David Epstein. *Shaping Time: Music, the Brain, and Performance.* New York: Schirmer Books, 1995.

Reviewed by Gary E. Wittlich[1]

David Epstein's *Shaping Time* is an engaging study dealing with various aspects of musical time, especially with tempo and tempo relationships. Divided into five parts and with nearly five hundred pages of text and more than eighty pages of extensive endnotes, the book is a sequel to his earlier *Beyond Orpheus*,[2] with considerable expansion of the issues of musical time raised there that he felt needed further study, chiefly "explorations of periodicity and phase synchrony as fundamental bases of time keeping" (5). As in his earlier study, the musical focus of *Shaping Time* is instrumental music of the Western classic/romantic tradition, with brief consideration of some early twentieth-century tonal works. The study is also informed by Epstein's participation in interdisciplinary seminars on biological aspects of aesthetics organized by the psychologist Ernst Pöppel at the Institute for Medical Psychology at the Ludwig Maximillian University in Munich, as well as by his study at the Max Planck Institute for Behavioral Physiology in Seewiesen, by his experience as an orchestral conductor, and by his study and discussions with the conductors George Szell and Herbert von Karajan. In his words, *Shaping Time* is

> . . . an inquiry into deep-lying questions about music, addressed to musicians and written via the perspectives and terminology intrinsic to music, perspectives enlarged by appeal to the brain and physiological sciences. (xii)

This review is divided into two parts, the first a summary of salient features of the successive parts of *Shaping Time,* and the second a

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[1]I wish to acknowledge the assistance of Dr. Lisa Kurz and Mr. Jay Hook, both of Indiana University, with whom I discussed a number of issues raised in *Shaping Time.*

[2]David Epstein, *Beyond Orpheus: Studies in Musical Structure* (Cambridge: MIT Press, 1979).

commentary on the issues raised in the book. All illustrations are taken from the book and are numbered as they appear there.

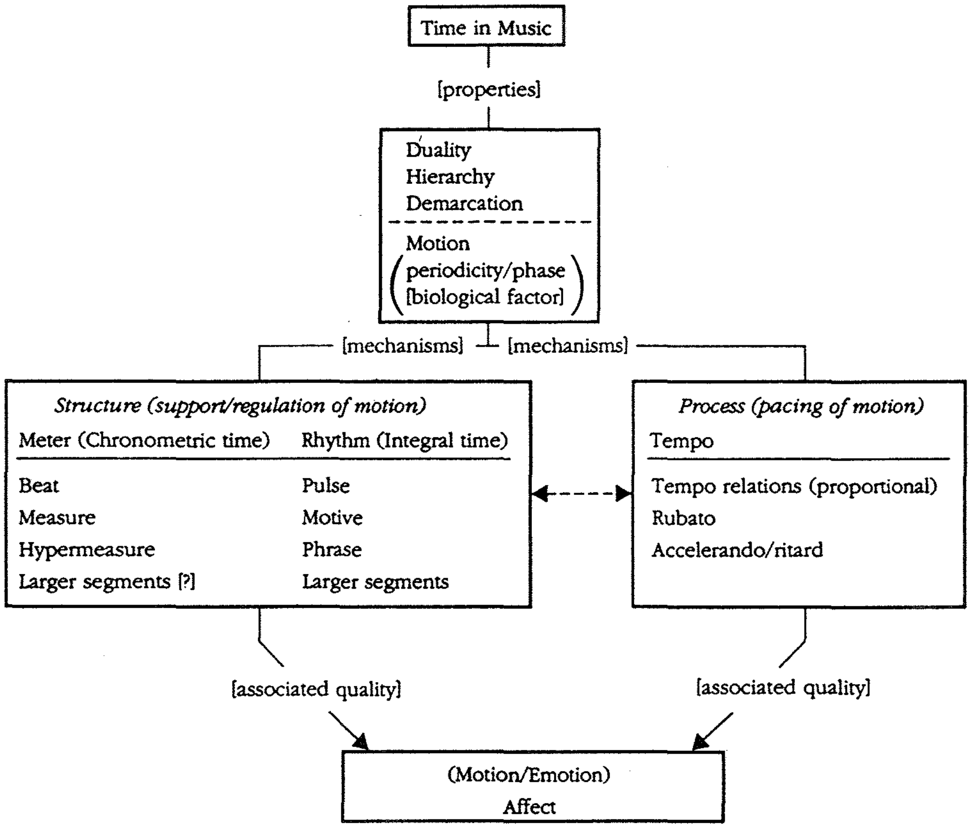
Part 1: Time, Motion, and Proportion (Chapter 1)

Part 1 of *Shaping Time* consists of a single chapter in which Epstein introduces his primary purpose: to understand musical motion, in particular to counter past treatments of motion that he regards as largely "phenomenological, descriptive, often subjective—not always with the most convincing results," characterized by imprecise language "at odds with ways by which scientific and theoretical inquiry in the modern world seek to view experience" (5). Rather, motion is discussed

> . . . in terms of its mechanisms—mechanisms of construct and mechanisms of control—thereby providing a bridge between structure per se, which has been the prevalent view of music for some decades, and the indefinables of affect that are closely related to the experience of motion and resist translation to the medium of words. This perspective integrates diverse aspects of music, particularly tempo, which is seen to be correlated with matters of rhythm and meter, articulation, harmony and line—aspects of music that have often been seen as issues in themselves. These musical elements are further seen as hierarchized. Yet more, they are shown to serve the broader function of supporting and controlling motion, a function that in turn is allied with what may be the ultimate goal of music, that of expression and affect. (5)

Epstein's point of departure is his model of time structure in music, shown below (fig. 1), which has its conceptual origin in *Beyond Orpheus.* The properties of musical time are essentially those of time in general. To be understood, time must be somehow demarcated (segmented) into durational units, which in turn are organized hierarchically. Duality denotes the co-functioning, potentially conflictive aspects of clocktime and experiential time. Their musical counterparts are the structural mechanisms meter and rhythm, which in turn are broken down hierarchically into those elements aligned beneath the

Figure 1. Epstein's model of time structure in music (p. 11)



Meter and Rhythm headings. Reflexively related to the structural mechanisms are the processive mechanisms that control pacing, including both tempo relationships and those aspects that alter continuity, namely, rubato, accelerando, and ritard. Most critical conceptually is that pacing of motion is served by tempo, which to Epstein implies structure, not *ad hoc* aspects of music determined by whim: "Failure to realize this may be one of the major causes of tempo confusion, of unsatisfactory choice of tempo" (11). Found throughout the book are numerous comments criticizing many, if not most, performances as being flawed in one way or another in the performers' approaches to tempo.

Rounding out the introductory chapter is a discussion of the role of analysis. Epstein acknowledges the role of intuition and its sufficiency as a basis for many performance decisions. Analysis becomes necessary, however, when things go wrong, when ". . . the elements do not seem to fit, or when performance speaks at odds with what the music seems to demand" (17). He acknowledges analytic debt to Schenker, as well as to others who have written on musical time and rhythm, though his analyses, especially his analytic symbology, borrow more in spirit than in detail from those writers. He calls for descriptive analysis and requires that the description must yield quantitative expression, for ". . . theory in the abstract, lacking measurable specificity, provides little beyond an intuitive sense of rightness by which we can assess its validity" (17). At the same time, he eschews prescription because it implies predictability and replication, which he believes are inappropriate to theory in the arts, the purpose of which is to

> . . . describe system(s), their structures and interrelations, [and] their usage. . . . Nothing would bore us faster than a musical system consistently and predictably used in exactly the same ways, down to the smallest detail. One of our highly prized values in music upholds just the opposite practice: The most creative composers work both with and against the constants of a musical system, by their inventiveness "upsetting" its consistency and thereby altering it, expanding is implications and its possibilities. (17)

Part 2: Rhythm, Meter, and Motion (Chapters 2–3)

The second part of *Shaping Time* comprises two chapters, the first of which is entitled "Thoughts for an Ongoing Dialogue" and is devoted essentially to elaboration of Epstein's time model, as well as to a review of issues of rhythm and meter dealt with by numerous writers in publications since the 1950s. His fundamental premise is that rhythm and meter are dual time systems that function in parallel and that are processed similarly, an idea that he finds compatible with current thinking in neurophysiology and cognition. Physiologically, macrolevel systems (cardiovascular, pulmonary, endocrine, renal, gastrointestinal, muscular, and neural) appear to function autonomously in some respects, as do some microlevel systems, among them aspects of the nervous system bearing on perception and cognition (41). Receptor cells, for example, receive and respond to the components within the acoustic spectrum in various ways, transmitting along various neuronal paths the data that are ultimately processed cognitively. Cited specifically in support of parallel processing is the work of neurobiologist G. M. Shepherd, who believes that our neural organization in effect provides different channels of transmission for different auditory stimuli, as well as work of Stephen Handel, who develops a similar notion, *stream segregation.*[3] Epstein does not, however, suggest that rhythmic and metric information is processed in the same way as are basic auditory stimuli, but rather that the parallel with such processing is suggestive:

> Certainly the processing that we believe to occur in discerning rhythmic/metric structures is on a high cognitive level. Like neural streaming, this processing involves a morphologically unified parameter—the temporal stream of music. That stream is not heard in fine-scale neurophysiological terms of frequencies and amplitudes alone, however. It involves additional perceptual frames concerned with phrase and metric quanta, concepts differing from lower-level neural mechanisms in their time scale and the complex nature of their musical substance. Parallel processing of these high-level parallel conceptual systems has yet to be proven. The neural and physiological bases for such processing, however, seem to be of fundamental function. (42)

The bulk of the chapter is devoted to further discussion of the structural and processive mechanisms in his time structure model, with a review of the contributions of other writers along the way, and with its focus primarily on metric and rhythmic ambiguity on middle and

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[3]Shepherd's book is *Neurobiology* (New York: Oxford University Press, 1983). The term channel has also been used by William Benjamin in a discussion of musical group classification to denote such musical parameters as melody, harmony, and texture. See "A Theory of Musical Meter," *Music Perception* 1, no. 4 (Summer 1984): 355–411, especially p. 377. Handel's book is *Listening: An Introduction to the Perception of Auditory Events* (Cambridge: MIT Press, 1989).

macro structural levels. His view is that it is a "forlorn hope" to expect to develop a theory that would resolve problems of ambiguity within musical structure. But he regards this as

> . . . a positive statement, not the tocsin of analytic doom. For ambiguity does not spell confusion, in the sense of chaotic organization. To the contrary, its multiple avenues of organization, their pluralistic interpretations and variegated perspectives, are the stuff of artistic vitality. Ambiguity is thus an index of creative depth, a guardian against perceptual ennui: Dittersdorf is pleasant to hear, and as easily put out of mind. Mozart continually fascinates; his ambiguity quotient is echelons higher. (47)

The second chapter of part 2 comprises analyses of excerpts from a number of instrumental compositions containing rhythmic and metric ambiguities, examining in particular how conflicts between the parallel domains of meter and phrase serve to create tensions that in turn influence motion characteristics of each excerpt. The first part of the chapter deals with phrases and segments within the confines of measures and hypermeasures, and the second deals with larger spans. As an example of ambiguity on smaller levels, he shows an excerpt from the first movement of Bizet's Symphony in C. After considering what appears to be a metrically anomalous beginning section, he uncovers a metric/rhythmic plan operating in much of the movement, the essence of which is that large-scale metrical groupings (hypermeasures of varying lengths) are offset from the phrases. What appear to be successive downbeats at the beginning, he suggests, are really downbeats of different characters, the first beginning the piece and helping to establish the meter of the movement, and the second serving a rhythmic role by articulating the first phrase. Another example from the symphony's last movement is discussed in terms of how static harmony accompanying a sixteenth-note perpetual motion leads to a tendency to take the tempo too fast if one fails to consider the articulation characteristics of the instruments involved. Here the character of the *vivace* tempo rather than sheer speed is determined to be the primary criterion for tempo choice (69). Other analyses follow of portions of works by Haydn, Dvorák, Mozart, Bach, and Brahms. A final example from Scriabin's Piano Concerto in F-sharp Minor is included to demonstrate what Epstein considers to be a compositional flaw in the form of a rhythmically unintegrated, hence unnecessary, ten-bar dominant prolongation within the coda.

Part 3: On Tempo and Proportional Tempo (Chapters 4–9)

This is the largest part of the book, comprising six chapters, all of which focus on tempo relationships. Tempo, according to the author,

> . . . exerts one of the most powerful controls in music, affecting everything that will occur in the performance—indeed, in a performer's conception—of a work. It is virtually a master control, for through the pacing of a performance (i.e., its tempo), all details of the music are unfolded in the critical dimension of real time. (97)

The choice of an appropriate tempo, however, tends to rest on personal authority, tradition, the score, and intuition, none of which Epstein believes to be fully satisfactory as a determinant.

Epstein's central thesis is that tempo relationships between different movements within a composition, or between different sections within a movement, are intrinsically related via a common pulse, and that the simple ratios 1:1, 2:1, 3:2, and 4:3 comprise the set of tempo relationships appropriate for most tonal music (101). Within his analyses, he occasionally finds other ratios, but he contends that the limit is 6:5 because phase synchrony is involved. That is, for ratios higher than 4:3, the time needed for pulses to create in-phase relationships generally exceeds the fundamental time frame within which the nervous system cognitively processes basic temporal units (discussed below on p. 111).

Chapter 5 reviews the concept of proportional tempo and continuous pulse through historical sources, as well as through recent writings. Of special interest in the chapter are the various tables drawn from historical sources listing standard tempo categories associated with measurements taken from devices such as metronomes, pendulums, and barrel organs, dating from the baroque and classical periods. While not all measurements illustrated demonstrate Epstein's preferred proportional relationships, in general the evidence supports his theory.

The sixth chapter is concerned with biological bases of proportional tempo. Just as tonal music relies on periodicity, so do humans rely on cyclic recurrence of events at regular intervals as they perform various actions, such as coordinating exercise routines with music or rhythmic counting, or coordinating breathing and gait while running. He reasons that if it can be shown that biological timing mechanisms play a role in regulating the periodic impulses that musicians know as pulse or beat, and if it can be shown that these mechanisms regulate pulse periodically, then a case can be made for biological constraints exerting musical constraints affecting how we conceive of, compose, and perform music (136). Evidence for this view is supported by a rapidly growing body of scientific literature.[4]

Key issues are periodicity, hierarchy, and phase, which he believes are the essence of musical time structures in classical and romantic music (137). He posits proportional tempo as essentially phased periodicity. Tempos in 1:1 relationship maintain their operative pulse in-phase, the beat remaining the same in both tempos. In a 1:2 relationship, the faster pulse nests within the slower one. In 2:3 and 3:4 tempo relationships, what remains congruent is not the pulse itself, but subpulses. Phase becomes particularly important in cases where the beat and the pulse become dissynchronous, as in rubato, which at times can extend to broad levels of structure comprising several phrases or sections. Control of time on broad levels, he believes, is the crux of high art, and that the basis of this art ". . . is biological at its core—the ability of our physiological system(s) to maintain temporal periods to precise and exacting degrees, and to coordinate these periods in complex interrelations" (137–38).

Much of the sixth chapter is devoted to research in brain science

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[4]As this review was being completed, I learned of a new World Wide Web site that purports to include links to some 55,000 neuroscience sources accessible via a sophisticated search engine. A quick search turned up some interesting sources related to music. The URL is: http://www.acsuiom.org/nsr/neuro.html.

that bolsters Epstein's ideas. While knowledge about how the brain processes temporal data is not codified, there are recurrent theories, among them (1) that the brain and nervous system appear to process information in the form of discrete quanta encoded as pulses of brief duration, much as a clock breaks up continuous time into discrete units; the parallel in music is that musical time must be demarcated in some fashion to be capable of functional use (138); (2) that temporal behavior depends on the periodic firing of neurons, many of which are adapted for specific purposes and which act in specific ways in their rate and mode of performance; the musical parallel is that music is bound to periodic order (139); and (3) that periodic, or oscillatory, behavior may be the fundamental dynamic mode of living systems and a basic dynamic mode of matter (139).

To perceive events, whether they be aural, visual, or tactile, as discrete and ordered requires a minimum processing time of some 20 milliseconds (ms), known as the *temporal order threshold*. Knowing the order of events is necessary to make sense of them. Pöppel has speculated that there is a *perceptual moment* within which we process time as subjective quanta, the critical frequency of which appears to be 30 ms, a time span that also represents a basic frequency at which tasks tend to be performed by the sensory and motor system (143). In a study of speech perception, he has shown that when a central oscillatory mechanism is entrained by external stimuli, the speed of information processing occurs at multiples of the central oscillation. Epstein contends that if the stimulus is musical, then pulse serves as a carrier wave and implications for proportional time keeping are obvious, though he acknowledges other research reporting that entrained oscillation frequencies are variable. Entrained oscillations appear to fit in phase with an oscillating central processing unit in cycles having periods of 30–40 ms, which fit within the period of an underlying central processing unit within a range of 2–3 seconds (the subjective, or psychological present). The relationship is thus hierarchic: shorter basic pulses fit within larger ones (e.g., two beats of an allegro movement fit within one beat of a slow movement tempo)[5] (146).

In chapter 7, Epstein outlines criteria for designating proportion and for acceptance of tempo differences as proportional. In his analyses, he employs metronome values (MM) and real time durations in both seconds (sec) and milliseconds (ms). While he discusses a variety of measurement techniques, including recent computer applications, he found that tape measurements provided him with accuracy to within 5 ms as he scrubbed the tape back and forth over the playback heads to assess precise attack points of sound.[6]

Epstein's criteria for assessing timing include three elements. First, he selects a 20-ms minimum for judging separate events (based on the perceptual moment), even though he considers it arbitrary and notes that evidence on which the criterion has been determined has been laboratory-based, "dull time" experiments devoid of musical contexts. Second, he borrows from the idea of a subjective present to determine a time frame of up to 3 sec for integrating separate events into coherent units. From these two bases arise larger, more complex time structures and interrelationships organized hierarchically (164–66).

His third criterion is the *Weber fraction,* which he uses to determine whether tempo relationships are proportional. This idea is based on work of the nineteenth-century physicist E. H. Weber, who investigated how great the quantitative difference in a given stimulus external to the viewer must be in order for that difference to be perceived (e.g., how much brighter a light must become in order to be recognized as brighter, or how much louder a sound must become to be recognized as louder). He found that different thresholds apply for different stimuli

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[5]For more information on rhythm in music and language and on entrainment, see J. Devin McAuley's dissertation, "Perception of Time as Phase: Toward an Adaptive-Oscillator Model of Rhythmic Pattern Processing" (Ph.D. diss., Indiana University, 1995), 1–12. McAuley also references some research on temporal perception in music too recent to be reported in *Shaping Time*. The document is available as Research Report 151 from the Indiana University Cognitive Science Program, Psychology Building, Bloomington, IN 47405.

[6]At a tape speed of 190.5 mm/sec (7.5 in/sec), 1 mm of tape converts to 5 ms of time (1/190.5=0.005).

and that the threshold in each system is not a number but rather a percentage of the stimulus itself. The difference tends to be about 5 percent on average and is called *Weber's Law* (or *fraction*). Other researchers later found that the Weber fraction applies for time periods ranging from about 250 ms to 2.0 sec, with the number being higher for timings both below 250 ms and above 2.0 sec. The Weber fraction thus represents a just noticeable difference (JND)[7] (167–68).

To account for internal timing activity, Epstein looks to the principle of reafference, essentially a process by means of which performers can adjust performance actions on the basis of feedback provided by the nervous system, although it is unclear whether cognitive processes or internal clock processes control such feedback. Research, again by Pöppel, suggests that subjects can learn to produce timing intervals to within an accuracy of 1 to 2 percent, which Epstein suggests provides some idea of the accuracy individuals can achieve in internally produced timings (168–70).

The focal portion of part 3 is the substantial eighth chapter, which is devoted to a study of tempo proportion assessments in more than twenty works by major composers from Mozart through Stravinsky, some discussions lengthy and detailed, others brief and general. His approach is not to compare extant recordings in terms of their specific timings but rather to consider works from the point of view of what he considers to be commonly heard tempos. Most of the works examined do not include MM markings, but in those works that do (e.g., Beethoven's Symphony no. 5, Schumann's Symphony no. 1 and Piano Concerto in A Minor), many do not fit with his proportional tempo theory. In these cases Epstein argues for alternative tempos, using score notation, commonly heard tempos, or problems with the metronomes of the time or with period instruments or players as supporting evidence. Epstein's reading of Mozart's Symphony no. 40 will suffice to demonstrate how he plies his analytic methodology to support tempo proportion in this and the other works included in the chapter.

In *Beyond Orpheus*, Epstein postulated an initial tempo for the

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[7]McAuley's dissertation, cited above, provides a good discussion of the Weber fraction, most of it in accord with Epstein's.

symphony of MM 80–84 (for the half-note) and determined that successive movements are related by simple ratios. In a review of that book, I found that in several recordings by reputable conductors, first movement tempos ranged from 100 to 110 for the half note, while last movement tempos ranged from 67 to 72 for the whole note. Moreover, while some of the movements within each performance demonstrated proportional relationships by simple ratios, those ratios did not hold generally.[8] Epstein now prefers a starting tempo at MM 100–104 for the half note, basing his choice on recent research by a variety of writers who worked from documents of the era and earlier, as well as on evidence he finds in the score.

In the examples that follow, to determine percentage differences between perfect and near-perfect ratios, the following formula may be used:

$$\Delta = \frac{[r \times t_1] - t_2'}{t_2}$$

(where t_1 = beat duration in tempo 1, t_2 = beat duration of the ideal tempo 2, t_2' = beat duration of the actual tempo 2, Δ = deviation, and r = one of the ideal ratios posited by Epstein) (518–19 n. 3). Thus a tempo relationship in beats/minute of 120:156 approximates a 4:3 ratio, with a t_2 of 160 and a Δ of 4/160, or 0.025 (2.5%), which falls within the 5 percent requirement of the Weber fraction. Epstein's examples 8.4a–i appear in order below with brief comments (183–93).

Epstein concludes his discussion of Symphony no. 40 by granting that numbers can be misleading and unrealistic because of their seeming certainty in defining relationships. In relation to example 8.4h below, for instance, he notes that it would be questionable to assert that listeners can actually hear and relate tonally unstable passages in terms of their timings and proportion. Yet,

> It is not unreasonable . . . to suggest that we do sense some meaningful proportion, some temporal connection between the two

[8]The review appears in *Music Theory Spectrum* 3 (Spring 1981): 150–57.

Figure 2. Epstein's ex. 8.4a: Incipits of the four movements with Epstein's suggested tempos and proportional relationships

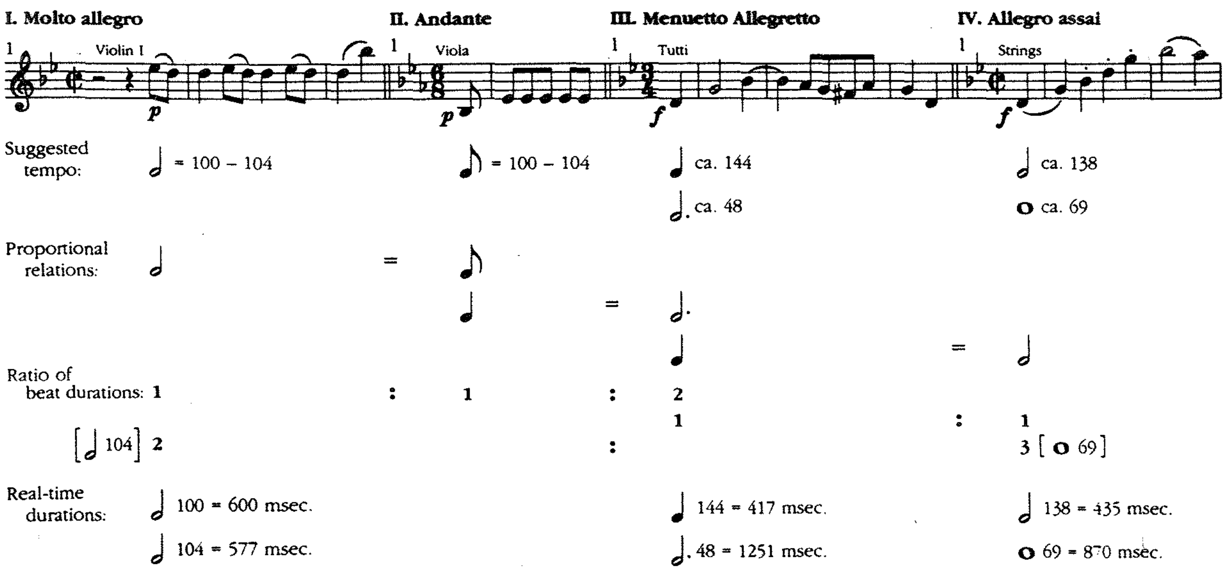


Figure 3. Epstein's ex. 8.4b: Motivic sixth interval and ms timings in movements 1, 3, and 4

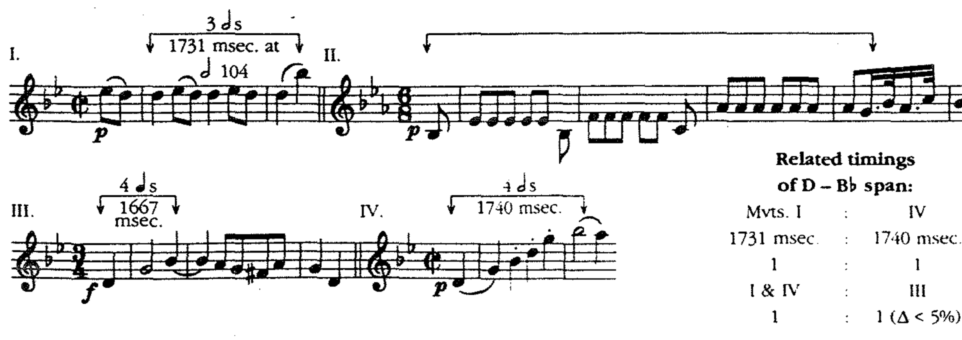
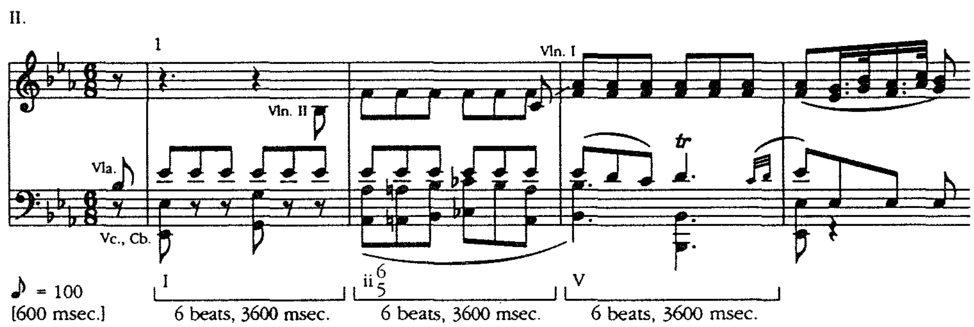


Figure 4. Epstein's ex. 8.4c: Timings of similar accompaniment patterns in movements 1 and 4, one of a number of relationships illustrating "corner movement" stylistic similarities (see especially ex. 8.4f–i)

Figure 5. Epstein's ex. 8.4d: "II-V" progressions in three movements and their timings

Figure 6. Epstein's ex. 8.4e: "I-II-V" harmonic patterns and their timings



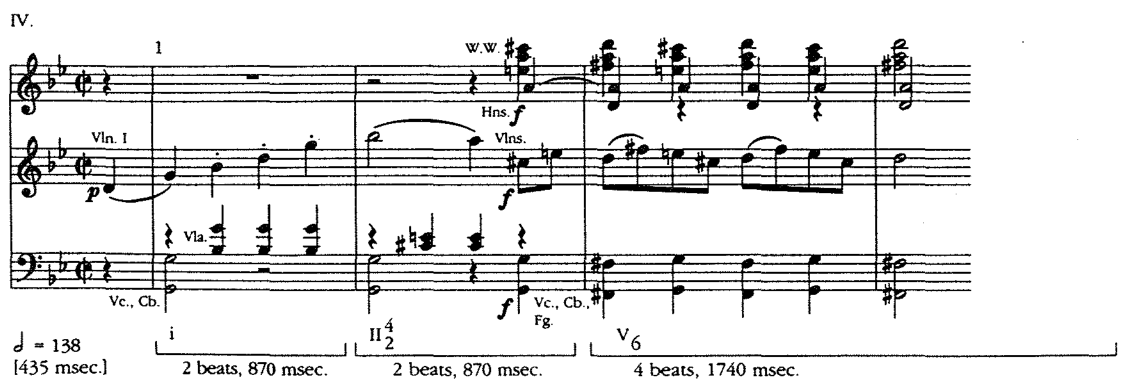


Figure 7. Epstein's ex. 8.4f: Comparable bass line spans in the corner movements

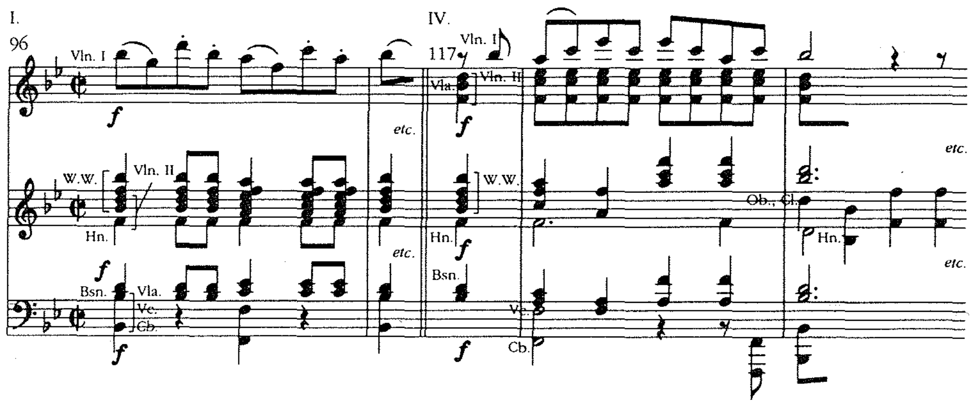
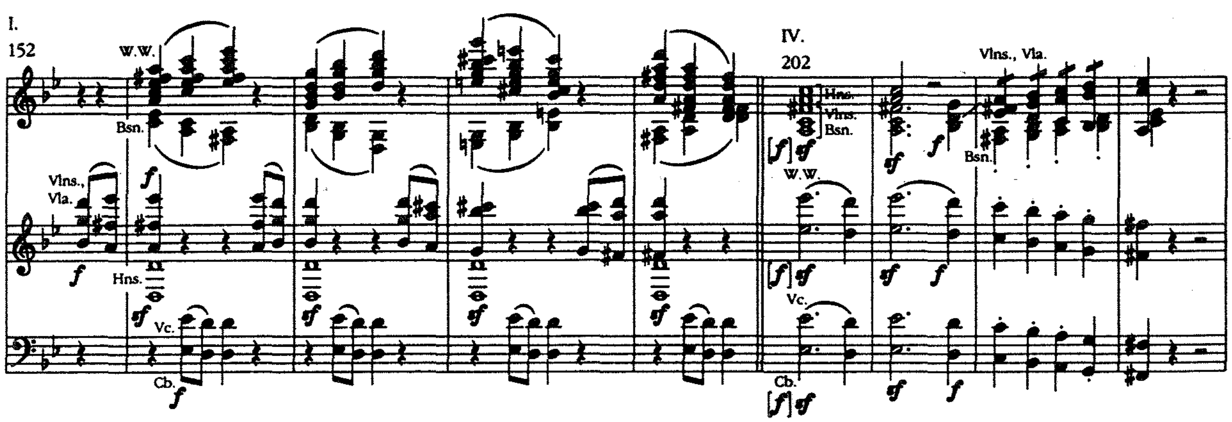


Figure 8. Epstein's ex. 8.4g: Similar dynamics and instrumentation in codetta sections closing expositions in the corner movements

Figure 9. Epstein's ex. 8.4h: Timings of similar chromaticism and exploration of remote regions in the corner movements

Figure 10. Epstein's ex. 8.4i: Similar approaches to recapitulations in the corner movements



> passages. . . . To point out the comparable character and durations of these particular segments is to specify in precise terms what we probably perceive in a more general way—two tautly related elements of the structure. (191)

Concluding part 3 of *Shaping Time* is a chapter that raises the question of whether proportional tempo relations are universal and offers supporting evidence in the form of improvised music collected by anthropologists on tape and film representing case studies from a variety of cultures from across the world. These studies include dance, ceremonial, religious, instrumental, and "bargaining" music from Africa, Tibet, Nepal, Venezuela, and New Guinea. These data all reside at the Max Planck Institute for Behavioral Physiology in Seewiesen, Germany. If, Epstein conjectures, the tendency toward periodic time keeping that underlies proportional tempo resides within our neurobiological and neuromuscular systems, then "could we not expect to find similar tempo relations in the music of other cultures, cultures distributed around the globe?" (337).

One particularly interesting example is the bargaining procedure exemplified by the Himou custom of the Yanomami Indians of Venezuela.[9] In the Himou custom, buyer and seller establish their positions through "contract-singing," a kind of antiphonal chanting in which the seller initiates a phrase echoed by the buyer. The seller's speech inflects very much like song with rhythmic patterns that are "virtually motivic" (345). As the seller, who always leads the alternation of phrases, anticipates an agreement, he becomes increasingly excited, the result of which leads to fluctuating speech tempos. From the "performance" studied, which covers some thirty-eight minutes overall, Epstein collected data representing some 143 tempo timings (beat durations) measured by a stopwatch, with each timing representing a point at which he perceived a tempo change.

From among various possible statistical functions to which the data

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[9]Epstein's article "Tempo Relations: A Cross-Cultural Study," *Music Theory Spectrum* 7 (1985): 34–71, is essentially an earlier version of the information presented in this part of *Shaping Time*.

might be fit, Epstein found the exponential curve to be the most appropriate one for characterizing the varying tempos over the course of the performance. He compares the 143 data points with time points predicted by an ideal exponential curve whose beginning tempo is that of the performance beginning tempo. While overall the data points show considerable discrepancy from the ideal, within the performance he finds several tempo plateaus, areas that he characterizes as time spans containing a beat that oscillates about an essentially steady pulse with only minimal change. When the plateau timings are compared, the values are much less discrepant and show proportional tempo relations. He concludes that the exponential curves and linear regressions to which the data fit

> . . . seem to confirm the intuition of many musicians that tempo changes, whether "irrational" or graduated by some calculus of change, take place within controlled or ordered limits. They function, in other words, in relation to some governing pulse. (349)

Part 4: Flexible Tempo (Chapters 10–13)

In this part of *Shaping Time*, Epstein concerns himself with flexible tempos, beginning with rubato and following, in order, with accelerando and ritard. In these chapters (the first of which is a brief introduction and the last a brief summary of some of the ideas presented in the book) he fits flexible tempo section timing data points to various kinds of mathematically determined curves.

In chapter 11, Epstein reviews the two common approaches to the performance of rubato: the classical "robbed time," in which certain melody notes were given more time while the accompaniment maintained a steady beat over relatively short time spans; and the broader, more encompassing romantic approach, in which tempo flexibility tends to dominate the entire musical complex and with greater distortion. Regardless of which view one ascribes to, rubato playing, like any other expressive playing in high art, requires control, lest the rubato become "spasmodic," thus meaningless (373). The duality of time (strictness vs. flexibility) and the artistic tension that skilled performers create are key:

> Phase dissynchrony and ultimate resynchrony seem the critical focus of rubato playing. What we feel so keenly, and what creates the tensions and excitement of what is a musical game played on a very high interpretive level, is the incongruity of two parallel but decoupled time systems that prevail throughout the musical passage. The return of these systems into phase triggers the release of tension, and with it our gratification for a musical game played with skill and artistry that lift the performance to a different level—the upper reaches of that musical Valhalla that is the province of elegant timings. (415)

To quantify rubato, Epstein defines a *ground* (also called *ground beat*) element to define metric control against which the more flexible pulse moves, distorted by rubato for expressive purposes.

> [A]s a general rule this resynchronization of beat and pulse lies within the extreme bounds of the phrase itself. It is at the phrase end (which in its timing is simultaneous with the attack of the next phrase) that the two systems realign." (373)

This is the nineteenth-century notion of rubato, his model for which has the following properties:

1. *Periodicity/phase*: This is the metric component that establishes the ground period underlying the full phrase or larger segment. For the phrase, the ground is the beat against which the pulse works, while for the larger unit, the ground may be a measure or a hypermeasure.

2. *Hierarchy*: Hierarchy here denotes levels of duration, of which there are three that he finds important in the three different compositions studied in this chapter: beat-to-phrase, phrase-to-section, and initial-section-to-total-piece. The in-phase relationship of an initial period to the overall segment is found to hold in each of the levels. What this means is that the proportions caused by

rubato, which commonly form shorter or longer overall timings than those implied by the notated proportions, when considered in terms of the ground unit (the "counting" unit, as it were), determine lengths that fit in phase in terms of integral, not fractional, units. That is, if the ground unit is a beat 1 second in length, then the total time taken for phrase will be some whole number multiple of the beat within an error of 10 percent. The 10-percent error size that he allows for phase fit discrepancies is based on the idea that biological systems are rarely exact and on his consideration of limits of perception over smaller spans extrapolated to create what he regards as a "tough standard" (377).

3. *Special features*: These are unique, generally smaller features (e.g., recurrent upbeat figures) that themselves display proportionally related timing features.

A final quantifying measure is what he calls *retained integral proportion*, which is established to determine whether the performance with rubato that alters proportions implied by the score notation is itself integrally related proportionally. For example, if the written proportion of phrase to ground segment is 6:1, a performed version relating the two units as 7:1 would be proportionally integral (378).

The case studies that Epstein includes in his rubato studies are two Chopin works—the Mazurka in A minor, op. 17, no. 4, recorded by Guiomar Novaes (Vox), and the Waltz in A-flat, op. 69, no. 1, recorded by Dinu Lipatti (Angel)—and one Brahms work, the Intermezzo, op. 76, no. 4, recorded by Walter Gieseking (Seraphim). A brief discussion of the Mazurka in terms of its periodicity and phase relationships will give a sense of Epstein's approach to the study of rubato.

His analytic procedure is straightforward. First, determine the ground beat in seconds; these "true operative beats" must be found by measuring values in the opening bars and are matters of judgement (388). Second, determine the overall length of the phrase in seconds. And third, divide the overall length by the ground beat to determine phase synchrony. If the number is within 10 percent of an integer, the fit is considered good. Ground beat units may differ from phrase to phrase and may comprise units of different lengths: a single beat, a whole measure, a hypermeasure, or a more complex segment, usually a motive. This he believes demonstrates the flexibility of pulse. In most cases, he finds the ground beat at or near the beginning of a phrase; for example, in the first phrase of the Mazurka, it is the first beat. Reproduced below (fig. 11) is his example 11.1a, the first twenty-six measures of the piece, followed by his examples 11.1d (fig. 12) and 11.1e (fig. 13), the latter of which defines the symbols used in the example. All phrases in the piece are eight measures long, with the exception of the four-measure introduction prior to the double bar shown in figure 11.

Figure 11. From Chopin, Mazurka in A Minor, op. 17, no. 4

In figure 12, the first row of the table within the beat-to-phrase relationships is read as follows: In section A, subsection a, the first phrase has a total performed duration of 13.512 seconds. The ground beat is determined to be the first quarter note of the phrase, .709 seconds. By dividing the phrase total duration by .709, one arrives at the number of ground beats within the phrase, in this case 19.0578, which deviates from the integer 19 by .0578, or 5.8 percent, and which thus falls below the 10-percent deviation criterion for integral fit. Thus, the interpreted phrase is five beats shorter than the notated twenty-four beats. As Level I of the table shows, only one of the fifteen phrases exceeds this criterion. All rows are read similarly, including the phrase-to-section (Level II) and section-to-total-piece relationships (Level III).

In the case of those ground units larger than a beat (see fig. 13), Epstein resorts to what he calls *hidden pulse averaging:*

> Despite their odd lengths, these units play the same role in the phrase as elsewhere, that of opening statement. Their lengths are a clue to a different concept of ground beat, however—namely a "hidden" pulse, one that hovers in the background, never explicitly stated but rather implied by the ways the nuances that inform the beat are shaped. It is thus suggested only, played with, played "around." (388)

He regards this kind of averaging as effectively a reversal of the smaller ground beat, which is stated initially but then in a sense becomes hidden as the phrase departs from it. In another example he shows that while the durations of the beats within the first two measures of the first phrase are all different, ranging from the ground (and longest) beat of .709 sec to a low of .517 sec, each of the first two measures themselves has a total duration of 1.732 and 1.645 sec, respectively, a difference of less than .1 sec. From this he infers that the opening ground beat exerts an averaging effect. This is not the same, by the way, as taking the total duration of the phrase and dividing by the number of beats, for that would be self-fulfilling and would have little to do with what he considers to be a truly operative beat (388).

Figure 12. Epstein's ex. 11.1d: Rubato-phrase relationships in Chopin's Mazurka, op. 17, no. 4

(1) Section	(2) Phrase No.	(3) Phrase Dur. (sec.)	÷ (4) Ground Beat of Phrase (location in phrase)	(4) Ground Beat of Phrase Dur. (sec.)	= (5) Phase Sync. (Phase Fit) (no. of ground beats in phrase)	(6) Δ	(7) In Sync. (✓ = yes)
LEVEL I (Beat : Phrase)							
A a	1	13.512	♩	.709	19.0578	5.8%	✓
	2	15.307	𝅗𝅥.	1.381	11.08	8%	✓
	3	14.709	♩	.614	23.96	4%	✓
	4	17.001	I	3.402	4.997	0.3%	✓
b	5*	13.743	mm. 3–4	2.803	4.9	10%	✓
a'	6†	14.761	m. 2	1.638	9.01	1%	✓
	7‡	16.976	2♭	4.331	3.92	8%	✓
B	8	11.066	𝅗𝅥.	1.57	7.05	5%	✓
	9	10.504	𝅗𝅥.	1.49	7.05	5%	✓
	10	10.22	𝅗𝅥.	1.286	7.95	5%	✓
	11	12.373	2♭	2.499	4.95	5%	✓
A'	12	15.302	♩	.661	23.15	15%	?
	13	17.927	♩	.85	21.09	9%	✓
CODA	14	13.213	𝅗𝅥.	1.906	6.93	7%	✓
	15	14.714	♩	.667	22.06	6%	✓
LEVEL II (Phrase : Section)							
A	(phr. 1–7)	106.009	Phr. 1	13.512	7.845	15.5%	?
B	(phr. 8–11)	44.163	Phr. 8	11.066	3.991	0.9%	✓
A'+ CODA	phr. 12–15	61.156	Phr. 12	15.302	3.997	0.3%	✓
LEVEL III (Section A : Total Piece)							
Piece		211.328	Section A	106.009	1.993	0.7%	✓

Summary

Level 1—14 of 15 phrases (93.3%) are in-phase (Δ ≤10%)
1 of 15 phrases is marginally in-phase (Δ = 15%)

Level 2—2 of 3 phrases are in-phase (Δ = 0.9% and 0.3%)
1 of 3 phrases is marginally in-phase (Δ = 15.5%)

Level 3—1 of 1 phrases is in-phase (Δ = 0.7%)

* Phrase 5, with its new theme (section b), begins in rubato—i.e., the first segment (mm. 1–2) is played in "held-back" fashion. A *tempo* is reached by mm. 3–4, the second segment of phrase 5, which fits the total phrase duration in-phrase, as seen on the chart. Further confirmation that segment II (dur. 2.803 sec.) is in tempo is found in phrase segment III (mm. 5–6), for it is exactly the same tempo.

Internal subdivisions of phrase segments II and III do not further explain the timings of the phrases. That is, neither the durations of m. 3 (1.354 sec.) nor m. 5 (1.575 sec.) are integral with the respective phrase lengths. Thus it is the overall durations of these similar segments that are significant, and seen as the ground beat of the phrase.

† Phrase 6, a return to the principal theme (a'), begins slowly (i.e., in rubato; its duration 2.184 sec.). A *tempo* is reached by m. 2 (1.638 sec.).

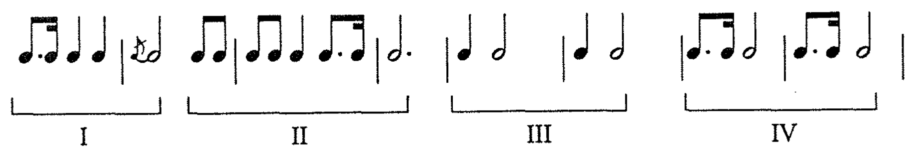
‡ A point of further interest: The closing phrase of section A (phrase 7), despite the notable ritard in its fourth segment, is marginally if not fully in-phrase in two respects, as shown below:

Phrase Dur.	Ground Beat	Phase Sync.	Δ	In-Sync.
16.976	[𝅗𝅥.] 2.157	7.87	13%	✓ (?)
	[I] 3.307	5.13	13%	✓ (?)

Figure 13. Epstein's ex. 11.1e: Key to symbols used

♩ = 1st ♩, m. 1 of phrase
𝅗𝅥. = m. 1 of phrase
I = phrase segment I } See below
II = phrase segment II }
m. 2 = measure 2 of phrase
2 b = 1st 2 bars of phrase
2 m = 2-measure group (symbol used only in sections b, B, and Coda)

Phrase segments, Sections A and A' ‡



‡Note: Rhythmic variants follow the same segmentation.

In his twelfth chapter,[10] Epstein considers ritards and accelerations: "Ritards and accelerations are among the most intuitive acts of musicians. They are not among the most accomplished events in concert halls, however" (417). The case studies in this chapter take as a point of departure a model with three properties:

1. *Integral boundaries*: Accelerations and ritards do not proceed toward *ad hoc* goal tempos but rather join with tempos that are presumably predetermined, meaning tempos that relate in terms of Epstein's preferred ratios.

2. *Cubic curve*: The intrinsic shape of accelerandos and ritards

[10]This chapter is co-authored by Jacob Feldman, a doctoral student in Brain and Cognitive Sciences at MIT. A mathematical version of some of the information in this chapter appears as a co-authored paper by Feldman, Epstein, and Whitman Richards entitled "Force Dynamics of Tempo Change in Music," *Music Perception* 10, no. 2 (Winter 1992): 185–204.

described mathematically in terms of their timing data points tend to fit with the definition of a cubic curve, and at times, a cubic spline,[11] which reflects the kinetics of limb and joint movements and hence reflect natural physical tendencies. Moreover, cubic curves have a property such that given the beginning and end points and their slope, there is only one trajectory that can be drawn between these points to fit its mathematical description, which lends uniqueness to the curve. In his final chapter, he suggests that the cubic spline may represent something of a timing template with which we "inevitably compare the actual curve [implied by hearing the initial tempo points as a ritard or an acceleration commences] being performed" (482).

3. *Special features*: A good composition embraces a unique structural plan which must be determined if the study of tempo modification is to be seen in context.

The naturalness of the cubic curve is mirrored in human actions, in which changes are generally characterized by smooth rather than by jerky motion—for example, the smooth, graceful motions that characterize most skilled dancers and athletes. Hence there is a sense of aesthetic pleasure associated with this curve. It may also be related to a neural syndrome that tends to favor motions of graduated character, which motions conform to the cubic curve (420). Epstein's analogy for this kind of curve, especially the idealized cubic spline, is a roller coaster that gradually increases speed from the top of its tracks into its descent, then gradually slows as it reaches the bottom of its travel and rises again in its travel to its next descent.

Among his case studies are works by Dvorák, Stravinsky, DeFalla, and Tchaikovsky, the last of which is discussed briefly below. The performance Epstein studies is the first movement of Tchaikovsky's Symphony no. 4, recorded by the Vienna Philharmonic Orchestra and conducted by Herbert von Karajan (DGG Digital Cassette).

[11]A cubic spline is an "S" curve. A cubic curve may be thought of as an incomplete form of a cubic spline.

Epstein's attention is directed to mm. 138–63, the "temporal anatomy" of which is charted in his example 12.7a, shown below as figure 14. This is the transition between the secondary and closing theme groups in the exposition of the movement, which includes a fifteen measure continuous acceleration marked *poco a poco stringendo al . . .* , mm. 7–22 in the figure. The accelerando recovers the original tempo near the end of the excerpt after the slower second theme.

From the Notes portion of the chart, it can be seen that Segments I and III, the "steady state" portions of the example, are integrally related by a 3:2 ratio derived by comparing the average measure durations of Segment I (that is, Tempo II of the movement) and Segment II (the original Tempo I). The averages shown at the top of the graph denote proportional changes between successive beats, determined by dividing the duration of beat 2 by beat 1, that of beat 3 by beat 2, and so on (422). These are shown in the Notes in terms of standard deviations, which he then divides by the means in order to show the degree of "spread" of the data from the mean and from which one can judge the goodness of fit (555–56 n. 6). The fit to the cubic model is determined by means of a cubic polynomial equation as a prediction of the duration of each beat in a ritard or acceleration time series. The goodness of fit is expressed by the symbol R^2, which denotes the square of the correlation between the value predicted by the cubic regression equation and the actual data. All computations were performed by computer (556 n. 7).

Figures 15 and 16 below show how the data fit to cubic curves. In figure 15 (Epstein's ex. 12.7b), only the data within mm. 7–22 (fig. 14) are included. As the example illustrates, only the upper "bump" of the ideal cubic (S) curve appears, the rounded bump indicating a smooth deceleration preceding the acceleration with a high correlation of .943. To complete the cubic curve, Epstein then adds the data from mm. 22–23 of the excerpt, the portion that appears at the beginning of the return to Tempo I but prior to the climactic *fff* indicated by the composer at m. 24 of the excerpt. The addition of these data complete the cubic curve as shown in figure 16 (Epstein's ex. 12.7c). Epstein suggests that adding these data to complete the cubic spline is logical, for the closing theme does not arrive until m. 24, concurrent with the

Figure 14. Tchaikovsky, Symphony no. 4, movement 1

Seg. I (steady state) (av. = .977) | Seg. II (*accel.*) (R^2 = .943)

Proportional change:		.98	.94	1.07	.97	1.01	.89	1.02	1.03	1.03	.98 .97
Bar pulse: (sec.)	3.466	3.381	3.192	3.402	3.289	3.307	2.932	2.997	3.076	3.155	3.102
Bar:	1	2	3	4	5	6	7	8	9	10	11

NOTES

1) Integral boundaries: Tempo II (average bar duration): Tempo I (average bar duration) = 3.3395 sec. : 2.1894 sec. = **3 : 2** (Δ 1.66%)
2) *Accel.*: Cubic fit index: R^2 (Seg. II) = .943
3) Steady state indices: a) Tempo II av. (average bar-to-bar proportional change) (Seg. I) = .977 (St. D. = .0612; Var./mean = 6.3%)
   b) Tempo I av. (average bar-to-bar proportional change) (Seg. III) = .995 (St. D. = .088; Var./mean = 8.8%) [N.B.- Small data base]

Seg. III (steady state) (av. = .995)

.95	1.08	.9	1.04	.96	.96	.96	.92	.99	.96	.998	1.04	.87	1.07	
3.016	2.871	3.097	2.787	2.892	2.78	2.656	2.546	2.339	2.32	2.231	2.226	2.32	2.018	2.152
12	13	14	15	16	17	18	19	20	21	22	23	24	25	26

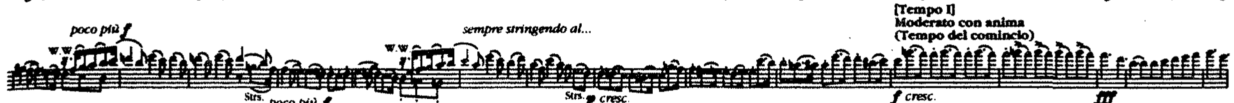
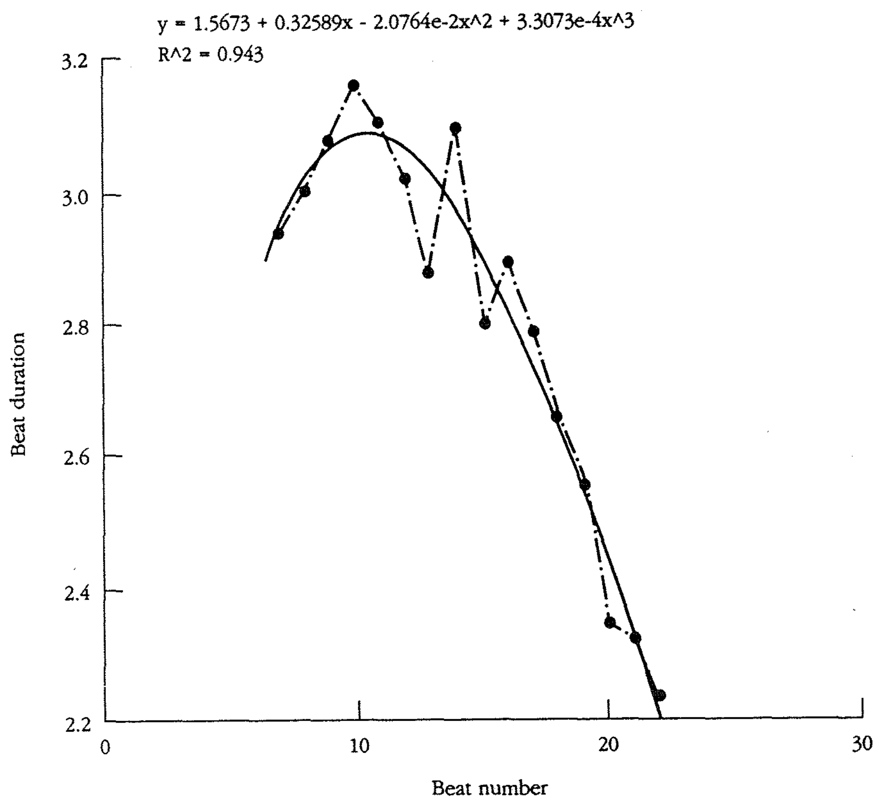


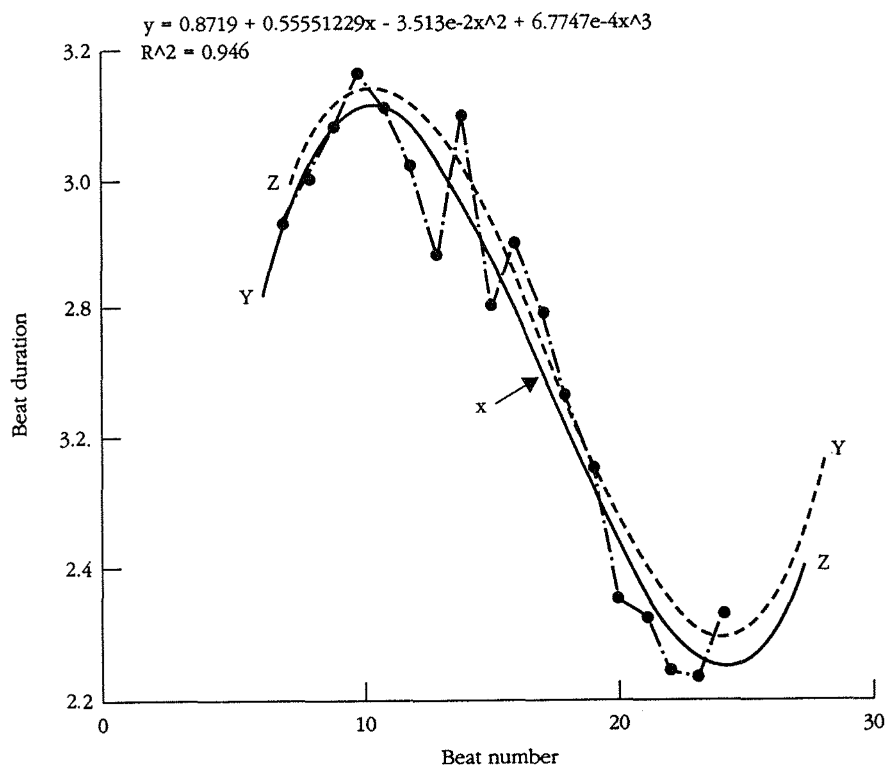
Figure 15. Tchaikovsky, Symphony no. 4, movement 1



climactic dynamic marking. Their inclusion also jibes more, he contends, with what may have been the conductor's concept of the passage and what Epstein regards as "greater fidelity to artistic concept" (434).

The graph in figure 16 shows a solid line for the cubic curve fit to the data of the performance. The beginning, midpoint, and endpoint are marked as Y, x, and Z, respectively, with the midpoint serving as an axis of symmetry, which is a characteristic of such curves. The dotted line is included to show that rotation around the axis of symmetry produces a mirror of the curve. This reflects research on kinematics of motor movements, the essence of which is smoothness of coordination that minimizes jerkiness in trajectories of motion between points of equilibrium (435). With respect to the performance of this passage, Epstein notes that von Karajan was long intrigued by issues of musical

Figure 16. Tchaikovsky, Symphony no. 4, movement 1



time and that according to the conductor's remarks, von Karajan developed an inner sense of pulse that allowed him to play with the time in subtle ways to manipulate tempo (as fig. 14 demonstrates), yet with overall control to produce artistic results. In Epstein's words,

> Very likely the paradigm [the cubic curve model of ritard and acceleration] in this instance is intuitively felt, as are the steps away from its core quanta. Yet its controls are at work. The line that separates the intuitive from the analytical, the felt concept from its quantized cognition, is often hazy. The mind seems to oscillate between the two modes, rapidly so in the moments of truth that are performance. Yet the model prevails. Without it we have artistic chaos. (438)

Part 5: Epilogue (Chapter 14)

The final part of *Shaping Time* is called an epilogue and comprises a single chapter on affect and emotion. Yet Epstein regards the chapter as a focal goal of all that precedes it in terms of emphasis on motion and tension. Hermeneutic in character, the chapter deals with affective aspects of parts of Debussy's *Nuages*, Mendelssohn's *Fingal's Cave,* Wagner's *Tristan und Isolde,* Mozart's Piano Concerto in D Minor, K. 466, Beethoven's Symphony no. 9, and Mahler's Symphony no. 1. A brief consideration of his treatment of the Mozart concerto will suffice to give a flavor of the chapter.

Epstein begins by tying affect to key, noting that Mozart wrote few works in D minor and that his works in that key (the unfinished *Requiem*, for example, and parts of *Don Giovanni*) suggest an association with depression and gloom. He speaks of a sense of entrapment and struggle in the concerto, both of which he sees as structural analogs of affective content. To enhance affect, he suggests changing the way the opening materials of the concerto are usually performed by the strings. Instead of playing the repeated D minor triad in the upper strings somewhat detached, he suggests playing legato and *sul tasto,* the latter to avoid any possible brightness of sound. For the motive in the lower strings, he suggests differential dynamics such that the basses will be somewhat louder than the cellos. "Heard this way, an entirely different piece appears, music haunted, somewhat depressed" (468).

Tonally, the entrapment/struggle paradigm is represented at the outset by two phrases that appear to break free from the key of D minor but that in fact are prevented from doing so by a third phrase "stated aggressively in a *forte* context at m. 16" (471). Within the passage, rising harmonic tension in mm. 9–12 contributes to affective tension,

> . . . which inheres in a sense of incremental forward motion and small degree of rising dynamics—qualities whose denotation by obvious symbols like crescendos or hairpin swells were eschewed by the Classical style. The incremental tensions persist, in fact increase,

> leading through the top of the melodic line (m. 14) only to recede with a sense of resignation as the music falls back into D minor. (471)

Another passage (mm. 33ff.) has a similar plan with still wider ramifications, for it appears in the area of the second theme group within the instrumental exposition and then later is used with a derived theme for what he designates the second-group theme in the solo exposition. Placement of themes in the instrumental exposition outside the tonic was not typical for Mozart, who tended to save the ". . . color, excitement, and tensions of more remote keys for the music of the solo instrument" (471). Epstein notes only one other exception in the concerto repertory (K. 449, in E♭).

More examples follow demonstrating the idea of struggle in the concerto. He notes "virtually physical, slashing motions of the strings in the triplet figures . . . that invoke the feeling of fighting against confining bonds," as well as a harmonic struggle created by progressions through "satellite" harmonies, yet pulled back into D minor.

> D minor is not just prevalent; it is an immovable force. . . .
>
> This sense of struggle affects the way one plays the passage. Without such a concept the *forte* may be just another *forte*, the articulations just another set of marked staccati, the progressions merely a set of largely conventional chords in minor key. Played within the framework of struggle, these factors assume greater dimensions, different connotations, all of which inevitably come out in ways words cannot depict. (473)

Throughout his discussion of Mozart's concerto, and indeed throughout the chapter, Epstein is concerned with reconciling the structural with the affective and showing how viewing one affects one's view of the other. About one passage (mm. 98ff.) he comments that the struggle to escape from D minor is heightened by chromaticism in the solo materials and by a dominant prolongation (mm. 108ff.) that virtually imprisons the music:

> [S]tructure is enriched by an awareness of the affective purpose to which it is put. A positivist/structuralist view of this passage would validly focus upon the predominance of dominant harmony, as well as the increment of the V-i harmonic rhythm within the last three bars. The fuller picture reveals the effect of this passage—an intensified sense of struggle, the impossibility of escaping the confines of D minor. Seen in this perspective, the quickening of the harmonic rhythm at the close of the phrase is more than technical manipulation; it is the final stage of a heightened frustration, a maximizing of the sense of imprisonment. That awareness must inevitably affect the way these bars are played—their articulation, dynamics, pressure of forward motion—in brief, their total musical context, as seen by both soloist and orchestra. (477)

Finally, he comments on the difficulty of accounting for affect in narrative language or by means of symbology, noting that the affect of an art work is unique and impervious to translation across media, but that in reality translation is not necessary. His comments provide an encapsulation of much of what *Shaping Time* is about:

> What is crucial is that our affective concept itself be shaped and precise. In the search for an intuitive grasp of music, it is helpful to recall not only the fused state in which affect and structure exist, but the role that motion plays in this fusion. More often than not it is the nuances of motion that effect, modulate, and ultimately control musical affect. To grasp affect, then, we may well look to motion; to shape affect, we must shape motion, which means control of its pertinent mechanisms. (477)

Commentary

On tempo proportion

Choice of an appropriate tempo is no doubt one of the most important decisions a performer has to make, for the pacing of events is critical to understanding their functional relationship. Epstein's lengthy part 3 presents a good deal of historical and analytical evidence to support his theory of intra- and inter-movement tempo relationships by simple ratios within tonal music. It is true enough, as he contends (99–100), that tradition provides a faulty basis for musical performance decisions. But despite his generally persuasive, in many cases fascinating, analyses, the question is begged why he did not resort to empirical research by assessing timings in extant recordings rather than to base his analyses on his judgement of commonly heard tempos, especially since many of the recordings include performances conducted by authorities he recognizes, for example von Karajan and Szell, the latter of whom served as his mentor during a fellowship with the Cleveland Orchestra in the 1960s.

A number of other questions are raised by his presentation, among them the following:

1. If phase is critical to temporal proportion, then should pauses between movements in a work be timed so that the pulse of the next movement is in phase with the pulse of the previous movement? It is questionable whether conductors consciously time the pauses between movements or that they intentionally relate a previous movement's pulse with that of the upcoming movement. I discussed Epstein's proportional theory with four conductor colleagues, all of whom have had extensive instrumental conducting experience. While two of them acknowledged that there are some works in which musical evidence strongly suggests proportional relationships, in general they say that they do not plan their tempos consciously in terms of proportions, simple or otherwise.

2. If the psychological present extends to less than three seconds, then since pauses between movements are commonly longer than three seconds, will listeners be able to retain the pulse from the previous movement and relate it to the following? If our body is entrained well to a pulse, then we may be able to remember it over a considerable time span; think of a melody that gets into one's head and is hard to forget. But once a subsequent movement gets underway, particularly if its materials are not obviously linked with those of a previous movement, my experience suggests that we

concern ourselves more with the pace at which the details of the music being heard unfold than with how they unfold in relation to those of the previous movement(s).

3. Does the quantification that Epstein provides in his analyses validate tempo proportion as the basis for tempo choice and relationships within musical works? While he acknowledges that numbers can be misleading because of their implicit precision, his extensive use of quantification implies considerable belief in their supportive value. The prestige of the hard sciences has made quantification desirable, but as Leonard Meyer has noted, quantification per se does not make a theory stronger. Rather, the numbers provide a basis for devising tests of a theory or hypothesis.[12] To validate Epstein's tempo proportion theory, some experiments would have to be conducted in which listeners are given the opportunity to choose from among several performances that differ only in terms of their respective movements' tempos. Experimentally, it would be possible to use one of the various recording pianos to produce Musical Instrument Digital Interface (MIDI) code of actual piano performances and then to manipulate the numerical timing parameters without affecting the other MIDI data in order to produce a variety of timing versions of the otherwise original performance.[13] The manipulated versions, including one with Epstein's preferred proportional relationships among movements, could be played for listeners to determine their preferences. If a majority of the listeners preferred the performance in which movements were related by the simple proportions, then some added strength would be lent to Epstein's ideas. The same data could also be used to test whether listeners can in fact discern

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[12]See Leonard Meyer's "Commentary" in the special issue of *Music Perception* 13, no. 3 (Spring 1996): 455–83, especially pp. 468–69.

[13]It will likely be possible in the relatively near future to attach MIDI recording devices to all instruments so that even orchestral recordings will permit isolating (and hence manipulating the sonic details of) any instrument or instrumental combination, something that is not possible in analog recording.

proportional tempos. And if they can, then the data could be used to test the limits on perception of proportional tempo, including whether the Weber fraction is an appropriate limit.[14]

4. If proportional tempo relationships according to simple ratios were preferred during Beethoven's time, then why do only some of his published MM markings demonstrate such relationships? The same question can be raised about the Schumann examples included in the eighth chapter. The obvious answer (apart from flaws in the metronome of the time) is that composers chose tempos that they found appropriate to the content of their compositions at the time, some of which did result in proportional relationships in the ratios Epstein prefers, others of which did not. A desire for more dramatic contrast between sections or movements within a work might very well have suggested contrasting (in the sense of non-proportional) tempos.[15]

From personal experience in timing a variety of recorded performances, as well as from evidence collected by graduate students in a recent seminar, few tempo relationships were found that measure up to Epstein's preferences, which calls into question either the performances or Epstein's theory. As Leonard Meyer has observed about some experiments in musical preferences, it is a mistake to conflate explanation and experience.[16] We can likely provide a rationale

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[14]Interestingly, the seemingly restrictive 5 percent limit of the Webern fraction sheds a different light on Edward Cone's discussion of commensurate and incommensurate tempos in his article "Twelfth Night," in *Journal of Musicological Research* 7, nos. 2–3 (1987): 131–56. Cone cites tempo ratios of MM 88:112 (11:14) in Beethoven's First Symphony and MM 132:84 (11:7) in the Seventh Symphony as being incommensurate, that is, not in small ratios. Using Epstein's reckoning, both ratios would be commensurate in terms of his small ratio criterion: 88:112 is in a 3:4 relationship, and 132:84 is 3:2, both within 4.5 percent of the ideal.

[15]The issue of the role of contrast in tempo choice is raised by both Leonard Meyer ("Commentary," 471) and Edward Cone ("Twelfth Night," 146).

[16]"Commentary," 456.

for proportional tempo relationships among movements in many compositions, but unless we can provide some evidence that the many extant recorded non-proportional performances by acknowledged artist conductors and performers are somehow temporally flawed, tempo proportion has to be considered but one possibility among others for relating tempos within compositions.

On flexible tempo

Manipulating musical materials to create what several researchers have called "expressive timing" is one of the means performers have of exercising control over the pacing of musical materials. Coming into and out of metric focus, as it were, can be musically satisfying and important for communicating musical structure.[17] Epstein's discovery of integral proportion in three nineteenth-century solo piano compositions is fascinating. Yet there is no experimental evidence to support integral proportion as a common practice. What integral proportion means for the performer is thus unclear. Moreover, the subjective nature of choosing the ground beat units lends an aspect of self-service to the enterprise.[18]

There is also the matter of changes in taste and their influence on tempo choice and flexibility. Ideas and tastes change over time, as did Epstein's in his choice of initial tempo for Mozart's Symphony no. 40.

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[17]The role of timing variations in projecting musical structure is discussed in a variety of articles, among them Caroline Palmer, "Mapping Musical Thought to Musical Structure," *Journal of Experimental Psychology: Human Perception and Performance* 11 (1989): 331–46; and Eric Clarke and Cathy Baker-Short, "The Imitation of Perceived Rubato: Preliminary Study," *Psychology of Music* 15 (1987): 58–75. David Shea's unpublished dissertation, "A Comparative Study of Interpretive Decisions in Selected Unaccompanied Clarinet Solos Using Computer Graphics Technology" (Indiana University, 1996), is also interesting for its findings of how skilled clarinetists articulate structure in three twentieth-century compositions for solo clarinet.

[18]As this review was being written, a review of *Shaping Time* by the psychologist Bruno Repp appeared in *Music Perception* 13, no. 4 (Summer 1996): 591–604. Repp calls into question the ground beat concept, especially when it is the first beat of a phrase, due to the common practice of lengthening of initial phrase units (600).

It is unlikely that the rubatos performed by Wanda Landowska in the Bach's *Well-Tempered Clavier* preludes and fugues would conform to Epstein's criteria for musically acceptable rubato. Frankly, to my ears they sound overdone. But does that make Landowska's tempos wrong, or simply more romantic than current tastes prefer? To say that her tempos are wrong implies that there are absolute standards for style, which is not defensible. It is likely, as has often been said, that there is no accounting for taste (at least not via quantification).

Epstein's findings about ritards and accelerandos also raise the question of whether these aspects of flexible tempo are only fully satisfying when they can be modeled as cubic curves. While smoothness in ritards and accelerandos is no doubt desirable over erratic changes of pace, factors other than tempo may be equally important to the perception of aesthetic value, including the shaping of dynamics and the nature of instrumental articulations.

Using current technology, it would be possible to determine whether listeners prefer ritards and accelerandos that reflect the models that Epstein regards as ideals. With MIDI data recorded from an actual performance, one could manipulate the timing data to produce an ideally performed version along with several foils, and then play back the various performances to determine listener preferences. Whether or not listeners prefer the ideal, the same technology might be used in conjunction with computer graphics to help train performers via visualization to see how they play. Such pedagogical aids are highly valued in the sciences and could be effective for the performing arts as well.[19]

On human motor control and musical performance

Epstein's discussion of bodily kinesthetics and musical performance raises the question of how such knowledge is of value to the performer.

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[19]Rudolph Arnheim has observed that for a musical composition to be surveyed as a structural whole, it must be perceived as some kind of visual image. See Alexander Brinkman and Martha Mesiti, "Graphic Modeling of Musical Structure," *Computers and Music Research* 3 (Fall 1991): 1-42.

Perhaps it is enough simply to understand that there is a connection because of our experience with our own bodies or from viewing the motions of others, particularly motions that we cannot perform ourselves. A chapter by Patrick Shove and Bruno Repp in *The Practice of Performance* suggests that this is so.[20] Based on research on motion in music by early researchers and on more recent work of Manfred Clynes and others, they conclude that expert performers (and listeners) have a mental model of principles of natural movement which they apply to tempo changes in music. For a tempo change to "sound natural," it must apparently conform to those principles. They conclude

> . . . that performed music, by virtue of its temporal and dynamic microstructure, has the potential to represent forms of natural motion and to elicit corresponding movements in a human listener. While a rigid rhythm may inspire only foot tapping or finger snapping, an expressively modulated structure can specify movements with complex spatial trajectories which, for the purpose of demonstration and analysis, can be realized as guided movements of the limbs or the whole body.

Execution of the movements is not necessary in order to appreciate the motion information; rather, experienced listeners judge this by ear. Shove and Repp believe that an aesthetically satisfying performance is one whose expressive microstructure satisfies basic constraints of biological motion while also being responsive to the structural and stylistic requirements of the composition.

On structure and affect and the role of analysis in performance

Throughout *Shaping Time*, Epstein is concerned with both affective response and structural analysis. It may be, as Epstein suggests in another publication, that structure and affect are different sides of the

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[20]Patrick Shove and Bruno Repp, "Musical Motion and Performance: Theoretical and Empirical Perspectives," in *The Practice of Performance*, ed. John Rink (Cambridge: Cambridge University Press, 1995), 55–83.

same coin.[21] We know, for example, that music is processed in both sides of the brain, the right side for affective, the left for cognitive information.[22] He reports an experiment in which researchers tested neural responses to music and found that non-professional listeners showed more right brain activity, thus more affective response, while musicians tended to use both sides of the brain. In support of dual hemispheric processing of music is evidence that the two hemispheres of the brain are comprised of some 200 million fibers interconnected in a complex of intercommunicating networks.[23]

More support for the link between affect and cognition is found in a recent research project measuring highly skilled cellists' timing, stroke amplitude, and bow pressure as reflected in the coordination of the elbow, wrist, and bow in the performance of musical excerpts by Brahms and Schubert.[24] It was found that bowing was a function of tempo and musical structure, that there were distinct modes of performance for each excerpt, and that the performers executed similar motions within each one. However, when the Brahms excerpt was performed at the tempo of the Schubert, and vice versa, the articulation patterns became more varied and the regularities of motion found in the performances at correct tempos were absent. The researchers' experiments led them to conclude that the coordinative structures assembled by the performers were determined specifically to meet their

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[21]David Epstein, "A Curious Moment in Schumann's Fourth Symphony: Structure as the Fusion of Affect and Intuition," in *The Practice of Performance*, 126–49.

[22]See, for example, Howard Gardner, *Frames of Mind: The Theory of Multiple Intelligences* (New York: Basic Books, 1983); John Sloboda, *The Musical Mind: The Cognitive Psychology of Music* (Oxford: Clarendon Press, 1985), especially pp. 260–65; and H. W. Gordon and K. Bellamy, "Neurophysiology of Brain Function: An Overview," in *Music, Speech, and Brain*, ed. Johan Sundberg, Lennart Nord, and Rolf Carlson (London: Macmillan Press, 1991), 311–17.

[23]Epstein, "A Curious Moment," 128.

[24]See Helga Winold, Esther Thelan, and Beverly Ulrich, "Coordination and Control in the Bow Arm Movements of Highly Skilled Cellists," *Ecological Psychology* 6, no. 1 (1994): 1–31.

musical goals, that understanding musical structure and a desire to express a musical idea are what make musical performance a reflection of the cognitive and the emotional intentions of the performer, not merely mechanical reproduction.

The connection of musical affect and structure has implications for professional music study within higher education, in which applied and academic studies are commonly separated. If affect and structure are connected, then it makes sense to coordinate carefully, if not combine, applied and academic music study, not to continue to regard them as separate activities, despite the administrative convenience of doing so. With new technology and with information drawn from research on expressive performance and performance synthesis,[25] we now have means for visualizing performance practice, which in turn can be used to formulate pertinent questions about how those aspects that performers can shape to produce affect—principally timing, articulation, and dynamics—relate to aspects of musical structure determined through traditional analysis.

Music theorists commonly approach music from the point of view of its structure, using the score as a starting point. In a recent article, Joel Lester suggests that we might profitably take performance as a starting point, countering Donald Francis Tovey's remark that players should understand what they play with the idea that analysts should understand what they analyze.[26] Epstein's study provides support for this idea, or at least for a balance of approaches, by demonstrating effectively the interconnectedness of structure and affect.

Shaping Time is impressive for its breadth, its generally convincing arguments, its musical analyses, and the many ways in which music is linked with other disciplines. From the point of view of performance, tempo proportion in terms of simple ratios is something that can be

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[25]Epstein mentions a number of studies in *Shaping Time*, as does Devin McAuley in his dissertation cited earlier. Additional information is found in Gary E. Wittlich, Eric J. Isaacson, and Jeffrey E. Hass, "Computer Applications in Music Composition and Research," *Advances in Computers* 36 (1993): 180-89.

[26]Joel Lester, "Performance and Analysis: Interaction and Interpretation," in *The Practice of Performance*, 197-216.

practiced or not, depending upon the disposition of the performer or conductor. The many well-argued analyses clearly provide a starting point for those interested in such relationships. How knowledge of integral proportion or mathematical modeling of ritards and accelerandos can influence performer decisions is, however, much less clear. It is likely that this information will be of more value to researchers than to performers. Yet there is no doubt that our conceptualization of music affects how we perform it, create it, and apprehend and relate its details as listeners. What Epstein provides for us is food for thought about musical time, its properties, and how the elements of music are shaped artistically in time. It is a book well worth taking the time to read.