be a statistical artifact.

[21]It is not in boldface in the table because the highest loading of that pianist (as well as of others at the bottom of the table) probably was on a factor that did not reach significance in the analysis.

[22]In a recent study (unpublished), the average timing profile was synthesized and presented to listeners for aesthetic judgment. It was found to be perfectly acceptable but lacking in individuality.

[23]A perceptive analysis of piano competitions is provided by Joseph Horowitz in his book, *The Ivory Trade*. Here is how he described the winner of the 1989 Van Cliburn International Piano Competition: "For one thing, he chose repertoire to highlight what he played least controversially. ... He readied his pieces not toward spontaneous, inspirational performances but toward performances that would leave nothing to chance, even under abnormal pressure. His only goal was to win" (Horowitz, 1990, pp. 101–102).

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