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Anatomy of a Performance: Sources of Musical Expression

CAROLINE PALMER
Ohio State University

Research on music performance often assumes that a performer's intention to emphasize musical structure as specified in a score accounts for most musical expression. Relatively unstudied sources of expression in performance include notational variants of compositional scores, performer-specific aspects, and the cultural norms of a particular idiom, including both stylistic patterns that exist across musical works and expectations that arise from a particular musical context. A case study of an expert performance of a Mozart piano sonata is presented in which influences of historical interpretations of scores, performer-specific treatments of ornamentation and pedaling, and music-theoretic notions of melodic expectancy and tension-relaxation are revealed. Patterns of organization internal to the performance expression transcended the coarse-grained information given in scores, suggesting that performance is a better starting point than a musical score for testing theories of many musical behaviors.

DESPITE the fact that music performance provides a rich perspective on our musical experiences, our understanding of music performance has not caught up with empirical study of other types of musical experiences. Take for example the empirical research published in this journal (one of the leading journals in the study of music cognition) in the past 5 years: fewer than one fifth of the articles address performance, and twice as many address perception of music. Some of this disparity arises from the fact that only a minority of people perform music formally in our culture, whereas almost everyone listens to music. Another source of the disparity arises from the imperfect (or absent) methodologies for studying performance; a single performance typically results in a large quantity of complex measurements, and analysis techniques have been lacking. Recently, techniques for measuring and quantifying performance have improved with the advance of computer-aided musical instruments.

Requests for reprints may be sent to Caroline Palmer, Psychology Dept., 1885 Neil Ave., Ohio State University, Columbus OH 43210. (e-mail: cpalmer@magnus.acs.ohio-state.edu)

Perhaps a more important reason for the small number of performance studies comes from a subtle but widely held premise in study of Western art music that performance is primarily an intermediary stage between a musical composition and its apprehension by a listener. In this view, the main source of information is the composition, and the performer's job is to clarify the composer's message. Another way of stating this belief is to say that there exists an ideal interpretation for each musical score, which serves as the goal for performance. This premise is most obvious in a common reliance on the score as the starting point for music-theoretic analyses and most psychological studies of perception. However, studies based on interviews with performers suggest that musicians construe (and resolve in different ways) structural ambiguity in each musical piece (Nakamura, 1987; Palmer, 1989), and perceptual studies suggest that interpretive aspects of performance (not specified in the score) influence perceptual judgments about musical structure (Palmer, 1988; Sloboda, 1983).

The goal of this paper is to elucidate sources of performance expression beyond traditional score-based explanations, based on a case study of an expert piano performance. I hope to convince the reader of a different premise: that performance is a better starting point than a musical score for testing theories of many musical behaviors. Research on music performance typically focuses on expression arising from a performer's emphasis of musical structure as specified in a compositional score. There are, however, many other sources of performance expression, including notational variants of compositional scores (different editor's and publisher's editions), performer-specific styles, and influences of stylistic expectations based on cultural norms. I will focus here on performance influences that can arise from historically informed score interpretations, music-theoretic proposals for stylistic expectations, and performer-specific characteristics, such as treatment of ornamentation and pedaling.

I will discuss a case study analysis of a virtuoso piano performance of the first movement of the Mozart Piano Sonata in E♭ Major, K. 282 (see this issue for a copy of the score). Wolfgang Amadeus Mozart's compositions are considered an important part of the classical piano repertoire by many musicians, and concert programs that include only or mostly Mozart are common nowadays. With a resurgence in the interpretation of classical music on period instruments, performance of Mozart's music has become of special focus. Interest in the interpretation of Mozart's keyboard music is high, and many books are devoted to the topic (cf. Badura-Skoda & Badura-Skoda, 1962; Landon, 1990).

In a sense, the goal of this paper resembles a reverse engineering problem: working backwards from a performance to uncover, or more accurately, recover, the sources of performance expression. As such, the study has several potential weaknesses: it lacks the ability to generalize beyond the immediate context. It also lacks a large sample to rule out alternative hypotheses, a weakness of all case studies. Despite these limitations, small numbers of performances examined under "naturalistic" conditions (without experimental manipulation) are a common approach to the study of performance, because they indicate what sources of performance expression are possible (not necessarily probable).

Notational Information

Compositional scores, including original manuscripts (autographs) and edited versions, can offer insight into the possible intentions of composers. In cases for which the autograph is not available, as with this sonata, musicians often rely on historically informed estimates, called *Urtexts,* of what the autograph would have contained. There is some argument over what information Urtexts should contain. For instance, the many Urtext editions available for this sonata differ in several ways, including dynamics, phrasing, articulation, and pedaling indications. What implications do these differences have for performers, for whom a score is often a point of departure in studying a musical piece?

Figure 1 shows two editorial differences in phrasing indications in the first movement of the Mozart sonata from the Barenreiter Kaessel (1986) Urtext (often called the Neue Mozart-Ausgabe), the Peters (1951) Urtext, and the Wiener (1973) Urtext editions (redrawn). The first row (1A) shows the phrase marking around a particularly important cadence in measure 8, in which three to four voices weave in and out. The different phrasings of the alto and tenor voices, marked with arrows, reflect decisions about their degree of delineation and relative importance. The example in the second row (1B) is from measure 11 and repeats in measure 12, in which the phrasing of the soprano voice varies. Sadie (1979) and Barenreiter editions agree

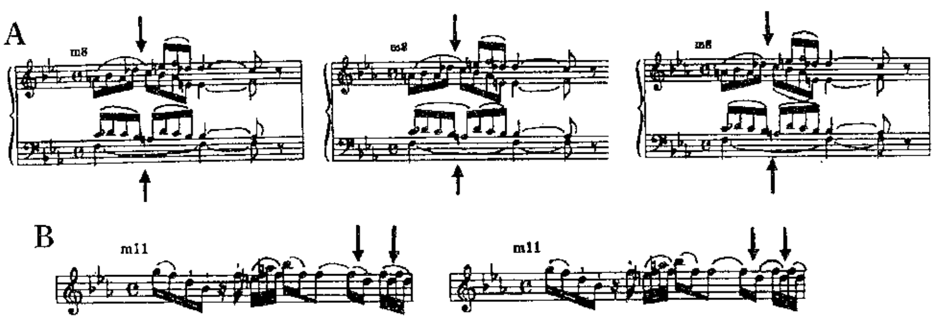

Fig. 1. Different edited markings of the Mozart K. 282 sonata (redrawn). (A) Phrasing in measure 8. (B) Phrasing in measure 11.

with the first phrasing in 1B; Kalmus (1949) and Peters editions agree with the second. Grouping of melodic tones in this passage suggest different degrees of melodic expectancy and tension-relaxation, music-theoretic factors discussed later.

Another example of score-based differences in interpretation is found in the opening dynamic marking, which is not specified in most Urtexts for the Mozart sonata but is often marked by individual editors. A large range of opinions exist among the different editions. The Barenreiter Kaessel edition gives forte as the opening dynamic level; the Theodore Presser (1960) edition gives mezzoforte; the Peters Urtext edition gives mezzopiano; and the Schirmer (1918) edition gives piano. The opening dynamic level is one indicator of the interpreter's plan for the scope of dynamics throughout the performance; this broad a range of opinions suggests differing views on dynamic scope. In sum, these editorial differences suggest that even Urtexts are ambiguous as to the composer's intentions, and so attempts to explain performance expression solely in terms of scores must be incomplete.

Of course, some aspects of musical structure are specified unambiguously in compositional scores, such as melodic contour and meter, and editorial markings sometimes serve to emphasize these forms of musical structure. For example, dynamic markings in many of the Mozart sonata editions coincide with changes in melodic contour; the contour peaks in the first eight measures are marked forte in most editions, and the troughs are marked piano. Although meter is usually marked explicitly in musical scores by a time signature and measure markers, these sources of information are available only to performers and not to listeners, who must discern meter from other cues. Composers' placement of note events in different metrical positions often corresponds to the notated meter; previous study of the piano sonatas of Mozart indicated that more note events are placed in positions of strong than weak metrical accent (Palmer & Krumhansl, 1990). Figure 2 shows the same relationship for the first movement of the K. 282 sonata in both the melody (soprano voice) and accompaniment (alto and bass voices); note placement corresponds to metrical accent strength in this piece. These examples point to the common co-occurrence of multiple correlates of musical structure in a compositional score, which may influence performers' use of expression.

An Expert Performance

Next I will turn to performance-specific sources of expression that transcend score-based information. Many performances of the Mozart piano sonata are available on commercial recordings. Acoustic recordings present some measurement problems, however, such as the determination of onset

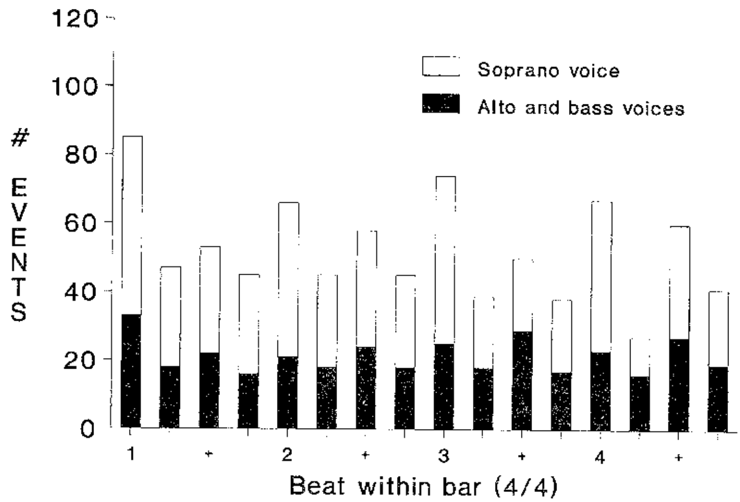

Fig. 2. Frequency distribution of the note event onsets in the first movement (without repeat).

times and intensities of the component tones in chords. Fortunately, recent technological advances allow recording of multivoiced music on computer-monitored acoustic pianos, obviating some of the measurement problems of acoustic recordings. A virtuoso performance of the Mozart piano sonata (also available on compact disc) was recorded on a computer-monitored grand piano, which measures the timing and intensity of note events and foot-pedal movements without altering the touch or acoustics of the instrument.

Concert pianist Philippe Entremont recorded the entire K. 282 sonata on a Boesendorfer SE acoustic grand piano. Mr. Entremont has an extensive concertizing and recording career in Europe and the United States, including more than 10 compact-disc recordings of Mozart's piano music. He took the first repeat only (the first 15 bars) in the first movement (a second repeat is notated near the end of the movement). There was no indication of improvisation, as sometimes found in interpretations of Mozart's keyboard works (cf. Malcolm Bilson's fortepiano recording of this sonata, Hungaroton, 1991). Writings on performance practice of Mozart's keyboard music often describe a restrained but expressive style, and in particular an emphasis of the vocal or melodic line; the performance described here is an example of this style.

The Boesendorfer SE piano is a computer-monitored acoustic grand piano. Its measurement resolution is finer than that of standard MIDI instruments: it measures 1024 levels of hammer velocity for each note event and 256 levels of foot pedal (from all the way up to all the way down). Pedaling is measured every 10 ms for the damper (right) pedal and every 20 ms for the soft (left) pedal. Note event onsets and offsets are measured every 1.25 ms. The performance described here used a range of 300–900 values of hammer velocities and the whole range of foot-pedal levels. All information is detected by optical sensors and passed to a personal computer.

GENERAL CHARACTERISTICS OF PERFORMANCE EXPRESSION

Piano performance contains many deviations from the regularity of score information in terms of note durations, intensities, and articulation (note offset-onset relations), in addition to voicing (synchrony among notated simultaneities) and foot pedaling. Figure 3 shows the opening measure plus one beat of the performance in fine detail; pitch height increases on the y-axis and time on the x-axis. Note events are indicated by rectangles, intensities by shading (the darker the rectangle, the louder the note), and the damper pedaling is shown at the bottom (pedal depressions are shown in black). Immediately apparent is the range of intensities, durations, and chord alignment of note events. I will examine these performance variations, concentrating first on some of the structure-expression relationships posited from prior findings reported across many performers and next on performer-specific patterns of expression.

One general characteristic of expressive performance that has been well documented is patterns of rubato or changes in interonset timing. Large

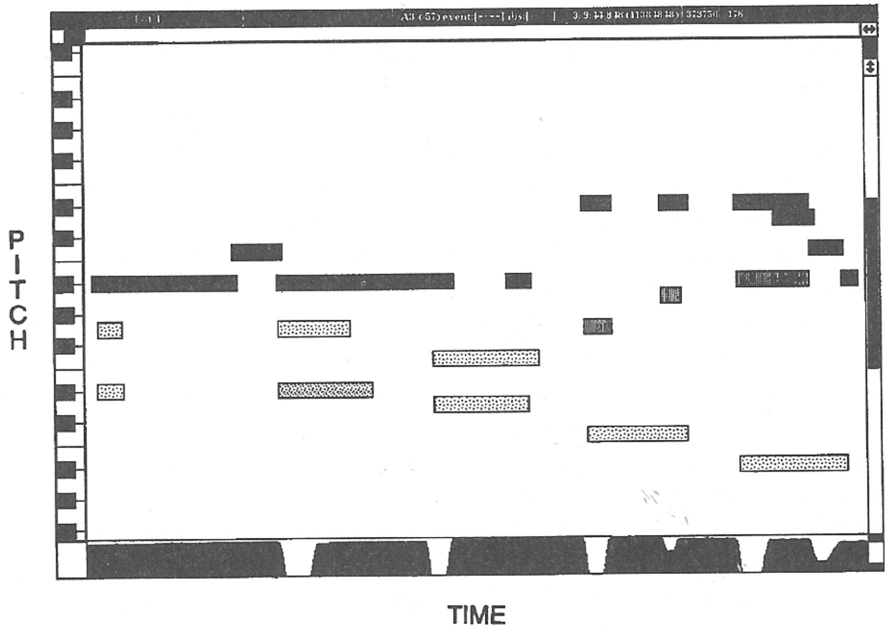

Fig. 3. Piano roll notation of the performance for the first measure plus one beat.

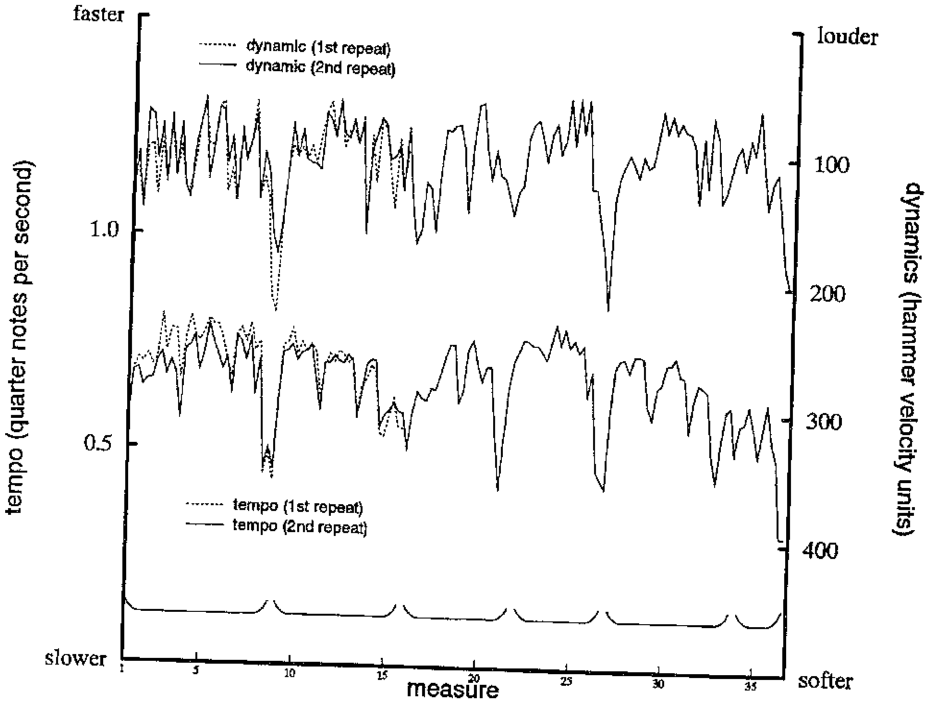

Fig. 4. Timing and dynamic patterns across the entire performance, including repeats.

amounts of slowing in tempo often occur at phrase boundaries, called phrase-final lengthening. Todd (1992) proposed an inverse relationship between performance timing and dynamics based on an energy model of movement dynamics; the slower an event the quieter it is, the faster the louder. Figure 4 shows the timing (in tempo units of quarter notes per second) and intensity (in hammer velocity units) at a fairly global level of timing, the beat level, for the melody (the soprano voice in most locations) across the entire performance (excluding ornamentation, which has no precise notated timing).[1] In contrast to Todd's (1992) work, which reports values averaged over chord tones that occur on each beat, only the melody tones that occur on each beat are measured here because the melody displays the greatest range of dynamics and timing. Figure 4 shows the predicted relationship (correlation across the entire performance = $-.53$, $n = 203$, $p < .01$); the more the tempo slows down, the quieter the note events are played.[2] The locations of greatest slowing and quieting are at major

1. In the absence of the soprano voice, the other tones present within that beat were used to determine timing and intensity values.

2. The signs of the correlations reported here are reversed from the relationships shown in the figures because Boesendorfer hammer velocity values are expressed in time/distance units (a larger velocity value denotes a softer dynamic level).

phrase boundaries in the movement, which are marked beneath the graph—the same locations marked as section endings by listeners in Krumhansl's study (this issue). Interestingly, the locations of largest change in performed dynamics (mm. 26–27) and tempo (mm. 8, 21, 26–27) correspond to locations of largest change in tension ratings in Krumhansl's perceptual study (this issue, Experiments 1 and 4).[3]

When we examine the timing and dynamic patterns at the local level of every melodic event, we see more variation. Figure 5 shows the dynamics (in hammer velocity units) and interonset durations (expressed in 16th notes) for the first eight measures of the melody, over both repeats (again, performed ornaments were excluded from this analysis). A correlation between the timing and intensity patterns across the entire performance reveals a weaker relationship at the note level ($r = .36$, $n = 607$, $p < .05$) than shown above at the beat level. The two repeats are remarkably consistent, both in timing and dynamics; correlations among the interonset timing ($r = .93$, $n = 173$, $p < .01$) and intensity patterns ($r = .81$, $n = 173$, $p < .01$) on a note-by-note basis suggest that the performer did not alter the interpreta-

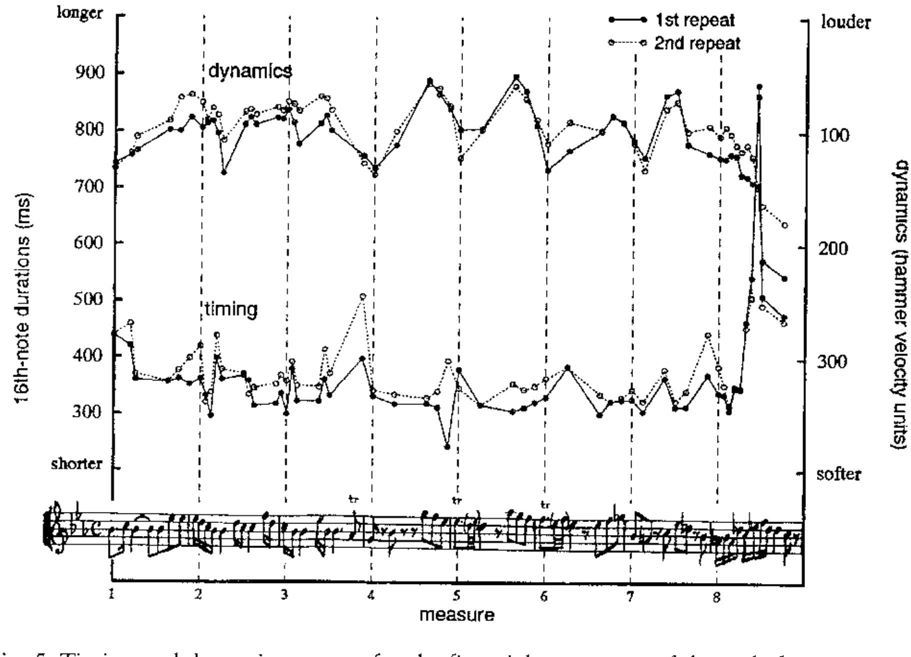

Fig. 5. Timing and dynamic patterns for the first eight measures of the melody.

3. The performance nuances were not directly contrasted with the perceptual ratings because of different measurement scales (listeners' ratings were recorded every 250 ms; the performance nuances were unconstrained except by the temporal resolution of the instrument).

tion or method of emphasis from one repeat to the next. As the expressive use of tempo and dynamics at the note level was highly consistent in this performance, the reduced correlation at the note level does not simply reflect more variability at lower (shorter) duration levels. Instead, the generalized relationship proposed between dynamics and timing holds best at the more global phrase structure level (Todd, 1992). There are, of course, many factors contributing to performance expression at the local note level that are not captured by phrase-structure relationships; some of these are discussed next.

Many local musical features influence expressive dynamics. Pitch height and melodic contour in particular shaped the dynamic pattern in this performance. Figure 5 indicates greater intensities at melodic contour peaks and lower intensities at contour troughs (as suggested in many editorial dynamic markings as well); a small but positive correlation was seen between the dynamic level of melody tones and their pitch height across the entire performance ($r = .12$, $n = 607$, $p < .01$). Dynamic emphasis at points of greater pitch height has been suggested by analysis-by-synthesis models (Sundberg, Askenfelt, & Fryden, 1983) and in empirical studies of pianists' performances (Drake & Palmer, 1993). I will return to the role of pitch height later in a discussion of music-theoretic influences on expressive use of dynamics.

Expressive timing of note onsets in this performance revealed vertical as well as horizontal influences. The synchronization of chord tone onsets (which are notated as simultaneous) reflected a tendency to lead with the melody (the highest-frequency voice shown in Figure 3). In previous studies of piano performance, the melody onset preceded other voice onsets in chords (notated as simultaneous) by 20–50 ms on average (Palmer, 1988, 1989), and listeners' identifications of melody were influenced by these differences (Palmer, 1988).

In the performance described here, most melody leads (defined as the difference between the soprano voice onset and the average of remaining chord note onsets) fell between –5 and 50 ms. However, the melody occasionally lagged behind other chord tones by large amounts; six melody lags were clearly distinguishable from the leads, the melody lagging an average of 100 ms behind the other chord tones. All six melody lags occurred in the same musical context: a melodic tone that was paired with harmonically dissonant simultaneities, occurring on a strong metrical beat, and resolving on the next event. For example, the first lag occurred at beat 3 of measure 7, where an E♮ is paired with an E♭. A strategy to delay the melody tone would reduce the acoustic dissonance resulting from simultaneously sounded tones. Although not all melodic dissonances were treated in this manner, all lags did correspond with dissonances, suggesting a performance strategy to attenuate dissonances arising from simultaneously sounded tones.

The average melody lead, excluding the six lags, was 25 ms. Thus, melody leads may have served to segregate the melody from accompanying voices, and melody lags, to reduce dissonant simultaneities.

PERFORMER-SPECIFIC EXPRESSION

Each performer has distinctive patterns of expression that contribute to listeners' preferences for different artists. One such characteristic that stood out in this performance was the treatment of rhythmic cadences. The peak in the timing pattern shown in Figure 5 corresponds to a lengthening of the last 16th note before the first half-cadence in the movement (at m. 8). There are three instances of this same rhythmic pattern preceding a cadence in this movement (in m. 8, first and second repeats, and m. 26), which the performer treated identically. Figure 6 shows the intensity and timing patterns (in 16th-note durations) at these locations. The consistency across instances is particularly striking. The last 16th note is lengthened much more than the others and precedes a drop in dynamics. This pattern is not simply part of a phrase-final lengthening; the following note events do not continue to lengthen. Perceptual studies document the increased salience of penultimate note events in rhythmic patterns such as these (Drake, 1993); this lengthening may serve to draw listeners' attention to the upcoming cadence.

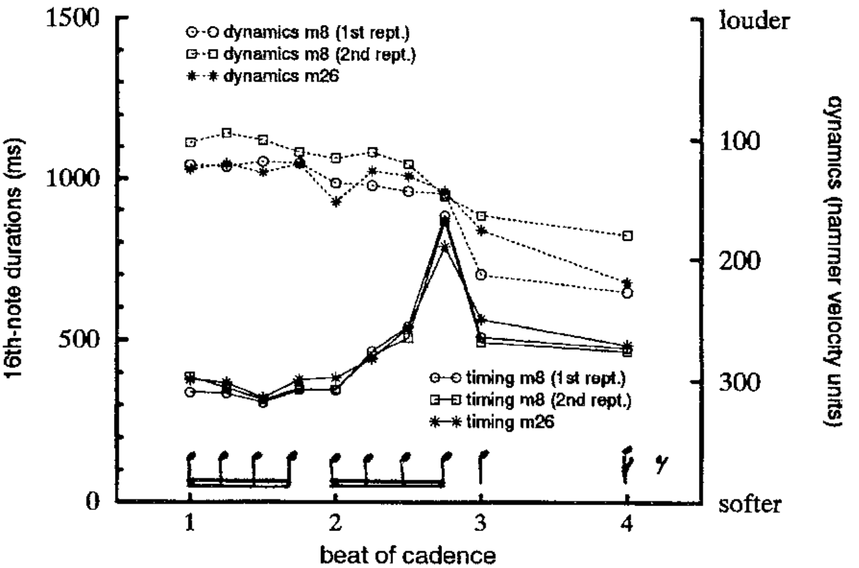

Fig. 6. Timing and dynamic patterns for three locations of the rhythmic cadence first appearing in measure eight.

Another expressive characteristic that is distinctive of each pianist is the use of pedaling. Despite large variations in pedal use, pedaling has not been the focus of empirical study (see however Heinlein, 1930, and more recently, Repp, in press). The damper (right) pedal allows strings to continue to vibrate regardless of which keys are depressed and thus connects events that otherwise would be detached. The soft (left) pedal shifts the entire keyboard action on a grand piano to the right, so that one less string per note is hit by each hammer, causing a reduced volume. In the performance described here, the soft pedal was depressed 24 times, and 20 of these coincided with a notated marking of decreased dynamics in most of the score editions.

The performer's use of the damper pedal was more complex. Figure 3 shows the damper pedaling during the first measure plus one beat of the piece. The pattern is quite regular; the pedal is lifted shortly before note event onsets and is depressed some duration after note events are sounded. How does the performer synchronize damper pedal depressions and releases with note events? Figure 7 shows the precision with which pedal changes are synchronized with the first sounded note event (melody tones) in each chord.[4] The temporal lag between the onset of each pedal change (depressions and releases) and the nearest note onset is shown in 7A, and the same relationship between pedal changes and note offsets (measured by key releases) is shown in 7B. The conditional probability of a note event occurring within some time lag, given a pedal change, is shown on the y-axis (the range of time lags, shown on the x-axis, was defined by the average 16th-note duration in this performance, 372 ms, so that a pedal change would not overlap with multiple successive note events). As Figure 7 indicates, the performer tightly synchronized pedal releases to occur before note onsets; most (40%) preceded a note onset by less than 50 ms. In contrast, pedal depressions were not as precisely synchronized with note onsets and peaked at 120 ms after a note onset. In contrast with note onsets, pedal changes were not synchronized with note offsets.

Why are pedal releases but not depressions synchronized with key presses? Given that the damper pedal functions to continue a sound, it is logical to synchronize pedal releases before note onsets, to prevent unintended dissonances across successive events. In contrast, there is no urgency to depress the damper pedal relative to note onsets because fingers typically continue to depress the keys for some time after a note event is sounded, until the fingers must move toward the next key presses. In summary, the pianist carefully synchronized the damper pedaling with finger movements, such

4. For cases in which contiguous pedal changes occurred in the same direction (depressing or releasing), and the later pedal changes were less than a quarter pedal (value of 64), the contiguous pedal changes were combined and coded as one pedal change with pedal depth equal to the sum of the components.

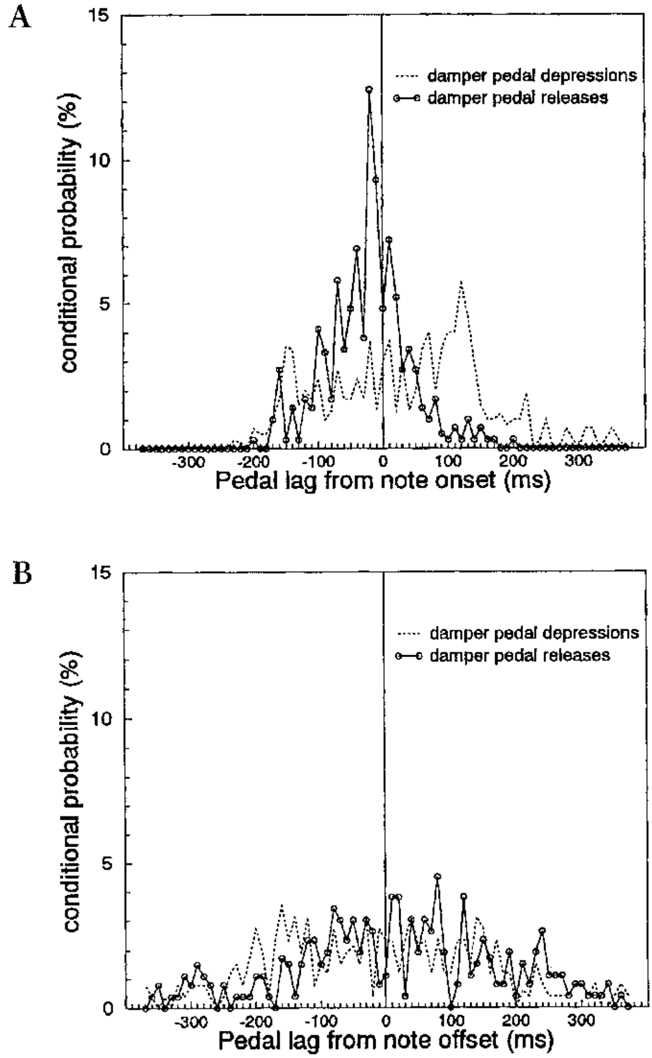

Fig. 7. Synchronization of damper pedaling (depressions and releases) with note events. (A) With note onsets. (B) With note offsets.

that the pedal was released within approximately 50 ms before the next note onset, and the pedal was depressed more variably in relation to note events. Thus, damper pedaling in this piano performance demonstrates fine-tuned coordination between finger and foot movements and an organization internal to expressive performance that does not arise from score-based information.

A final expressive characteristic that is often distinctive among performers is the treatment of ornaments; ornaments are stereotyped figures that have been substituted for or added to original notes in a musical voice. Originating in spontaneous improvisation, ornaments are often written in shorthand in a compositional score and thus leave room for interpretation. Ornaments in Mozart's music can be interpreted in several ways: they can tend toward anticipation, contain rhythmic ambiguity, and start on or off a beat. A common premise is that score-based factors such as dynamics, rhythm, and other notated information influence the interpretation of ornaments (Neumann, 1986).

Ornamentation in the K. 282 sonata consists primarily of appoggiaturas, which are typically performed on the beat or anticipated, and trills, which are typically begun from the diatonic second above the note and are followed by a turn. Some disagreement exists over whether appoggiaturas should be performed on or before the beats to which they are tied; appoggiaturas that are played before the beat can signal continuity and those on the beat can signal distinctness (Narmour, 1992; Neumann, 1986). In this performance, 23 of the 26 locations notated as appoggiaturas in the melody (including repeats) were played significantly early (on average, 189 ms before the left-hand events with which they coincided). The appoggiaturas that were performed on the beat occurred in measure 2 (twice) and in measure 36, the very beginning and ending sections of the movement.

The treatment of trills in this performance offers another example of internal organization to expressive performance that does not arise from an external source such as the score. One question of interest to psychologists is whether the durations of the parts of an ornament retain a proportional relationship across different tempi (do the parts retain the same relative timing?). Relational invariance is interpreted as evidence for a generalized motor plan that permits reproduction of the same movement pattern at different rates, such as different performances of the same music at different tempi.

The Mozart sonata contains several trill ornaments that offer flexibility in the relative timing of the parts. There are seven instances of the trill first seen in measure 5 in the movement. This trill contains two parts: the trill pair (the repeated alternation of a notated pitch with the pitch a diatonic second above it), followed by a notated turn. Although performance practice writings on Mozart's compositions recommend that ornaments be played as evenly as possible (Badura-Skoda & Badura-Skoda, 1962; Neumann, 1986), the number of repetitions of the trill pair is subject to the performer's interpretation and capability. We can ask: are the durations of the parts of the ornament proportional to each other across different tempi? Although there is some argument over the degree to which the relative timing of all musical events alters with tempo changes, some evidence suggests differences in performance timing of ornaments across tempi (Desain & Honing, 1994; Repp, 1994).

Figure 8 shows the relative proportions of the parts of the trill across different tempi (defined by the ornament's total duration). The proportional duration of the repeated trill pair (up to the turn) is shown on the y-axis, relative to the total duration of each ornament (trill pair plus turn) on the x-axis. The number of trill pair repetitions performed within each trill appears in parentheses. The proportional duration of the trill pair correlated highly with the total duration ($r = -.82$, $p < .05$); the best-fitting line is shown in Figure 8. The trill pair duration was proportional to the trills' total duration, across a range of 1–2.5 s and a range of trill-pair repetitions (8–11). That is, the pianist adjusted proportionally the length of the turn as well as the length of the trill as the number of trill pairs changed. The timing of ornaments in this performance displayed an internal structure that is striking in its consistency; this structure is related to the performer's choice of tempo and not to information given in the score.

Cultural/Cognitive Norms

The final source of expression I will address that transcends the musical score comes from the cognitive and cultural norms that listeners and performers bring to musical experiences. This includes stylistic patterns that

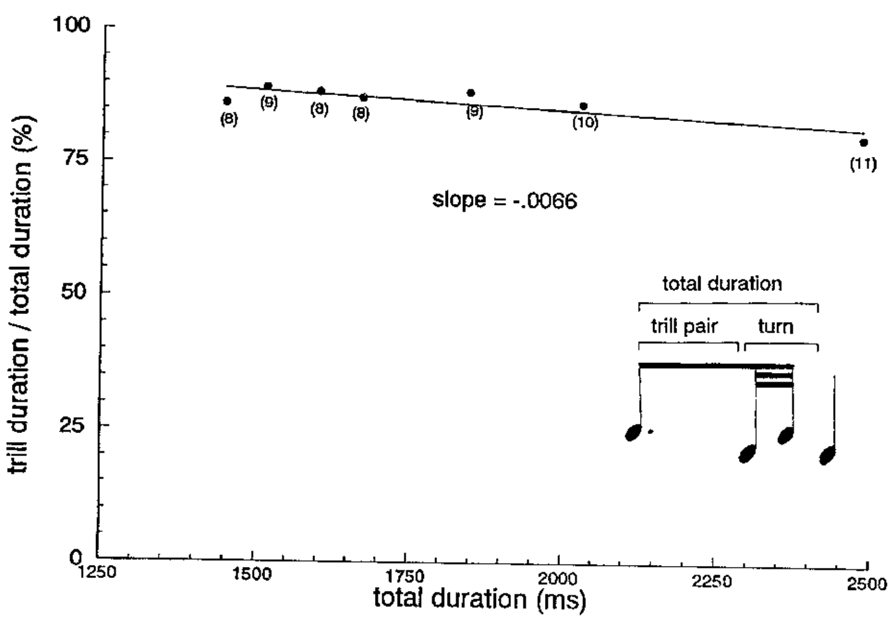

Fig. 8. Proportional durations of ornaments as a function of tempo (total duration) at which they were performed; number of trill pairs is shown in parentheses.

exist across musical works and expectations that arise from a particular musical context. Both music-theoretic and psychological theories of listeners' experiences have addressed the roles of expectations (Bharucha, 1987; Jones, 1976; Meyer, 1956; Narmour, 1990), schemata (Gjerdingen, 1988), and sensitivity to tonal idioms (Krumhansl, 1990; Lerdahl & Jackendoff, 1983). Yet little work has examined the role of these cultural and cognitive norms in performance expression. In the next section, I examine the Mozart performance in terms of two potential sources of expression based on norms proposed for Western music: music-theoretic predictions of tension-relaxation and melodic expectancy.

Music-theoretic and psychological approaches to listeners' musical experience contain factors that may not pertain to performance, and vice versa, and so perceptual predictions may or may not be verified in performance aspects. Nonetheless, if music communicates ideas between listeners and performers, then there may be some important performance correlates of the music-theoretic depictions of perceptual experiences. Again, I assume here that performance—not the score—is the best representation of music, and performers are likely to draw listeners' attention to the important event relationships depicted in these music theories.

I first compare expressive aspects of the performance with the music-theoretic predictions of tension and relaxation arising from harmonic relationships (Lerdahl, this issue). Lerdahl describes a model of the flux of tension and relaxation that one experiences in musical listening. Hierarchical tension is defined by the tonal pitch-space path between events in a prolongational reduction analysis (see Lerdahl & Jackendoff, 1983). The harmonic tension of each event is predicted from an additive combination of surface dissonance factors (scale degree, chord inversion, and nonharmonic tones in each event), pitch-space distance (in diatonic and chromatic circles of fifths), and the pitch-space distances of pitches hierarchically related to (inherited by) the current event. This model depicts tension values in terms of both perceptual (surface dissonance) and cognitive (pitch-space distance) factors, and so it may be applicable to some aspects of expressive performance. In particular, performers may emphasize positions of high tension more than positions of low tension.

The hierarchical tension-relaxation predictions for events in the Mozart sonata were compared with the tempo and dynamic patterns in the performance. Hierarchical tension values for each event are defined in terms of harmonic relationships with all events that subsume it (see Lerdahl, this issue, for further description). The higher the tension value, the greater the harmonic distance or difference between the current event and those around it. The hierarchical tension-relaxation measures (shown in Lerdahl, this issue, Figure 21) were correlated with the timing and dynamics of each melodic tone in the first eight measures from both repeats, with the exception of ornaments.[5] Although the tension values reflect contributions from all voices, the melody typically carries the greatest expressiveness in performance.

The tension-relaxation model did not correspond to the melody dynamics but did correspond to the timing patterns. A positive correlation between expressive timing and predicted tension measures ($r = .22$, $n = 108$, $p < .05$) indicated that the performer emphasized positions of high tension by lengthening them more than positions of relaxation. (The small correlation coefficients are in part due to the inclusion of both repeats, across which the music-theoretic predictions remain fixed but the expressive patterns are free to vary.) A multiple regression model, predicting expressive timing from the separate surface dissonance, pitch-space distance, and inherited pitch-space distance factors, also indicated a significant fit ($R = .29$, $n = 108$, $p < .05$); the inherited pitch-space distances contributed most to the correspondence with expressive timing.

Another expressive indicator of tension-relaxation in piano performance may be damper pedaling. Pianists typically manipulate the depth of damper pedaling to continue or smooth adjacent events by different amounts. For example, Figure 3 shows that the pianist sometimes used a full depression and release and sometimes used half-pedaling. Damper pedal changes often occur at harmonic changes that, if pedaled across, would cause dissonances. If the damper pedal is tied to points of harmonic change, we might expect a correspondence between depth of pedal change and amount of harmonic tension. The local tension measures for the melody, which are based only on surface dissonance and pitch-space distance (not including hierarchical pitch-space distances), were compared with the depth of pedal change (ranging from 0 or none to 255 or full) that occurred on or before each melodic tone in the two repeats of the first eight measures. A multiple regression analysis, predicting the depth of pedaling from the two local tension parameters, indicated that the performer changed the damper pedal more at points of predicted local tension (depressions: $R = .24$, $n = 116$, $p < .05$; releases: $R = .29$, $n = 116$, $p < .05$). Surface dissonance, not pitch space distance, contributed significantly to the depth of pedaling for both depressions and releases. This finding is in accord with the pianist's synchronization of pedal releases before note onsets, that avoid dissonances. Interestingly, the global tension values did not correlate with the pedal changes; only at points of predicted *local* harmonic tension did the performer tend to change the pedaling.

Narmour's (1990) theory of melodic structure also makes predictions for the listener's musical experience, incorporating bottom-up (style-transcendent) and top-down (stylistic) systems of expectation. Narmour's im-

5. For locations that did not contain the soprano voice, the expressive patterns for the highest-frequency voice were correlated with the tension predictions.

plication-realization model focused in part on local tone-to-tone expectancies in melodic continuation. General principles of perceptual organization influence melodic expectancy, including similarity, proximity, and common direction. The model describes a listener's cognitive response to melodic events as a succession of closures, implications, and realizations, and thus its predictions may be applicable to some aspects of expressive performance. In particular, performers may emphasize positions of high melodic change (where realization does not match implication) more than positions of low change.

I first compare the performance timing and dynamic patterns with the model's predictions of basic melodic expectancies (Narmour, 1990). Melody is conceptualized in terms of an additive combination of five parameters specific to pitch (interval size and direction). These include registral direction, intervallic difference, registral return, proximity, and closure (see Cuddy & Lunney, 1995; Krumhansl, 1995, for further information on coding). The performance intensity and timing patterns for the melody were compared with the predictions for that voice over both repeats of the first eight measures (the same musical section examined in the tension-relaxation measures), beginning with the second interval (third pitch). The melodic expectancy predictions did not correspond to expressive timing but yielded a good match with expressive dynamics. A significant correlation between expressive dynamics and the predicted melodic expectancy values ($r = .26$, $n = 104$, $p < .01$), indicated that the more the melodic realization deviated from its implications, the louder the performer played the notes. A multiple regression model, predicting expressive dynamics from the five individual parameters, indicated that all contributed significantly to the expressive dynamics except registral return ($R = .44$, $n = 104$, $p < .01$); parameters contributing most were closure (the less closure in interval direction or size, the louder the dynamics) and pitch proximity (the less proximal the pitches, the louder the dynamics).

Narmour's more recent model (this issue) extends the parametric predictions of melodic closure to each voice, incorporating parameters of harmony, duration, and meter. Closure values are predicted for each voice from an additive combination of bottom-up (melody, duration, harmony, bass position, and metric stability) and top-down (scale-step, chromaticism, tonal harmony) parameters (see Narmour's appendix, this issue). Closure is an important concept (both bottom-up and top-down) in this theory; closure refers to the termination or inhibition of implications created by preceding events. Lack of closure signals instability or change; thus, performers may emphasize positions of low closure more than positions of high closure.

The closure predictions for each voice were compared with the timing and dynamic patterns in the first three measures (both repeats). Only the expressive patterns of the soprano voice (melody) corresponded to the predictions; this may be a result of more events occurring in the melodic voice than in other voices in this passage (there were almost twice as many events in the melody as in other voices). Again, the timing patterns did not correspond well to the closure values, but the intensity patterns did; melodic intensity increased in positions of low relative closure (r =.40, n = 46, p < .01). Interestingly, the intensity patterns of the melody correlated even more strongly with the closure predictions summed across the three voices (shown in Narmour, this issue, Figure 27; r = .57, n = 46, p < .01), suggesting that the performer's use of expressive dynamics in the melody arises from a consideration of all voices.[6] These findings extend the correspondence reported between the basic melodic expectancies and expressive dynamics, further specifying the role of closure.

Why is tension-relaxation reflected in expressive timing and melodic expectancy in expressive dynamics? The two sets of music-theoretic predictions represent different psychological processes, as evidenced by a lack of correspondence between them (correlations between tension-relaxation and melodic expectancy predictions over the first eight measures were very low; r = .09, n = 52, p > .10). I offer two possible explanations here; the first is differences in the levels of musical structure that are captured by the theoretical approaches. The hierarchical tension-relaxation measures reflect influences of events from larger time-spans of the excerpt, whereas the melodic expectancy measures reflect only relationships between events and their immediate neighbors. That is, the hierarchical tension predictions incorporate both local and global measures of musical structure, whereas the expectancy predictions arise from local application of grouping principles.

A second factor is the roles that expressive techniques of timing and dynamics serve in music performance. Tempo rubato patterns are often viewed as indicative of phrase structure, a fairly global level of musical structure that can span large numbers of events, in contrast to dynamic expression, which often signals several kinds of local accents (cf. Drake & Palmer, 1993). Points of greatest tempo rubato reflected phrase structure in the analyses presented earlier (see Figure 4); phrase structure is an intermediate hierarchical level that is subsumed in the tension-relaxation measures and not in the melodic expectancy predictions. In contrast, expressive use of dynamics reflected local factors such as pitch height (see Figure 5), which contribute directly to closure predictions and only indirectly to tension-relaxation measures. These two explanations—levels of analysis and roles of expressive cues—are related; the use of expressive techniques may evolve in performance practice to reflect emphases on the different analytic levels that are represented by theoretical constructs of tension-

6. The relative contributions of the different voice predictions to the expressive dynamics could not be directly compared because of the varying number of voices at each location.

relaxation and melodic expectancy. Further work is needed to differentiate among sources of correspondence between performance and theory.

Conclusions

I have described several sources of expression in an expert piano performance that transcend traditional score-based explanations of performance. One source is notational variants on the same composition, which differ in the structural relationships they mark for emphasis. Another is performance-specific sources, including the synchronization of pedaling with note event onsets and the proportional durations of ornaments, which provide evidence for internal organization to expressive performance that transcends the coarse-grained information offered by scores. The final source of expression depicted here, from music-theoretic constructs of tension and melodic expectancy, suggests that performance and perception share a great deal and that performance is a more representative focus than scores for testing theories of listening.

These findings suggest that performers use expressive methods to elucidate their individual conceptions of the important relationships in a musical piece. The point of this case study is to demonstrate sources of expression beyond the score that contribute to performance. Two important consequences arise; the first is that music performance is more than an intermediary stage between a musical composition and its realization by the listener. This fact is not surprising, given that the phenomenon of using notated scores as a starting point for performance is only specific to certain cultures. Another consequence is that models of perception (which typically rest on score-based information) may hinge upon understanding the stimulus, the expressive performance, which forms the basis for most listening.

One impediment to overcoming the premise that performance simply clarifies the composer's message has been a lack of comparison between study of performance and music-theoretic and perceptual approaches to music cognition. Performance studies usually focus on fairly complex compositions that have not been the focus of many perceptual studies, and music-theoretic and perceptual findings are often based on either scores or score-like, quantized music. Studying one type of musical experience in isolation can, of course, be misleading. For example, listeners display biases in their interpretation of meter and melody in ambiguous musical settings, and performers' choices of how they accentuate those locations influence listeners' judgments (Palmer, 1988; Sloboda, 1983). Music-theoretic, perceptual, and performance-oriented examinations of the same musical piece, as in this collection of articles, offer an opportunity for direct comparison.[7]

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