

## Some Observations on Pianists' Timing of Arpeggiated Chords

BRUNO H. REPP

*Haskins Laboratories, 270 Crown Street, New Haven, CT 06511-6695,  
U.S.A.*

*E-mail contact: repp@haskins.yale.edu*

The timing of arpeggiated chords involving both hands sequentially was measured in performances of Edvard Grieg's *Erotik*, op. 43, No. 5, by ten graduate student pianists (who played the piece three times after brief study) and by eight commercially recorded ("expert") pianists. Arpeggio durations depended more on the preceding note value and position in the phrase than on the number of notes. The student pianists frequently overlapped the two hands, contrary to the notation. Those student arpeggios which were executed correctly frequently showed lengthening of the final and, less often, of the initial interonset interval. There were consistent individual differences in the students' timing patterns. The expert pianists showed even larger individual differences and few commonalities. The origins of these differences and their perceptual and aesthetic implications remain to be investigated.

### Introduction

The term *arpeggio* ("harp-like") refers to the successive playing of the notes of a chord. Narrowly defined, it is the "breaking" or "rolling" of a notated chord, usually because it is accompanied in the score by a verbal or symbolic instruction to that effect, such as a wavy vertical line. Broadly conceived, an arpeggio is any reasonably fast sequence of successive notes that spells out a chord. This study is concerned with arpeggios in the narrow sense. Moreover, the investigation is restricted to piano music from the late 19th century, in fact to a single piece from that period that happens to be rich in notated arpeggios.

Three characteristics are shared by most arpeggios in Romantic piano music: (1) They are played from the bottom up (*i.e.* in order of increasing pitch). (2) The highest note, which usually is part of the principal melody, bears the metrical accent. (3) The damper pedal is commonly used to sustain the chord tones. Other characteristics vary widely: The arpeggiated chord may fall within the span of a single hand or it may exceed it, requiring unusual stretches or changes in hand position; it may be divided between the hands, sometimes even with the left hand reaching over the right for the top note; or both hands may carry out arpeggios simultaneously, in which case the top note in the left hand assumes secondary importance. Arpeggios may also be executed where they are not notated, for special expressive purposes or because a chord exceeds the span of the pianist's hands. The expressive function of an arpeggio is primarily to prepare and delay the entry of the top note – a form of agogic accent (Riemann, 1884; Vernon, 1936; Clarke, 1985; Parncutt, in press) – and secondarily to change the sonic texture by individuating the component tones of the chord.

The present study is concerned with the timing of arpeggios, an aspect of expressive performance that apparently has not been examined previously in a quantitative fashion. As in other studies of expressive timing (*e.g.* Repp, 1992a), three aspects are of special interest. The first of these is tempo or total duration:

How quickly are arpeggios typically executed, and is their tempo (or duration) invariant or dependent on the number of notes and the context in which the arpeggio occurs? The second aspect is the timing pattern: Are the successive notes played at a constant local tempo, or are there accelerations and/or decelerations within arpeggios? If the tempo is not uniform, do the interonset intervals follow a smooth curve, as has been observed in the expressive timing of successive melody notes (Todd, 1985, 1995; Repp, 1992a), or is the pattern more irregular, as has been observed in the playing of scales (MacKenzie and Van Eerd, 1990), and do these irregularities reflect the distance between successive pitches (finger span) or the transition from one hand to the other? The third aspect of interest is the magnitude and consistency of individual differences in arpeggio timing.

A thorough investigation of these questions would require the examination of large numbers of performances of compositions in different styles, as well as the creation of systematically varied musical materials to be played in the laboratory. The present study had a more modest scope. It took advantage of a small MIDI data base recorded by the author, containing performances of four pieces by ten pianists. One of the pieces included a number of arpeggios and thus offered an opportunity to make some observations on their timing. The arpeggios, like the whole composition, were generally slow and expressive in character, which was advantageous for measurement because it presumably increased systematic timing variation relative to mere "motor noise". Moreover, each pianist played the piece three times, which made it possible to assess individual consistency and estimate the variability of timing patterns.

The pianists who provided the performances were highly skilled but (with one exception) unfamiliar with the music and had only little time to rehearse it. Their arpeggios thus reflected the relatively spontaneous application of standard technical routines – a situation likely to yield "typical" or "default" arpeggios, which was thought to be quite appropriate for the present investigation. However, because their productions did not represent the highest level of artistry and perfection, the arpeggios of experienced concert pianists who had recorded the same music were examined as well.

## Methods

### *The music*

The music was Edvard Grieg's *Erotik*, op. 43, No. 5, from Book 3 of his Lyric Pieces, composed in 1886. The initial eight bars are shown in Example 1, together with bars 29 and 32. The score (Peters Edition) contains 19 notated arpeggios. The first six (see Ex. 1) all involve both hands successively, and the chords are generally within the span of each hand. The only exception is in bar 8, where the left hand must reach over the right hand for the top note. Bars 9–16 are an almost literal repeat of bars 1–8, except that the left-hand chords in bars 9 and 10 are arpeggiated as well. The last five arpeggios occur in bars 20, 29, 31, and 32 (see Ex. 1 for bars 29 and 32). Four of them involve wider spans in the left hand, making it necessary to reach over the thumb with the index finger. There is basically only a single reasonable fingering for each of the arpeggios.

### *The pianists*

Ten graduate students of piano performance at the Yale School of Music (P1, P2, ..., P10) participated in the study as paid volunteers. Three of them were third-

## Ex. 1

Bars 1–8, 29, and 32 of Edvard Grieg's *Erotik*, op. 43, No. 5 (Peters Edition), with bar numbers added.

year (artist's diploma) students, one was in her second year, five were in their first year, and one was recorded a few months before he entered the graduate program. Their age range was 21 to 29, and they had started to play the piano between the ages of 4 and 8. Seven were female, three male. In addition, eight commercial recordings of the Grieg piece were obtained. The artists (henceforth referred to as "experts") and the record labels are identified in Table 1.

### Recording procedure

Individual recording sessions took place in a room housing an upright Yamaha MX100A Disklavier connected to a Macintosh computer via a MIDI interface. Each student pianist was asked to rehearse *Erotik* and three short pieces by other composers at the Yamaha for an hour. Subsequently, the pieces were MIDI-recorded in whichever order the pianist preferred, and then they were repeated twice in the same order. If something went seriously wrong in a performance, it was repeated immediately. One pianist, P4, 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 questionnaire asked, among other things, how familiar the music was. *Erotik* (which had been deliberately selected to be unfamiliar) was totally new to nine pianists; only P6 had played it previously.

TABLE 1  
The recordings of Grieg's *Erotik* used in this study.

<i>Pianist</i>	<i>Label and year of recording</i>
Leif Ove Andsnes	Virgin Classics CDC 7 59300 2 [1993]
Arturo Benedetti-Michelangeli	Teldec Historic 93671 [1942]
Geir Henning Braaten	Victoria VCD 19029 [1992]
Walter Giesecking	Angel 35450 [1957]
Peter Katin	Unicorn-Kanchana UKCD 2033 [1989]
Eva Knardahl	BIS-CD-104 [1977]
Isabel Mourao	Vox SVBX 5458 [?]
Balázs Szokolay	Naxos 8.550577 [1991]

### *Data analysis*

The MIDI data were imported as text files into a spreadsheet program, where the note onsets were separated from the other events (note offsets and pedal actions) and the highest note in each chord was identified. The temporal resolution provided by the Disklavier was about 5 ms. Relative onset times (ROT) were obtained by subtracting the onset time of the highest note from those of the lower notes. Thus, arpeggios were generally characterised by negative ROTs leading up to the highest note, whose ROT was zero. The absolute value of the largest negative ROT (almost always that of the lowest note) defined the duration of the arpeggio. The ROTs within each arpeggio were normalised by dividing them by the arpeggio duration, so that they ranged from  $-1$  to  $0$ . (In some instances, lower notes were played after the highest note, resulting in small positive values.) Finally, these normalised ROTs were averaged across the three or six occurrences of each arpeggio, and their standard deviations were calculated. For the lowest and highest notes, the standard deviations were zero, due to the normalisation. Interonset intervals (IOIs) among the original onset times were also calculated, without any normalisation.

The commercial recordings were digitised or transferred from CD to the hard disk of a Macintosh Quadra 660AV computer, and individual tone onsets in the arpeggios were located and labelled in the acoustic waveforms, using a combination of visual and auditory cues. SOUNDEDIT16 software was used to display the waveform and a running spectrogram simultaneously at various levels of resolution, and a cursor was moved from right to left in small steps, until the onset of a tone could no longer be heard. Tone onsets were sometimes difficult to identify, and the acoustic measurements thus include human measurement error that is absent from the MIDI data. From the measured onset times, ROTs and IOIs were calculated, as described above.

After a preliminary inspection of the student data, it was decided to limit detailed analysis to just seven of the 12 distinct arpeggios. The left-hand arpeggios in bars 9, 10, and 29-2 (*i.e.* beat 2 of bar 29) contain too few notes to be interesting. In bars 6-1 and 14-1 most student pianists failed to arpeggiate the right-hand notes. The arpeggios in bars 20 and 31 are technically uncomfortable and were often

played inaccurately by the students, due to the insufficient rehearsal time. This left the five repeated arpeggios in bars 3/11, 4/12, 5/13, 6-2/14-2, and 8/16, and the two unique arpeggios in bars 29-1 and 32 (the latter differing from that in bars 4/12 only by a single added note), all of which are shown in Example 1.

## Results and Discussion

### *Arpeggio durations*

The arpeggio durations are shown in Table 2. For the students, standard deviations across the six or three renditions are given in parentheses. For the experts, standard deviations could be computed over just two renditions, for the five repeated arpeggios. There was large variability in durations, both between arpeggios and between pianists. Yet, the standard deviations for repeated execution of the same arpeggio by the same pianist were often not very large, indicating considerable consistency.

The durations and standard deviations, averaged across the pianists in each group, are shown in Figure 1. It is evident that the students' arpeggios were faster than the experts' but had a very similar pattern of relative durations. Also, students

TABLE 2

Average durations and standard deviations (in ms) of arpeggios for the 18 individual pianists. Arpeggios with (tendencies toward) between-hand overlap or other anomalies are underlined in the student performances.

Pianist	Bars: 3/11 (6 notes)	4/12 (5 notes)	5/13 (5 notes)	6-2/14-2 (6 notes)	8/16 (8 notes)	29-1 (7 notes)	32 (6 notes)
P1	497 (57)	420 (46)	326 (21)	303 (13)	543 (49)	735 (64)	1083(102)
P2	900 (81)	<u>414</u> (30)	386 (24)	241 (79)	664(100)	1139 (70)	929 (53)
P3	<u>543</u> (100)	<u>333</u> (69)	<u>356</u> (39)	332 (33)	607(100)	<u>683</u> (146)	<u>743</u> (134)
P4	<u>481</u> (21)	<u>337</u> (26)	<u>236</u> (47)	<u>143</u> (31)	542 (18)	<u>716</u> (55)	711 (4)
P5	<u>561</u> (85)	<u>345</u> (34)	<u>334</u> (26)	<u>256</u> (106)	<u>467</u> (73)	<u>781</u> (89)	<u>368</u> (104)
P6	<u>347</u> (55)	<u>195</u> (23)	<u>143</u> (23)	<u>89</u> (17)	<u>274</u> (24)	<u>212</u> (37)	<u>359</u> (14)
P7	<u>392</u> (38)	<u>339</u> (47)	<u>345</u> (29)	430 (17)	<u>325</u> (60)	<u>323</u> (24)	<u>338</u> (33)
P8	<u>649</u> (32)	466 (37)	<u>234</u> (41)	<u>150</u> (18)	619 (34)	<u>728</u> (43)	<u>710</u> (44)
P9	588(167)	476(130)	343 (73)	<u>357</u> (11)	738 (74)	<u>835</u> (120)	1165(175)
P10	497 (55)	281 (32)	<u>274</u> (33)	<u>169</u> (29)	<u>505</u> (20)	<u>588</u> (42)	<u>1086</u> (72)
Andsnes	695 (63)	421 (75)	417 (73)	408	695 (31)	1067	664
Braaten	998 (69)	459 (18)	466 (16)	516 (14)	1077 (39)	398	1401
Giesecking	683(112)	449 (20)	486 (16)	316 (65)	771 (4)	1030	794
Katin	706(177)	398(124)	459(123)	215 (42)	454 (24)	909	1173
Knardahl	820 (69)	476 (26)	400 (37)	259 (8)	695 (92)	1150	938
Michelangeli	394 (77)	265 (77)	319 (37)	269 (67)	900 (4)	874	1018
Mourao	906(138)	513 (18)	370 (26)	411 (8)	984	1398	995
Szokolay	660 (18)	246 (6)	299 (16)	298 (14)	564 (16)	863	713

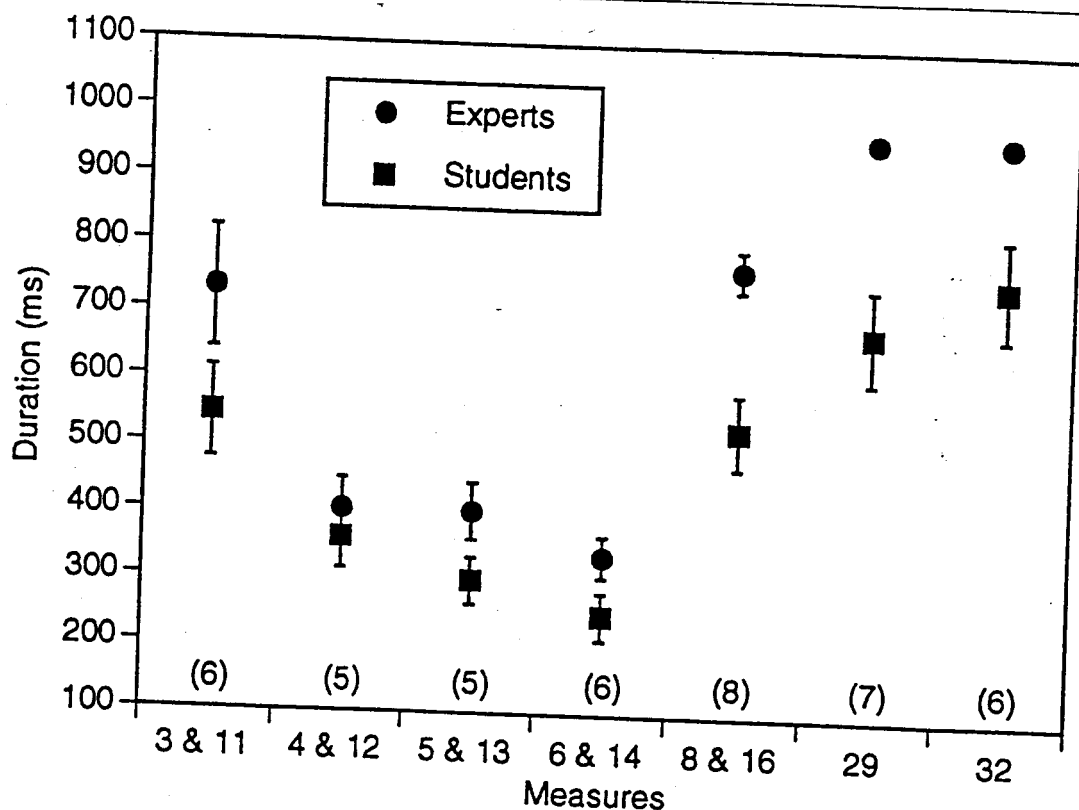


FIG. 1

Average arpeggio durations of experts and students, with average *within-pianist* standard deviations. Numbers in parentheses indicate the number of notes in each arpeggio.

and experts were about equally consistent in repetitions of the same arpeggio within and across performances. The average standard deviations were between 10 and 13% of the arpeggio duration and tended to increase with duration, though the experts were unusually consistent in their execution of the 8-note arpeggio (bars 8/16).

The durational differences between arpeggios can be explained only partially (if at all) by the number of notes involved: Although the two 5-note arpeggios were executed more quickly than the 7- and 8-note arpeggios, the three 6-note arpeggios had extremely divergent durations. A more pertinent factor is the value of the immediately preceding note in the score: The three short arpeggios (bars 4/12, 5/13, and 6/14) are all preceded by melodic sixteenth notes, two of the longer arpeggios (bars 3/11 and 29) by eighth notes, and the longest arpeggio (bar 32) by an eighth-note rest. An exception is the 8-note arpeggio (bars 8/16), which is preceded by a sixteenth note; its long average duration may be due to the large number of notes and the reaching over of the left hand. Yet another relevant factor, however, is position in the phrase, which in turn is related to the velocity of the larger musical motion in which the arpeggio is embedded (*cf.* Todd, 1985): The slow arpeggio in bar 29 initiates a phrase, the one in bars 3/11 a sub-phrasal unit, the one in bars 8/16 occurs towards the end of a phrase, and the very slow arpeggio in bar 32 is part of an isolated melodic gesture at a point of suspended motion

terminating a half-phrase. In contrast, the fast arpeggios in bars 5/13 and 6/14 occur at points within a phrase where the music pushes forward, while the one in bars 4/12 is at the end of an inconclusive half-phrase. In other words, the short arpeggios not only needed to be completed within a shorter nominal interval, prescribed by the value of the preceding melody note, but they also occurred at points of relative acceleration, whereas the long arpeggios tended to occur at points of deceleration. Although the factors of note count, preceding note value, and phrase position cannot be disentangled here, together they provide a plausible explanation of the average durational differences among the arpeggios.

The difference between students and experts in average arpeggio duration could have been due to an average difference in global tempo. Indeed, about half of the students, due to their unfamiliarity with the piece and probably misled by the small note values in the score, played it at an uncharacteristically fast tempo (more *adagio* than *lento molto*). Another reason, however, turned out to be that the students had executed the majority of the arpeggios in a non-standard way. This is illustrated in Figure 2, which shows the normalised timing of the arpeggio in bars 3/11 for the 10 student pianists. This arpeggio contains six notes, three in each hand. Three kinds of timing pattern can be seen. Pianists P3, P5, P6 and P8 overlapped the two hands so that their final notes (3 and 6) coincided; the first note in the right hand (4) was played together with or shortly after the second note in the left hand (2). These pianists were quite consistent in this kind of execution, even though it is not in agreement with the notation.\* Two other pianists, P4 and P7, showed a weaker tendency to overlap the two hands; they started the right hand (4) shortly before the final left-hand note (3). Only four pianists – P1, P2, P9 and P10 – played the arpeggio as indicated in the score, namely as a monotonic sequence of increasing pitch. All pianists (with the exception of P10 in one instance) were quite consistent in their style of execution, as is reflected in the relatively small standard deviations.

The students' execution of the other arpeggios presented a similar picture. In addition, there were a number of instances in which the right hand was not arpeggiated. All these anomalous cases are underlined in Table 2. Unfortunately, they constituted the majority of the data. Only two pianists, P1 and P2, almost always played the arpeggios the way they were intended to be played; the other pianists did so only occasionally. The experts, on the other hand, almost always played the arpeggios correctly. Figure 3 shows their normalised data for bars 3/11; the two renditions of the arpeggio are plotted separately here. Only one pianist, Szokolay, overlapped the two hands, and he also had some missing or inaudible notes (as did Michelangeli). All others show monotonic sequencing. This was true for the other arpeggios as well; there were only few anomalous instances, and they were generally not repeated. For this reason, they are not underlined in Table 2.

The student pianists' unexpected *penchant* for between-hand overlap and right-hand non-arpeggiation probably contributed to their shorter average arpeggio durations and had the consequence that only a subset of their data could be used to address the question of timing in properly executed (*i.e.* monotonically sequenced)

\*This style of execution is appropriate for simultaneous arpeggios in both hands, which would be notated as separate wavy lines preceding the chords on the two staves. As is pointed out in Cappeliens *Musikkleksikon* (1978), simultaneous arpeggios often sound more satisfying when the right hand starts after the left.

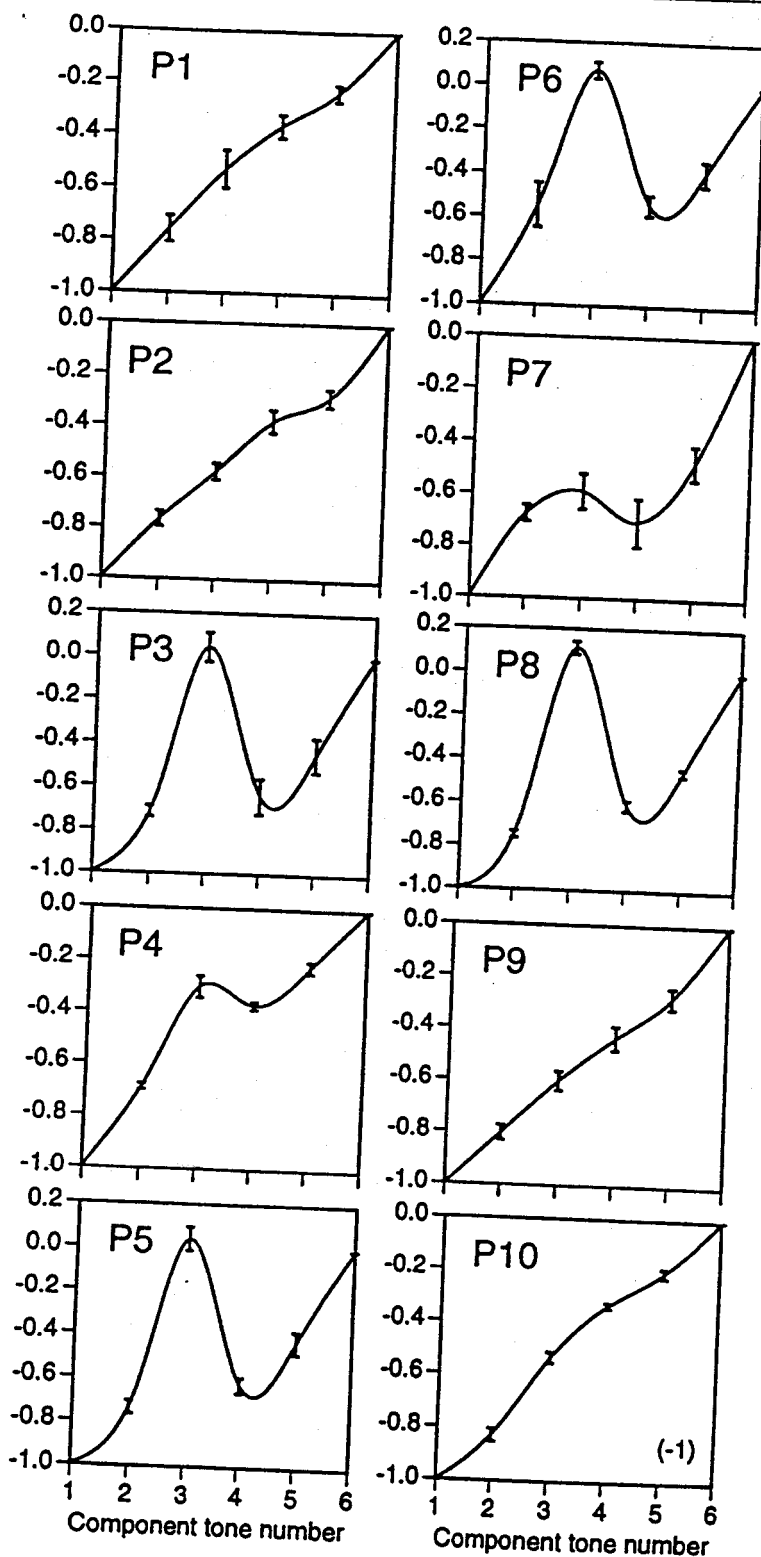


FIG. 2

Normalised arpeggio timing in bars 3/11 for the 10 student pianists, with standard deviations across 6 repetitions. (One of P10's arpeggios was omitted, as it differed radically from the other five.) The connecting lines are spline functions without theoretical significance.



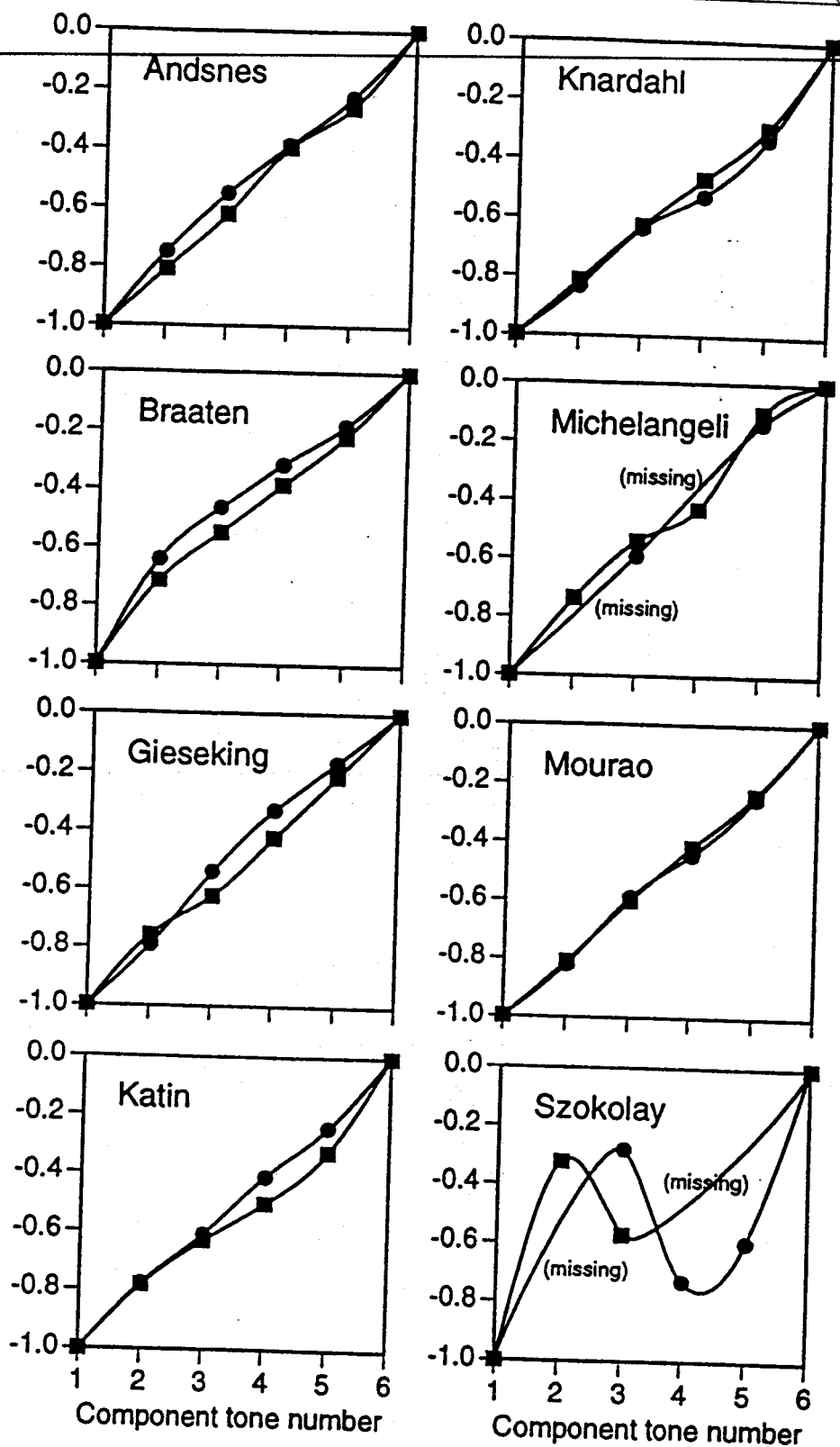


FIG. 3

Normalised arpeggio timing in bars 3 and 11 for the 8 expert pianists. The two arpeggios are shown separately. Missing onsets are indicated.

arpeggios.\* However, the amount of data seemed sufficient for this preliminary study.

From a visual inspection of Figures 2 and 3 it seems that few, if any, arpeggios were evenly timed, but it is difficult to tell from these graphs whether the timing variation is significant. For that purpose, it is better to inspect inter-onset intervals (IOIs), which will be discussed for each arpeggio in turn.

### Bars 3/11

Figure 4 shows the IOIs in bars 3/11 for the four student pianists who played this arpeggio as a monotonic sequence. Each graph shows the IOIs of the six individual renditions as well as the average IOIs with standard error bars. As a rule of thumb, two durations are significantly different when their standard error bars do not overlap. It can be seen that two pianists (P2 and P10) were highly consistent (though one of P10's arpeggios was omitted because it was non-

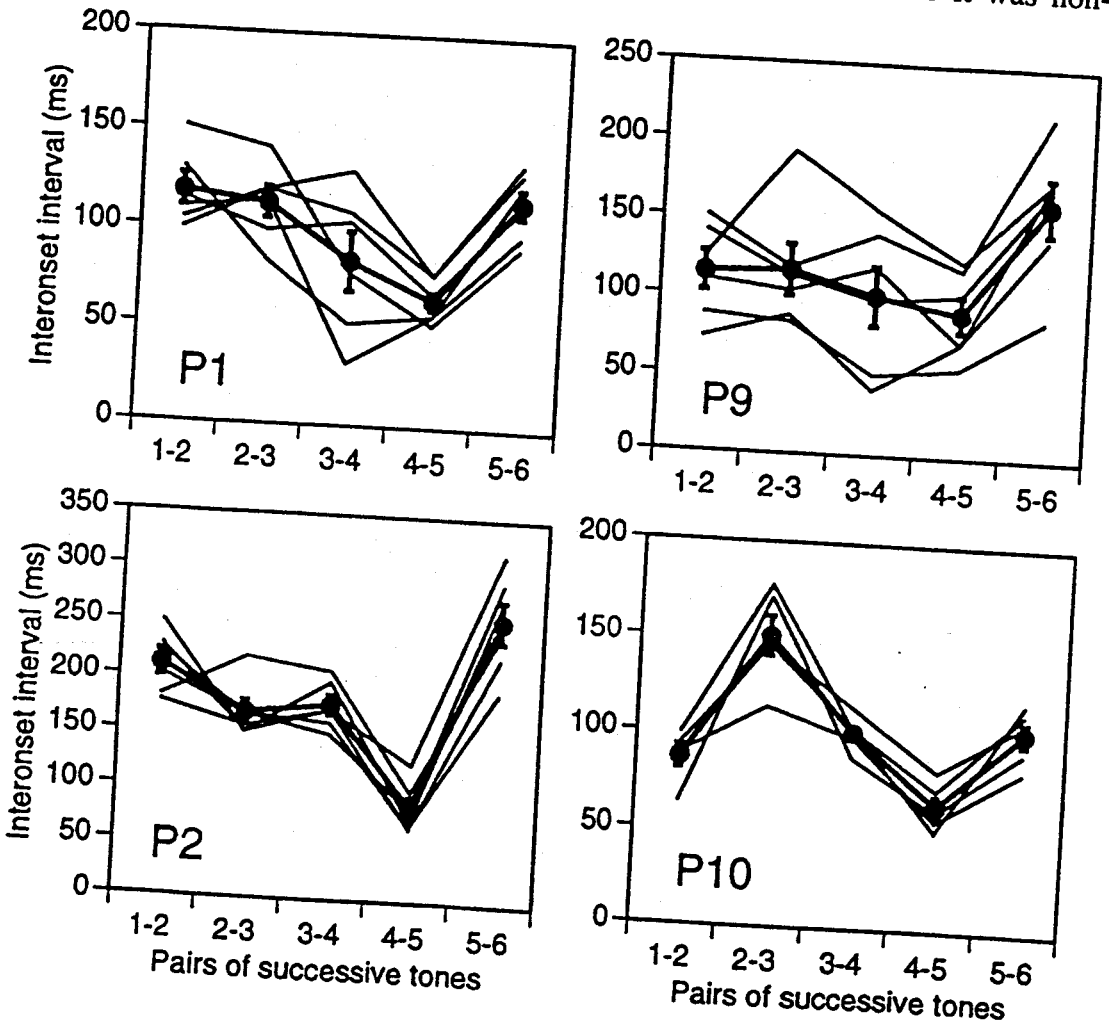


FIG. 4

Interonset intervals of sequential arpeggios in bars 3/11 for 4 student pianists.  
Means are shown with standard error bars.

\*The term "monotonic" is used in its mathematical sense here, meaning "in order of increasing pitch".

monotonic), and the other two (P1 and P9) were moderately consistent, varying more in tempo than in timing pattern. All pianists tended to accelerate up to the penultimate note, so that 4-5 was the shortest IOI, and then to delay the arrival of the top (melody) note, so that 5-6 was distinctly longer than 4-5. Only P10 started out with a short IOI. In none of these pianists did the between-hand IOI (3-4) stand out as particularly short.

Figure 5 shows the corresponding data of the expert pianists. All individual tokens are superimposed here, omitting those with missing notes or atypical characteristics, and the average IOIs are shown without error bars. There was considerable variability among pianists, but the majority, like the students, showed a lengthening of the final IOI.

Graphs analogous to Figures 4 and 5 were prepared for all arpeggios, but, to conserve space, they will be displayed only for bars 8/16. The results for the other arpeggios will be summarised verbally.

#### Bars 4/12

Of the four students who played the arpeggio in bars 4/12 properly, one (P8) exhibited strong final lengthening, and another (P1) a slight tendency; however, the other two (P9 and P10) did not. For all four pianists, the initial IOI (1-2), which occurs between the notes of an octave in the left-hand, was clearly longer

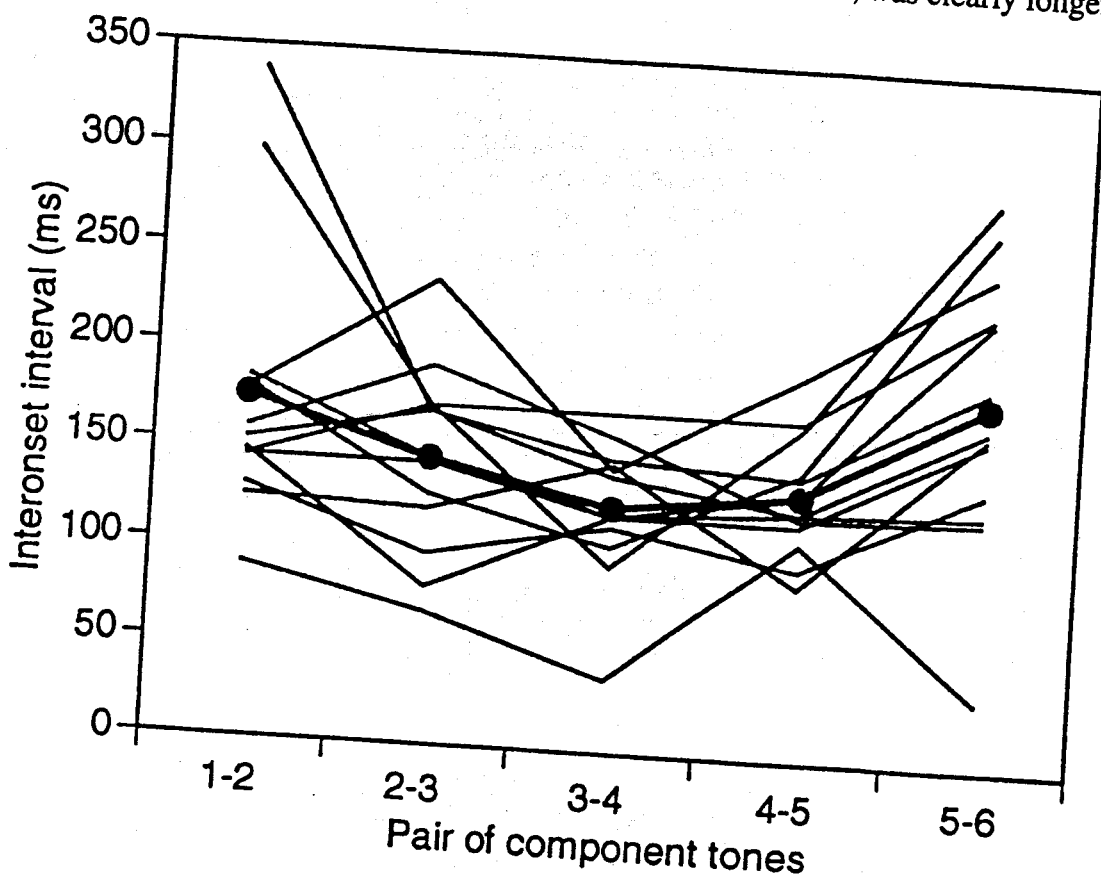


FIG. 5

Interonset intervals of complete arpeggios in bars 3/11 for the expert pianists, and their means.

than the following between-hand IOI (2-3). This was the only commonality among the four student pianists. The experts, too, showed much individual variation, and their average pattern showed a tendency for the last two IOIs to be longer than the first two.

#### *Bars 5/13*

Here only three students (P1, P2, P9) showed monotonic timing patterns. All three showed a long initial IOI, again for an octave in the left hand, followed by a short between-hand IOI. P1 and P2 both showed progressive lengthening in the last two IOIs, but P9 did not. The experts again showed great individual differences, so that their average pattern was hardly representative. However, it did resemble somewhat the timing exhibited by P1 and P2.

#### *Bars 6/14*

Three of the four student pianists considered here (P1, P2, P7) again showed initial lengthening, once again for a left-hand octave. The fourth pianist (P3) showed two quite different patterns, only one of which exhibited initial lengthening. All pianists tended to have a very short between-hand IOI at least some of the time. The most consistent pianist (P7) showed a progressive ritard in the right hand, and P1 and P3 also lengthened the final IOI, but P2 did not. Of the expert arpeggios, fewer than half provided complete data. Those all showed lengthening of the final IOI, but not of the initial (left-hand) IOI.

#### *Bars 8/16*

This was the largest arpeggio (8 notes) and required reaching with the left hand over the right to play the top note. Figure 6 shows the data for six student pianists. There was considerable consistency at the individual level, and also some commonality across pianists. Three of them (P1, P2, P3) had a short between-hand IOI (3-4), but the other three (P4, P8, P9) did not. All six showed a progressive lengthening of the last two IOIs. (Note that 7-8, too, is a between-hand IOI.) The experts, on the other hand, showed nothing of the sort, with one exception (Andsnes), as can be seen in Figure 7. They played the arpeggio fairly evenly, with a tendency to lengthen the initial IOI.

#### *Bar 29*

Only two student pianists (P1, P2) could be considered here. Both showed clear lengthening of the final IOI. P2 accelerated steadily up to that point, whereas P1 showed only slight acceleration and lengthening of the second IOI (2-3), which is a technically difficult spot (the index finger of the left hand reaching over the thumb). There was no indication of a short between-hand IOI (4-5). Both pianists were highly consistent in their timing patterns. The expert arpeggios were highly idiosyncratic; only a few showed final lengthening.

#### *Bar 32*

This slow arpeggio was played sequentially by three student pianists (P1, P2, P9). All three were highly consistent and showed final lengthening, but otherwise their timing was idiosyncratic. The experts again showed many different patterns, with a tendency to lengthen the initial IOI, but not the final one.

#### *Dynamic patterns*

The MIDI velocities of the student pianists' key depressions, which are closely related to the intensities of the tones played, were inspected to see whether individual

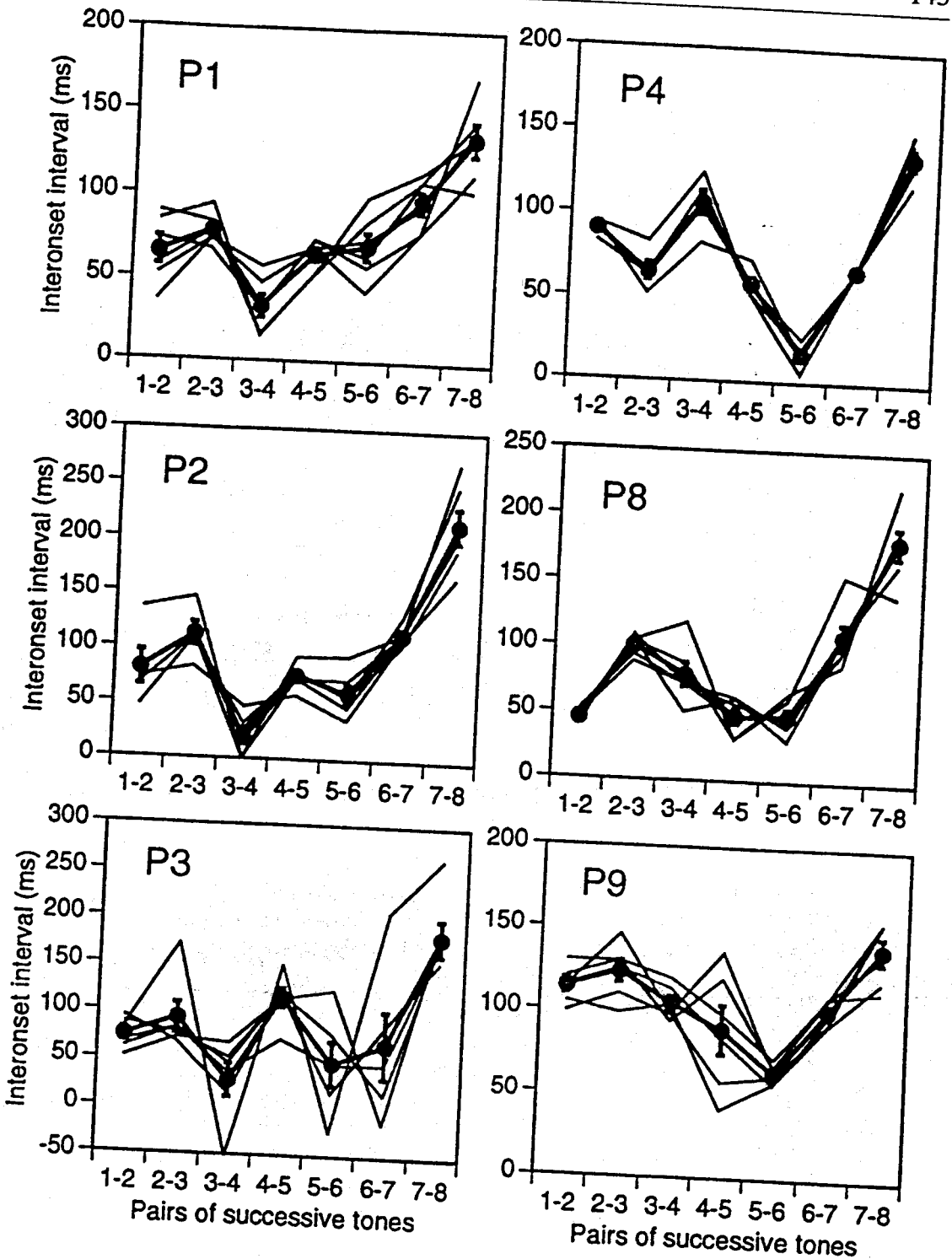


FIG. 6

Interonset intervals of sequential arpeggios in bars 8/16 for 6 student pianists.  
Means are shown with standard error bars.

differences in arpeggio timing were related to individual differences in dynamic differentiation of the arpeggio tones. There was a general tendency for the left hand to be played more softly than the right hand, and virtually all arpeggios

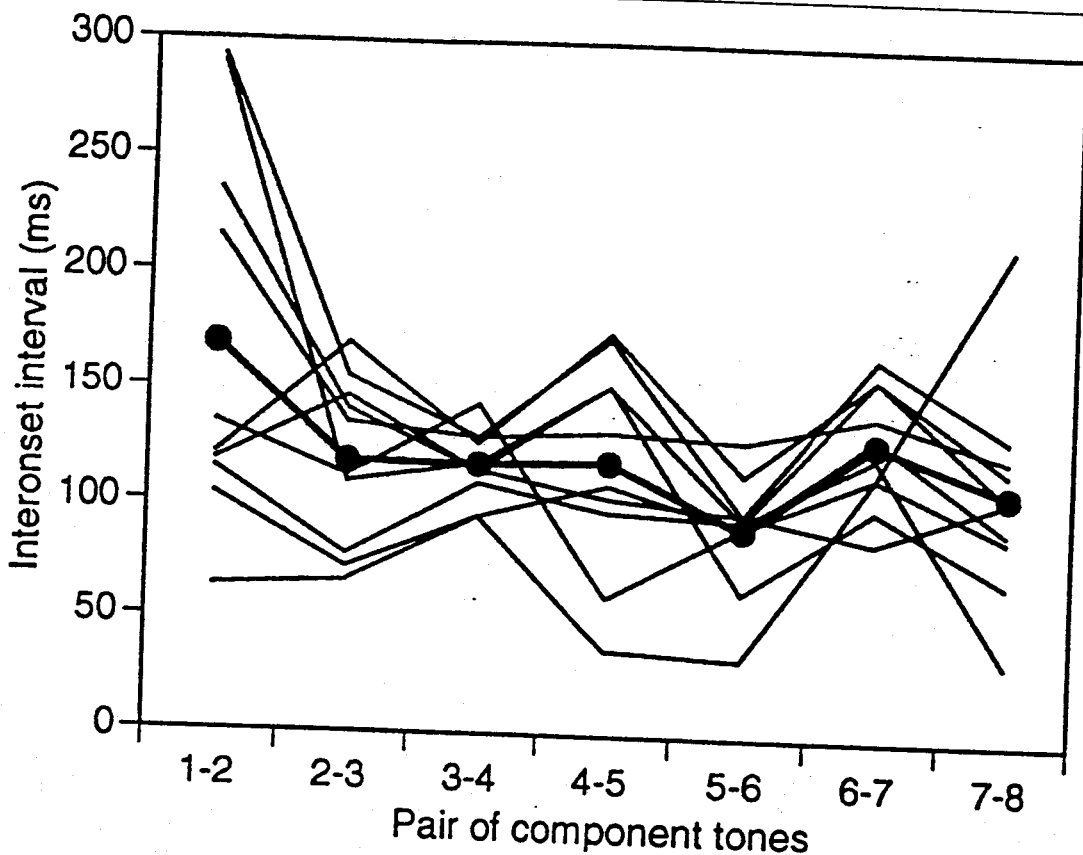


FIG. 7

Interonset intervals of complete arpeggios in bars 8/16 for the expert pianists, and their means.

showed a crescendo in the right hand towards the final melody note which – not surprisingly – was played most forcefully. However, individual differences in dynamics were not nearly as pronounced as those in timing. For example, P9 and P10 showed very similar dynamic patterns in bars 3/11, as did P4 and P8 in bars 8/16, even though these pianists timed the left-hand part of the arpeggios very differently (cf. Figs. 4 and 6). Thus, the individual differences in timing seemed to be independent of dynamics. In addition, it should be noted that the student pianists' tendency to delay the final note – the note with the highest velocity – is contrary to the “velocity artifact”, according to which a key struck with greater force causes a relatively earlier tone onset than a key struck with lesser force (Repp, 1996), and also contrary to a documented tendency of acceleration to accompany an increase in dynamics (Todd, 1992).

### General Discussion

Keeping in mind the limited scope of this first investigation of arpeggio timing, the following tentative conclusions may be drawn: (1) There are systematic deviations from even timing in expressive arpeggios. (2) These deviations are subject to large individual differences. (3) Fairly consistent tendencies – observed mainly among graduate student pianists in a “quick study” situation – include lengthening of the final IOI (preceding a melody note) and, less frequently, of

the initial IOI (especially when the left hand started with an octave). (4) Expert pianists' well-rehearsed arpeggio timing is even more diverse than student pianists' timing and shows few consistent trends.

The first conclusion raises the question of whether the deviations from strict timing are unintended consequences of motor constraints such as key (finger) distances and hand alternation, or whether they are deliberately (though perhaps unconsciously) introduced for expressive purposes. For the student pianists, hand alternation clearly played a major rôle, as evinced by their strong tendency to come in early with the right hand (Fig. 2). In their monotonically sequenced arpeggios, however, the between-hand (left-right) IOI was not particularly short, except in a few cases (Fig. 6). Their pronounced lengthening of the final between-hand (right-left) IOI in bars 8/16, however (Fig. 6), could have been due to cautious over-reaching of the left hand in that particular arpeggio, though it could also have been a deliberate expressive strategy. The expert pianists generally did not show any shortening or lengthening of between-hand IOIs, which indicates that hand alternation is not necessarily reflected in arpeggio timing. Similarly, it is difficult to see any obligatory consequences of key (pitch) distance or finger span on arpeggio timing in these data, given the considerable individual differences among pianists. Expert pianists presumably possess the technical skill to overcome any such factors and to achieve a timing pattern that serves expressive goals only. The student pianists evidently had difficulties with some of the technically more demanding arpeggios (bars 20 and 31, not analysed here, as well as bar 29 in one instance), but undoubtedly they would have overcome these difficulties if they had had the opportunity to practice the piece for a longer time. None of the technical requirements of the present arpeggios seems sufficiently taxing to have unavoidable consequences for timing.

This leaves the door open for interpretations of arpeggio timing in terms of expressive intentions. Such interpretations are complicated, however, by the individual differences among pianists, especially among the experts. To a large extent, arpeggio timing seemed to be idiosyncratic. Few arpeggios had smooth temporal acceleration-deceleration shapes, as is often the case with the expressive timing of phrases or shorter melodic units (Todd, 1985; Repp, 1992a; Epstein, 1995). Thus, arpeggios do not seem to be well-shaped expressive gestures in miniature. The high speed of execution probably makes precise temporal shaping difficult and perhaps unnecessary from a perceptual and aesthetic perspective. Nevertheless, a general acceleration-deceleration tendency seemed to be present, at least among the student pianists, which is in accord with the temporal delineation of a gesture. Final lengthening may have created an extra agogic accent within the agogic accent provided by the arpeggio as a whole, thus doubly enhancing the melody note. It remains to be determined to what extent these details of timing are actually perceptible. It may well be that listeners "expect" initial and final lengthening to occur in arpeggios, as they seem to do in more extended melodic groups (e.g. Repp, 1992b, 1995a).

The present data are not sufficient to determine whether there are consistent individual styles of arpeggio timing. Even the deviant strategy of overlapping the two hands was pursued by only one student pianist (P6) with complete consistency; paradoxically, she was the only one who knew the piece. P1 and P2, who rarely or never showed this pattern, both tended to exhibit initial and

final lengthening. Others were less consistent across arpeggios, but usually quite consistent across repetitions of the same arpeggio. They, and especially the expert pianists, seem to have a variety of timing patterns available that may help create special textures and tone colors. This would be entirely consistent with expert pianists' greater diversity and originality in timing longer passages of music (Repp, 1992a, 1995b). However, the perceptual and aesthetic significance of these patterns remains to be determined.

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