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

Review by David Butler[1]

Nothing is more essential to the due performance of music, than adjusting the time to the intention and meaning of the author. Many performers of the present day are guilty of a great mistake in playing the modern music too fast, erroneously supposing that quickness is a necessary character to distinguish it from the old. Haydn was so offended at the rude and hurried manner in which he found his music driven by the English, when he first visited this country, that he sent for the family of the Moralts from Vienna, to show the Londoners the time and expression with which he intended his quartettes to be played.

—Gardiner (1837, 177-8).

When William Gardiner wrote about modern music, he had in mind Haydn's quartets and Beethoven's symphonies. This means little by itself, but becomes more noteworthy when one is struck by some of the similarities between Gardiner's observations about musical time and those found in David Epstein's newest study. Epstein would probably be completely unsurprised by the resemblance. While *Shaping Time* is distinctive from its predecessors both in its size (nearly 600 pages, a bibliography of 500+ entries) and in terms of the multiplicity of its perspectives on musical time—employing not just the literatures of music theory, music history, counterpoint, and composition, but reaching into areas such as aesthetics (both empirical and speculative), psychophysics, cognition, and neurophysiology—much of it is built on old foundations. Epstein makes a strong case that his ideas are based on centuries-old conventions of musical composition and performance. Sensitivity to the ways in which music shapes time (and the reverse) can, Epstein proposes, be observed in the practice of generations of musicians carrying

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on the traditions of European art music from the Classical and Romantic eras—and such sensitivity might just be generalizable to the performance practice of musicians world-wide.

In the proportions of its content, *Shaping Time* is bell-shaped. Its 14 chapters are grouped within five sections, the first a one-chapter prologue. The second section ("Rhythm, Meter, and Motion") contains one chapter of lexical and epistemological groundwork, and a second chapter presenting exemplary works by European composers from the late eighteenth to the early twentieth centuries. The third section, entitled "Tempo," is really the heart of the book—six chapters (half of the book's pages) devoted to the theoretical, historical, and biological aspects of proportional tempo, sometimes referred to as "the theory of continuous pulse." The fourth section ("Flexible Tempo") comprises four shorter chapters on *rubato* and *accelerando/ritardando*. In the fifth and final section of the book ("Epilogue"), the author presents a one-chapter discussion of musical motion and musical affect, using four musical examples to illustrate his points that "...music [is] intrinsically wed to structure, and structure inseparably tied to motion" (p. 481) and that appropriately controlled musical motion fulfills our innate temporal expectations and thus makes a satisfying affective statement. The book closes with a lengthy compilation of notes, the aforementioned bibliography, and an index.

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Epstein proposes at the outset of the first section ("Time, Motion, and Proportion") that time is *the* critical element in musical performance, "in many cases the factor that separates the merely capable from the distinguished reading" (p. 3). The author follows with the assertion that musical time may be re-shaped most effectively, for better or worse, through tempo—the aspect of musical time that absorbs most of the author's attention. Ten of the book's chapters deal in one way or another with tempo, which the author characterizes as "... a major element of control, its parameter, virtually by definition, being the pacing of

a work, and thereby the rate by which a work unfolds its contents over time" (p. 27). Furthermore:

> The essence of temporal experience is movement, or motion, through time.... [Motion] is discussed [in this study] 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 (p. 5).

Epstein begins by addressing the general topic of temporality within and beyond music, laying out some conceptual and lexical preliminaries to his discussion of musical motion. This discussion revolves around the relationships between external and arbitrary musical time ("chronometric" or clock time) on the one hand, and the human experience of time ("integral" time) on the other. This dualism is one of several intertwining relationships illustrated in Epstein's model of time in music, shown in Figure 1.

The model is intended to capture several complex properties of musical time. One is the much-discussed relationship of meter (with its hierarchy of nested, extrinsic, and clock-like temporal levels) and rhythm (with its hierarchy of not-necessarily nested, intrinsic, and often irregular temporal levels). Together, meter and rhythm comprise the complementary structural aspects of musical temporality or motion, and both significantly affect (and are significantly affected by) the processive aspect of tempo. It is proposed that the pacing of motion in music is also hierarchic—but in the sense that tempi in a multi-tempo work are largely subsumed by a "steady, continuous, and thus common pulse" (p. 12) describable by small-integer superparticular ratios.

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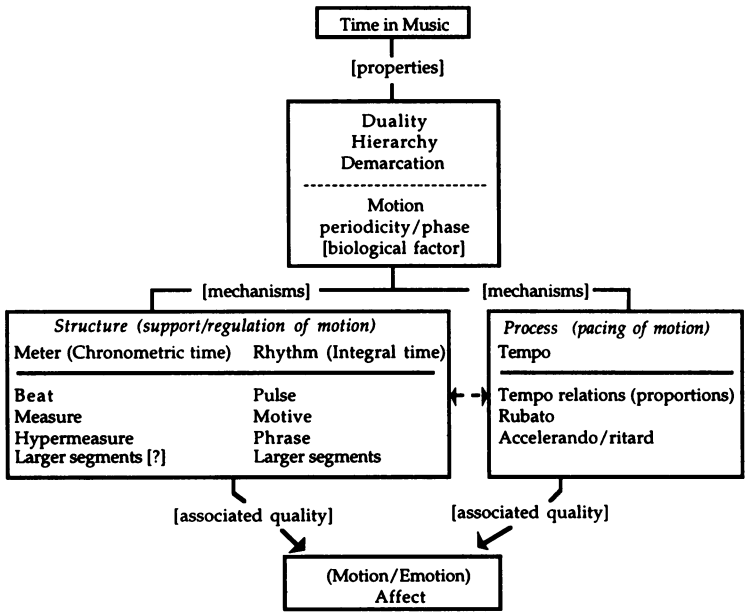
Gardiner (1837, 173–4) asserted that musical timekeeping had biological roots, proposing that choices of tempo in music are guided by the pace of walking, which he suspected was governed by the rate of the heartbeat. Epstein is chronologically positioned to be able to dig much deeper into the matter than Gardiner could have, and he does. A review of studies by speech-hearing

Figure 1. Epstein's model of time in music.



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scientists, neurophysiologists, biochemists, psychologists, and physicists leads the author to conclude that "[o]scillations in a number of biological systems conjoin by simple whole-number ratios (1:2 and so on) to build longer durations on hierarchic levels, the various periodicities synchronized in-phase. ... Pulse seems to serve as the 'carrier wave' in speech and music by which much information, some of it affective in nature, is transmitted between speaker and listener, performer and audience" (p. 154).

This conclusion, together with historical evidence found in theoretical treatises, score markings, and other sources spanning the period from the late middle ages through the present century, persuades the author that there exists an underlying harmonicity in the appropriate rates at which music (again, at least the

instrumental art-music literature of the European Classic-Romantic tradition) unfolds. The author proposes that

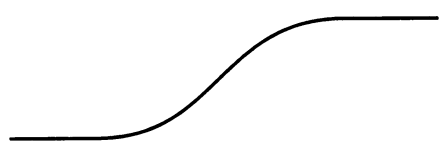
> ...in works of multiple movements, or in single-movement works with different tempos..., all tempos are intrinsically related via a common pulse. The relationship arises from the organization of the work as a unified and coherent whole in which all movements, all ideas, stem from underlying formative concepts of shape. ... These relationships of tempo can be concisely expressed by whole-number (integral) ratios. Significantly, the ratios are of low order (typically 1:1, 1:2, 2:3, 3:4, or the inverse) (p. 101).

The author proposes that the flexing of tempo, in the forms of *rubato*, *accelerando*, and *ritardando*, can be guided just as clearly by structural attributes of the music. The fundamental condition of *rubato*, according to this view, is "...the fit between periodicities of different lengths on the level of beat-to-phrase, and on yet higher levels" (p. 390). Regarding *accelerando* and *ritardando*, the author summarizes that

> ...the process is structured, and that integrally related tempos seem to bound the gradual changes in pacing that constitute the acceleration/ritard itself. Further, the controlling factor that governs the ritard or acceleration follows the pronounced algorithm of cubic curvature—often with the connecting properties of a cubic spline (p. 448).

A cubic spline, which Epstein (along with the chapter's co-author, Jacob Feldman) introduces early in the discussion of *accelerando* and *ritardando*, is a smooth and symmetrical s-shaped curve. If it were rendered graphically, architects and woodworkers would recognize it as a classic cyma curve, shown in Figure 2.

Figure 2. Classic cyma curve, or Epstein's cubic spline.



Epstein then proceeds to present evidence supporting his suppositions. The evidence takes as many forms as the author can

find. Some of it is more general in scope (such as treatises, tables of tempo relationships, metronomic devices and systems), and not limited to any particular piece, style, or school. Other forms of evidence are more specific to individual works. These include the obvious types, such as score markings and timing data from recordings; but Epstein also examines timings punched into player piano rolls and even timings pinned into barrels of an eighteenth-century British barrel organ.[2]

How persuasive is the evidence? Here one finds the makings of an interesting and important debate. The author repeatedly cautions that music is intrinsically a human enterprise, and that one cannot expect (and likely would be dissatisfied with) robotic perfection of temporal execution in musical performance; thus one should, he proposes, be prepared to cut a little slack in what one is willing to accept as reasonable representatives of the proportional tempo relationships of 1:1, 1:2, 2:3 and 3:4. Minor deviations from the ideal are certainly tolerated in other musical regards, as the research literature on such phenomena as categorical pitch, chorus effect, tuning/temperament, and inharmonicity in piano spectra will attest. Epstein proposes that a similar sort of perceptual window of tolerance be set up for measurable, but musically insignificant, deviations from these ideal ratios when the proportionality of tempo relations is studied. In other words, just as much of the pitch- and timbre-related periodicity heard in music is actually quasi-periodic, it should be accepted that some of the temporal periodicities

[2]There is some evidence supporting Epstein's ideas that does not find its way into *Shaping Time;* this is fully to be expected when evidence is to be found in so many divergent bodies of literature. One compelling example of such evidence is found in the results of Povel's (1981) study of musically trained and musically naive performers, all of who were required to imitate simple and more-complex temporal sequences. Povel found that performers were quite accurate in their imitations when beats were divided into shorter units having a 1:1 or 2:1 ratio. When performers were required to imitate patterns in which divisions corresponded to higher ratios, not only did accuracy levels drop, but errors ("severe distortions," 16) were systematic—and were viewed as attempts to perform the beat divisions as though their durations stood at 1:1 or 2:1 ratios.

experienced in actual musical sound are also nearly (but not precisely) periodic.

Two means of determining reasonable limits on deviations in timing are then advanced by the author. The first of these is a clock-time threshold of 20 milliseconds (msec), a "temporal order threshold" (Hirsh and Sherrick 1961) beyond which the average listener cannot determine which of two clicks preceded the other, or even that there are two separate clicks. The second criterion is the "Weber fraction" which, when applied to auditory time perception (Getty 1975) suggests that within the temporal range of around 400 to 2000 msec (that is, at metronomic settings of 30–150), "a tempo would have to change by more than 5 percent for the change to be noticed; furthermore, that change would have to take place within a 2-sec. period" (p. 167).

The first criterion seems not exactly applicable to this study. Hirsh and Sherrick (1961) wanted to determine the threshold at which the sequential order of two extremely short filtered pulses could be recognized; the pulses were separated by intervals of only 10, 20, or 30 msec. Does this sort of perceptual judgment really relate directly to the ability to judge whether a tone within an isochronous sequence is exactly "in place," or if instead it arrives slightly too early or too late in the temporal sequence (see, for example, Van Noorden 1975 and Jones 1976)? There seems to be an analogous case in the realm of just-noticeable-differences (JNDs) for pitch: we're much better able to distinguish tiny intonational errors when tones are presented as simultaneities and near-simultaneities, than when pitches are heard sequentially with an intervening silent time-interval.

We would also be wise to look carefully at the ±5% cushion allowed by the Weber fraction. This criterion allows a region of 10% around each of the four ratios Epstein lists in his hypothesis. Thus the author's proportionality theory is confirmed whenever one tempo leads to a second found to be within one of several regions. Figure 3 shows the possible regions that would confirm the theory assuming an initial metronomic setting of 60 beats per minute.

Figure 3. Examples of tempo regions defined by Epstein's proportionality theory.

Ratio	±5%	for example:
1:1	(0.95 to 1.05) : 1	57-63 : 60
4:3	(3.8 to 4.2) : 3	76-84 : 60
3:2	(2.85 to 3.15) : 2	86-95 : 60
2:1	(1.9 to 2.1) : 1	114-126 : 60

When we consider all the tempos allowed by the ranges in the right-hand column, we find that 35 of the 69 beats per minute in this tempo range (M.M. 57–126) fall within the ±5% tolerance. This means that the odds are roughly 1 in 2 that any tempo one encounters by chance within this tempo range could be interpreted as evidence supporting the author's proportional-tempo hypothesis. So it seems that the temporal order threshold is based on data not clearly related to the topic of tempo; and it seems also that the ±5% margin corresponding to the Weber fraction may simply be not stringent enough a test of the proportional tempo hypothesis. The results of the first of three experiments conducted by Drake & Botte (1993) indicate that JNDs for tempo can be as low as 1.5% for tempo changes between isochronous sequences, and between even single temporal intervals, at an "intermediate" tempo (within the range of around 75–200 beats per minute). This suggests that the author might want to narrow the margin of tolerance somewhat below ±5%, although it is unclear how much narrower the margin should be. The lower JNDs reported by Drake & Botte resulted from listeners' responses to short (2–7 tones), monotonic, isochronous sequences of 50-msec-long tones; responses to carefully regulated but more musically realistic stimulus patterns might show even greater sensitivity to small changes in tempo—or JNDs might become larger.

A related question arises with regard to the nature of perceptual evidence needed to provide convincing support for the assertions in this book. Very early in the book, the author gives notice that novice musicians may not have what it takes to

comprehend the full musical significance of some of the principal assertions found in *Shaping Time:*

> Because time is so complex and elusive a factor in music, one must have experienced works deeply and often if perceptions and judgments about their temporal aspects are to ring true. ... We can, for example, make telling observations about melody, harmonic rhythm, or formal constructs on the basis of several listenings to a work. Comparable judgments about tempo, however, or about the way a piece must move—how it must flow, hold back, accelerate, ritard, employ flexible pacing—demand extensive experience with the music before these often evanescent qualities can be grasped with surety (p. 5).

The author thus raises the issue of cognitive elitism, and there are substantial points to be considered on both sides. The opening volley—fired perhaps by the hard-ball empiricist—charges that the author is trying to bullet-proof his assertions by arguing that anyone who challenges them simply hasn't yet reached the author's final-state level of understanding of the musical work(s) under consideration. The author's assertions, in short, have been rendered unfalsifiable because any counter-evidence produced by empirical testing could be dismissed as having been generated by inexpert musicianship within the pool of test participants. The return volley, likely launched by those music theorists and cognitive scientists who recognize the critical importance of learning in the perceptual activities of attending and remembering, replies that if one asks untutored listeners to make high-level judgments of highly complex and context-variant musical patterns, one deserves to deal with all the statistical noise likely to surface in the test results.

In his book *Sound Color* (1986), Wayne Slawson sought to isolate and identify the frequency-amplitude characteristics of tone spectra so that they could then be arranged in sequential and simultaneous collocations, often emulating compositional practices traditionally associated with pitch combinations in western tonal and post-tonal music. Although it would not appear that Epstein intends to pursue an analogous goal with musical temporality, it is tempting to consider some simple analogies between pitch and tempo. Epstein's assumptions about proportional tempo, for example, among movements in a multi-

movement work does have an obvious counterpart in inter-movement key relationships commonly associated with the Classic-Romantic tonal tradition. There exists some evidence (Cook, 1987), however, that listeners tend to lose perceptual track of large-scale tonal relationships *within* movements; the recognizability of these relationships very likely is wiped out by interference from the immediate tonal context. Epstein similarly remains dubious about the musical importance of "deep meter," because he is unable to find a real consensus on determination of hypermetric structures.[3] He maintains that perception of "correspondences and collisions" between hypermeasure and phrase "seem the powerful components of temporal drive. Broader metrical levels, as a further stage on which to play out the drama of musical travel through time, seem questionable" (p. 46).

A different (but obviously related) phenomenon, sometimes called "pitch drift," can be observed when vocal ensembles, singing *a cappella*, slowly drift off-pitch (usually downward), often while singing with impeccable intonation among vocal parts. Few members of the audience are aware of this drifting, other than those who possess absolute pitch. The analogous temporal phenomenon, a subtle "tempo drift" certainly does exist, and is not to be confounded with intentional changes of tempo; but there seems to be little information on how much of the listening population possesses "absolute tempo" and recognizes this drift.

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What, then, is the primary contribution of *Shaping Time?* In several respects, David Epstein's contribution to the study of tempo resembles Eugene Narmour's contribution (e.g., 1990; 1992) to the study of melody: Each is a scholarly *tour de force,* a large repository of hypotheses generated by well-informed

[3]At least since the publication of his earlier book, *Beyond Orpheus* (1979, see esp. 61ff), Epstein has been consistent in his reluctance to assert that large-scale metrical levels impinge in any significant way on our musical thinking. This issue is certainly not resolved (for ex., see Kramer 1988, 415 note 16).

musical intuitions. Both Narmour's and Epstein's descriptions of musical processes are predicated on the interaction of bottom-up (Gestalt, or psychophysical, or neurophysiological) and top-down (learned, high-level, conceptual) mental operations, informed by grammar-like structural cues in musical sound. Furthermore, the central assertions by both authors invite further empirical verification of course.

Shaping Time has a strong and clearly articulated point of view. The writing is eminently clear and thoughtful. The editing is excellent, and musical examples are both well-chosen and well-produced. Most noteworthy, perhaps, is the book's remarkable integration—both in terms of its cross-disciplinary breadth, and because the author writes not as just a theorist or composer or conductor, but as a musician. The book is well worth all the time one gives it.

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