60

Models from Music

In these walls devoted to the marvels
I receive and keep the works
of the prodigious hand of the artist
equal and rival of his thought
one is nothing without the other.
Paul Valéry, inscription at the Palais Chaillot, Paris

Summary. We discuss contributions from music theory, performance, and technology to gestural modeling.

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Music in theory and performance is a field where thinking and embodied making, the mindful gesture, have been a traditional topic of attempts at theorization. It is a classical saying that music must be thought in the making, in performance. These insights are shared by Theodor Wiesengrund Adorno [8], Roger Sessions [972], Alexandra Pierce [848], Renate Wieland [1068], and Manfred Clynes [206], and we may just cite one representative statement by Adorno: "Notation wants music to be forgotten, in order to fix it and to cast it into identical reproduction, namely the objectivation of the gesture, which for all music of barbarian cultures martyrs the eardrum of the listener. The eternization of music through notation contains a deadly moment: what it captures becomes irrevocable.(...) Musical notation is an expression of the Christianization of music.(...) It is about eternity: it kills music as a natural phenomenon in order to conserve it—once it is broken—as a spiritual entity: The survival of music in its persistence presupposes the killing of its here and now, and achieves within the notation the ban from its mimetic representation." Despite these harsh insights, Robert S. Hatten rightly complains that: "Given the importance of gesture to interpretation, why do we not have a comprehensive theory of gesture in music?" This reflects the dichotomy between performance practice, where embodiment and gesturality are well-known perspectives, and theoretical understanding, which might also be difficult because music theory has been a very rigid, algebraically shaped formalism that has had no chance to deal with topological considerations needed for gestural and embodied analysis.

This dichotomy appears condensed in David Lewin's celebrated book on musical transformation theory [605], where he asks: "If I am at s and wish to get to t, what characteristic gesture should I perform in order to arrive there?" He thinks about a dancer, about the embodied musical subject, and the metaphor is quite strong. However, Lewin's transformational theory is all but gestural; it is a very conservative formalism of abstract mathematical functions in the spirit of Emmy Noether of (at that time) modern algebra in the late 1920s, and there is no topology, no continuity or even homotopy, at all. Gesture research in music has however taken place in the field of computer-aided performance and in our own computerized implementation of musical performance gesture theory for the pianist's hand.

60.1 Wolfgang Graeser

Summary. Graeser's tragic biography and work: from symmetry theory to gestures.

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Fig. 60.1. Wolfgang Graeser. Zentralbibliothek Zürich, Mus NL 162 (Nachlass Wolfgang Graeser).

Perhaps the most radical and tragic first gesturally oriented scientific approach to music is that of Wolfgang Graeser (1906-1928), a German mathematician and music theorist, who had studied mathematics, physics, music, and oriental languages since the tender age of seventeen in Berlin and Zurich. He became famous for his symmetry-oriented analysis of Bach's *Art of Fugue* [387]. But a dramatic change in his understanding of music took place when he saw how dancers were rehearsing with Bach's Goldberg Variations. This led to his understanding that all of the musical essence was expressed in the dancers' bodily movement. His last writing was consequently an essay on embodiment [388], wherein he concluded: "Now we comprehend the body uncaged and without veiling insinuations." This explosion in his understanding was more than an intellectual insight, it effectively opened to him a completely new view of the essence of art. But it was also too much of a revolution in his understanding of human expression. At age twenty-two he committed suicide, overwhelmed by his deep and by that time lonely insights.

60.2 Adorno, Wieland, Sessions, Clynes

Summary. This section discusses four contributions to gesturality from prominent music performance professionals and theorists. Their position is quite radically opposed to the European tradition of score-based music.

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In the domain of music, gestures were first thematized in musical performance theory. This seems quite natural, since our hands and limbs are in many ways the physical medium between a written score and the sound of a musical piece. It is the philosopher and musicologist Theodor Wiesengrund Adorno, who made the first argument for a gestural understanding of music [8] in 1946: "Correspondingly the task of the interpreter would be to consider the notes until they are transformed into original manuscripts under the insistent eye of the observer; however not as images of the author's emotion—they are also such, but only accidentally—but as the seismographic curves, which the body has left to the music in its gestural vibrations." Adorno argues for what Mazzola had called "the score as a repertory of frozen gestures" in [718]. He does not argue for the emotional message of gestures. Rather, he argues for their nature as "vibrating" bodily utterances. At first sight, this may look overly materialistic and far from the symbolic meaning of musical creation, but we shall see in a moment that Adorno insinuates a spiritual component in the gestural dynamics. This perspective is in fact supported by the very history of score notation. Originally, scores encoded the gestural hints in the graphemes of Medieval neumes. These graphemes then successively morphed to the present notation, which has abstracted neumatic threads to discrete point symbols; see also Section 86.2.3.

Adorno's student, Renate Wieland, and her fellow scholar Jürgen Uhde [1068] make the teacher's approach more explicit and apply it the their system of piano performance. Wieland: "Originally affects were actions, related to an exterior object, along the process of internalization they were detached from their object, but they are still determined by the coordinates of space. (...) There is therefore something like gestural (space) coordinates." She makes clear that gestures are abstractions from concrete actions, however they remain geometric entities in some more generic space. Wieland also argues that the emotional

connotation in music originally is e-motion, out-movement, and so the gestural transmutation is not an artificial construct, but the restatement of the original phenomenon.

60.2.1 Theodor Wiesengrund Adorno

Theodor Wiesengrund Adorno has done deep analyses of performance, in particular with respect to their subcutaneous gestural implications as published in his posthumous work *Zu einer Theorie der musikalischen Reproduktion* [8]. It is interesting to see how Adorno gets off the ground with his gestural discourse on the same basis as Sessions and Clynes, namely a radical critique of the score-based reduction of music (translated from [8, p. 227/8]):

> *Notation wants music to be forgotten, in order to fix it and to cast it into identical reproduction, namely the objectivation of the gesture, which for all music of barbarian cultures martyrs the eardrum of the listener. The eternization of music through notation contains a deadly moment: what it captures becomes irrevocable.*
> *(...)*
> *Spatialization (through notation) means total control. This is the utopic contradiction in the reproduction of music: to re-create by total control what had been irrevocably lost.*
> *(...)*
> *All making music is a recherche du temps perdu.*

And later on (translated from [8, p.235]):

> *Musical notation is an expression of the Christianization of music.*
> *(...)*
> *It is about eternity: it kills music as a natural phenomenon in order to conserve (or "embalm" G.M.) it—once it is broken—as a spiritual entity: The survival of music in its persistence presupposes the killing of its here and now, and achieves within the notation the ban (or "detachment" G.M.) from its mimetic[1] representation.*

To begin with, Adorno, Sessions, and Clynes agree upon the fact that music notation, and its score, abolishes music, which is fixed and cast into a format for identical reproduction. It does so in objectifying the gesture and thereby martyring the eardrum, an act of barbarian culture. It is remarkable that musical notation is related to barbarian culture. The eternization of music in the notation's casting is killing music; it retains a dead body, not the living music. This eternity of dead—in fact, embalmed—bodies appears as a Christian ritual of sacred denaturation. The procedure of notation kills the music's here and now; its expressivity is annihilated, banned forever. The notational process kills through spatialization, which means total control. Time does not fly by anymore, a note is a point in a dead space of eternity. Adorno views this as being the great contradiction of notation in that it claims total control for a reproduction of what has been irrevocably lost. It is a *temps perdu*, and making music is doomed to a *recherche du temps perdu*.

Adorno then makes important comments on what he views as being the gestural substance of music (translated from [8, p.244/5]):

> *As each face and each gesture, each play of features, is mediated by the I, so the musical moments are the very arena of mimic in music. What must be read and decoded within music are its mimic innervations.*
> *(...)*
> *However, a pathetic or cautious or expiring location does not signify pathos, caution, or expiration as a spiritual thing, but maps the corresponding expressive categories into the musical configuration, and those who want to perform them correctly have to find those encapsulated gestures in order to mimic them.*

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[1] For Adorno, "mimesis" means "expression of expression," and this is precisely our context: The expression as content is expressed via rhetorical shaping.

(...)
Finding through reading: the decoding work by the interpreter; the very concept of musical performance is the path into the empire of mimic characters.
(...)
The spatialization of gestures, that impulse of neumatic notation is at the same time the negation of the gestural element.
(...)
By the visual fixation, where the musical gesture is positioned into a simultaneous relation to its equals, it ceases to be a gesture, it becomes an object, a mental thing.

Here Adorno refers to the mimetic category in his theory. It is the category "expression of expression." So it is about the expression of emotions, for example, not about emotions, and it is about the musical image of these expressions. Therefore, we have to read those mimic innervations of gestural expressions in music. Musical performance deals with the explication of those hidden innervations, with the action of displaying them in the making, here and now. And it now becomes clear that the neumatic notation creates static photographs of those gestures, which negate them by this spatial fixation. The spatial trace of a gesture is its negation, freezing it as a spatial object.

We should, however, briefly digress on the very concept of a space here, since it is not what a geometer or a physicist would call a space. In physics, a space is a geometric entity that can have different interpretations, so space-time is (locally speaking) a four-dimensional real vector space, and the mathematical structure of time is not different from that of the three space coordinates. Of course, the Lorentz metric distinguishes time in the metrical structure of space-time, but it is still a metrical space. In performance theory of music, time has a radically different role. The four-dimensional space of onset, pitch, loudness, and duration for piano music, which is used in score notation, does not have the ontology of musical time. Under no circumstances would the onset or duration coordinates be accepted as representing the time that takes place in performance. This *differentia specifica* in the performative time concept is related to gestures, not to geometric representation. For Adorno, gesture has an existential character; it cannot be objectivized; it only exists in the moment of the making; it is mediated by the I, which cannot be cast in a dictionary—the I is the non-lexical, the shifter, par excellence. However, it is not part of the subject, it is not subjective as opposed to being objective (the score objects are so). I is only mediated by the I, it seems to lie between subject and object; therefore, the utterance of a gesture is neither object nor subject.

Adorno continues (translated from [8, p.269]):

The true reproduction is the mimicry of a non-existent original.
(...)
But this mimicry of the non-existent original is at the same time nothing else but the X-ray photography of the text.
(...)
Its challenge is to make evident all relations, transitions, contrasts, tension and relaxation fields, and whatever there is that builds the construction, all of that being hidden under the mensural notation and the sensorial surface of sounds.

The true reproduction is not a reference to an object out there; the original is non-existent, and it is not the I, which would be an existent entity. It is something mysterious since there is an X-ray procedure, but it does not show something hidden in the dead object of the score. It is as if that mystery would be brought to existence by the very X-ray procedure. The innervation must be made, not only discovered and pointed to.

Adorno's concept of a gesture is as difficult as it is radically different from what can be described in terms of traditional subject-object duality.

Let us see what Adorno concludes from all these subtle reflections (translated from [8, p.269,270,271]):

What happens in true performance is the articulation of the sensorial appearance that reaches into the most hidden details, wherein the totality of the construction, the gesture of the work, reveals its mimical execution.

(...)

The concept of clarity defines the degree of an analytical performance: everything that exists as relations within the mensural text must become clear, but this concept cannot be understood in a primitive way, i.e. as a clarity of every single relation, but as a hierarchy of clarity and blurredness in the sense of the clarity of the overall structure, the mimic gesture.

And he summarizes this entire perspective on gestural performance (translated from [8, p.247]):

Correspondingly the task of the interpreter would be to consider the notes until they are transformed into original manuscripts under the insistent eye of the observer; however not as images of the author's emotion—they are also such, but only accidentally—but as the seismographic curves, which the body has left to the music in its gestural vibrations.

60.2.2 Renate Wieland

As a student of Adorno, piano pedagogue Renate Wieland (Figure 60.2), in collaboration with her colleague Jürgen Uhde, has developed a theory of piano performance that is based upon Adorno's gestural philosophy.

Fig. 60.2. Renate Wieland.

The remarkable feature of this work is that she succeeds in
(1) giving her approach a clear-cut separation from emotional dramaturgy and
(2) reshaping gesture theory in an explicit geometric language.

She makes these two points very clear in her text (translated from [1068, p.169]):

Musical gestures are perceived in the free conducting movement, in the playing movement and sublimated in the spiritual mimesis of pure imagination. Whatever the level, such experiments are always within space. Originally, affects were actions, related to an exterior object, along the process of interiorization they were detached from their object, but they are still determined by the coordinates of space.
(...)
Language reminds us everywhere of the connection of affect and movement and of the way gestures behave in space. It speaks about hautiness, elevation and inclination, about greatness of mind, pettiness, about respectful and forward, etc.
(...) There is therefore something like gestural coordinates; they can help ask how the gestural impulse out of the inner is projected into space, how it wants to expand, which direction is dominant: Is its energy vertically or horizontally active? Does it rather propagate ahead or backward? Upward or downward? To the right or to the left? Are forces acting more concentrically or excentrically? Does

the gesture rather point "inward," as we read in Schumann's work, or "outward"? Which amplitude does the expression choose? Does it live in all spatial dimensions, and with what proportion and intensity?

She reminds us of the etymology of the word "emotion": *ex movere*, to move from inside out. She also makes clear that the original setup is now internalized, but that it remains a spatial concept. She then gives examples of etymological shifts, which are parallel to this internalization process: Words now mean abstract things, but when we go to the kernel of a meaning, it is related to a spatial action. So the mimetic action in Adorno's sense is the expression of that spatially conceived gesture in the realm of musical space. She adds the following excellent illustration of a gestural mimesis in music (translated from [1068, p.169]):

Models of contrast between extreme vertical and horizontal gestures are found in Beethoven's Bagatelle op.126,2.
(...)
Aggressively starting initial gestures are answered by flat, conciliating gestures, where the extremes are polarized to the outermost in the course of the piece. In this way, asking again and again, gesture becomes plastic in the end. But it only succeeds insofar as it constitutes a unity, is emanated from one inner central impulse.
(...)
Gestures are the utmost delicate; where their unity is disturbed, their expression immediately vanishes.

It is again in Adorno's and Session's spirit that she views gestures as being extremely unstable in their existentiality: Nothing is easier than to disturb and vaporize a gesture. It is by this fact that Gilles Châtelet, one of the fathers of French gesture theory, has characterized gestures as being the smile of existence [190].

Wieland finally transcends her approach in a seemingly breathtaking intensification, which reads as follows (translated from [1068, p.190]):

The touch of sound is the target of the comprising gesture; the touch is so-to-speak the gesture within the gesture, and like the gesture at large, it equally relates to the coordinates of space.
(...)
The eros of the pianist's touch is not limited to the direct contact with the key, the inner surface of the entire hand pre-senses the sound, etc., etc.

She introduces what one could call the reverberance of a gesture, namely the gesture within a gesture, meaning that a gesture can incorporate other gestures, can become a gesture of gestures. We shall see later in Section 61.6, relating to our own research, that this concept is very powerful for the theory of gestures in that it enables complex imbrications of gestures, so-called hypergestures, for the construction of movements of movements of movements..., an idea that is crucial in the dynamics of musical utterances.

60.2.3 Roger Sessions

The dramatically intense but still underestimated role of gestures in performance has been described in a beautifully clear way by American composer and music critic Roger Sessions in his book *Questions About Music* [972, Chapter III]:

It is fairly obvious, I suppose, that our total awareness of movement—which in essence signifies our awareness of time *as a process—demands sustained attention, which is limited to the duration of the specific act of movement in question; it holds us captive, as it were, for the duration. We are aware of a beginning and an end. In respect to space on the other hand, the words "beginning" and "end" have an essentially metaphorical meaning; they represent boundaries or limits that remain even after we have become aware of them, as does all that lies between. Our attention is our own to husband and deploy as we wish. We can withdraw it and absent ourselves merely by averting or closing our eyes, and return whenever and for as long as we wish.*

What I am saying is that we experience music as a pattern of movement, as a gesture; and that a gesture gradually loses its meaning for us insofar as we become aware of having witnessed it, in its total identity, before. If it is to retain this meaning in its full force, it must be on each occasion reinvested with fresh energy. Otherwise we experience it, to an increasing degree, as static; its impact, as movement, diminishes, and in the end we cease to experience it as movement at all. Its essentially static nature has imposed itself on our awareness.

This is why I am convinced that the performer is an essential element in the whole musical picture. It is why I came to realize that my earlier dreams—that composers might learn to freeze their own performance, in wax or otherwise (tape recorders had not been invented at that time)—were, to put it bluntly, quite ill-directed. They were ill-directed, above all, for the reasons I have been outlining; a gesture needs constant renewal if it is to retain its force on subsequent repetitions. Composers above all should know this, especially if they have developed the practice of taking part in performances of their own work. Each performance is a new one, and the work is always studied and approached anew, even by the composer. The same, it should be obvious, is true of professional performers. I would go even much further and point out that there is no such thing as a "definitive" performance of any work whatever. This is true even of performances by the composer himself, in spite of the fact that recordings of his performances of his own work should be made and preserved, for a number of quite obvious reasons.

Session's discussion of movement as a processing of time leads him to acknowledge that this dynamical action is a gesture—not only in the making, but also in the music's perception. So he gives the argument for a messaging of gestures, and by means of gestures, which is our topic in this chapter. It is remarkable that he then recognizes that a gesture cannot preserve its meaning except in its energetic refreshment on each occasion of performance. This is very similar to the French theory of gestures; see Chapter 58 and [721, Chapter 7.2], which stresses the impossibility to tame living gestures.

He moreover recognizes the performer's essential role in the "whole music picture" and also reminds composers, himself included, that their work of musical creation is not accomplished until it is performed. This does not mean that a composer must intervene in the performance of his/her works. Some are dead and simply cannot do this anymore. No, it means that the completion of a musical work cannot be achieved before its performance has occured. In this

Fig. 60.3. Roger Sessions.

sense, performance is strongly what semioticians call a *deictic* part of the musical sign system: Musical signs reach their full meaning only and essentially through their pragmatic instantiation.

This second insight is strongly related to the gestural aspect since gestures are not lexicographic, they are shifters, as Sessions stresses with his "French" view on gestures. We are not astonished that Manfred Clynes refers to Session's writings in his critique of score-based music.

60.2.4 Manfred Clynes

The Australian pianist and theorist Manfred Clynes conceived expressivity as a shaping of performance in pulses, those embodiments of *essentic forms*, via specific deformations of duration and loudness; see [205, Section 13.3]. He claimed that such pulses were characteristic of the emotional expressivity of composers such as Beethoven, Mozart, etc. Clynes' pulses are not only emotional categories, but also, and perhaps more significantly, curves of gestural utterances. Clynes accordingly constructed and patented a machine, the *sentograph*, providing us with an interface to grasp such gestural movements. Following Clynes' ideas, Hungarian composer Tamas Ungvary has constructed a sentograph that can be used by improvising composers in order to play/create music by gestural input [1069]. Ungvary replaces the usual encoding of sound events at discrete points in a parameter space by an intrinsically gestural input that is given by variable pressure and angle on a joystick (Figure 60.4). Despite the fascinating perspective on musical creation, the

Fig. 60.4. Tamas Ungvary playing the sentograph. The joystick is accessed with the right middle finger.

gestural input remains very abstract insofar as no significant movement of the fingers is possible. The musician has to stay in contact with that fixed piece of metal and cannot move freely in space. This restriction heavily limits the natural human need for movements when gestures have to be created from the living body. Perhaps a more natural encoding of the input parameters would improve the expressive power of this interesting machine.

60.3 Johan Sundberg and Neil P. McAngus Todd

Summary. These two authors discuss gestural aspects in computational performance theory and cognitive modeling.

$$- \varSigma -$$

On a more down-to-earth level, gesture has been studied by Johan Sundberg and collaborators. In a paper entitled "Is the Musical Ritard an Allusion to Physical Motion" [560], Sunberg and Ulf Kronman have studied final ritard as a phenomenon akin to physical ritard. The model conjectures that a tempo decrease at the end of a musical piece would be related to a quadratic function, which appears for mechanical ritard with a constant force. So we suppose that we are given a constant force F, and its action on a given mass m, which generates a constant deceleration $a = F/m$ according to Newton's second law. Given an initial velocity v, the velocity after t seconds is $v - a.t$. Hence the distance $s(t)$ traveled after t seconds is $s(t) = \int_0^t v - a.\tau d\tau = t.v - a/2.t^2$. If the final velocity at time t_0 is 0, we have $t_0.a = v$, whence $s(t_0) = (v/a).v - a/2.(v/a)^2 = v^2/2a$. Therefore velocity at time t is $v(t) = v.\sqrt{1 - s(t)/s(t_0)}$. Supposing that this physical situation relates to the musical one by a constant c, i.e., $s(t) = c.E(t)$, E being the symbolic onset, we get $T(t) = T(t_0).\sqrt{1 - E(t)/E(t_0)}$. This implies

$$T(E) = T(E_0).\sqrt{1 - E/E_0},$$

namely the tempo at onset E being the above function of the tempo $T(E_0)$ at the beginning E_0 of the ritard, the onset E and the beginning onset E_0. The experimental situation is shown in Figure 60.5. The parabolic tempo curve relates to the phase I in the left graph. Phase II is interpreted as a linear tempo decrease.

Besides the poor fit of the measured tempo with the mathematical curve, the question arises why such a mechanical function should hold. What is the musical analog to mass, what is the force analog to a constant mechanical force? We do not see any musical structure entailing such a mechanical model. It is interesting
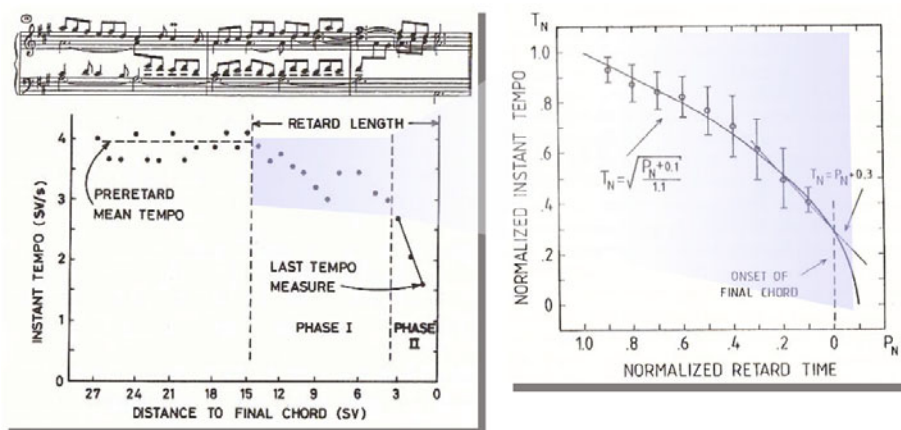
Fig. 60.5. The parabolic tempo curve (right figure) relates to the phase I in the left graphic. Phase II is interpreted as a linear tempo decrease.

that the ritard phase II relates to a quite sophisticated harmonic and melodic musical process, which is not taken into account.

Another mechanical model of agogics has been proposed by Neil P. McAngus Todd in [1060]. He rightly observes that the final retard is only a very special agogical situation and therefore models his tempo curves according to a superposition of accelerando/ritardando units that are defined by a triangular sink potential V. Accordingly, tempo is defined as a velocity v, and the total energy of the system, $E = \frac{1}{2}mv^2 + V$—supposed to be constant (why so?)—gives the velocity formula $v = \sqrt{2(E-V)/m}$. Todd further supposes that there is an intensity variable I for loudness, with a relation $I = K.v^2$ that is common to many physical systems. This yields the relation $I = 2K(E-V)/m$ and sums up to an aggregated formula $I = \sum_l 2K(E-V_l)/m_l$ if the grouping of the piece is taken into account. The idea is that there is a physical energy and intensity parameter system that controls the "surface" of the tempo (= velocity) via classical energy formulas. The background structure is an energetic one, i.e., the tempo curve and loudness are expressions of mechanical dynamics. The author comments on his method as follows [1060, p.3549]:

> *The model of musical dynamics presented in this paper was based on two basic principles. First, that musical expression has its origins in simple motor actions and that the performance and perception of tempo/musical dynamics is based on an internal sense of motion. Second, that this internal movement is organized in a hierarchical manner corresponding to how the grouping of phrase structure is organized in the performer's memory.*

The author also suggests a physiological correlate of this models:

> *...it may be the case that expressive sounds can induce a percept of self-motion in the listener and that the internal sense of motion referred to above may have its origin in the central vestibular system. Thus, according to this theory, the reason why expression based on the equation of elementary mechanics sounds natural is that the vestibular system evolved to deal with precisely these kinds of motions.*

Todd refers to the insights of neurophysiologists that the vestibular system is also sensitive to vibrational phenomena. The musical expressivity is therefore understood as an effect of transformed neurophysiological motion.

The drawback of this approach is that finer musical structures are not involved in the structuring of the energy that shapes tempo/intensity. And even if that could be done, there is an essential kernel of this shaping method that should be based upon paradigms of motion. These paradigms do not however appear clearly in the above approach. More precisely: The complex motion dynamics of the vestibular system cannot easily

be mapped onto the structures of performative expressivity. What is the operator that transforms whatever structures of motion into expression parameters? If music were isomorphic to motion, no such isomorphism could be recognized from Todd's approach.

60.4 David Lewin and Robert S. Hatten

Summary. Here we have a strong argument for a gesture theory in music and performance theory, however without a strictly theoretical conceptualization.
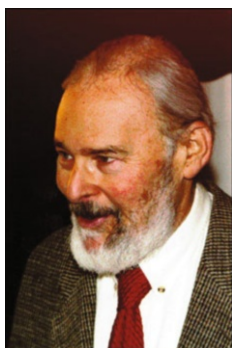
$$- \Sigma -$$

Coming from a seemingly opposite position, namely music theory, the American music theorist David Lewin (Figure 60.6) introduced in 1987 the gestural perspective in his seminal book *Generalized Musical Intervals* [605]. Well, nearly, since the theory and the textual representation are more complex. Lewin's book describes what is now called "transformational theory", later adapted by his student Henry Klumpenhouwer to become K-nets [599]. Such a network replaces an "amorphous" set of tone objects by a diagram, where the tone objects are placed at the diagram's vertices, while the diagram's arrows designate (affine) transformations mapping tone objects into each other; see [34] for a modern interpretation of this theory in terms of category theory. The strictly scientific setup of transformational theory is not really gestural. Lewin argues against what they call the "cartesian thinking", which observes musical objects as *res extensae*.

Fig. 60.6. David Lewin.

Opposed to this passive attitude, Lewin suggests that transformations between musical points (such as pitch classes, for example) are the new path to pursue. In [605, p.159], we read: "If I am at s and wish to get to t, what characteristic gesture should I perform in order to arrive there?" Now, this language sounds very gestural, but is dependent upon different mathematical principles. Let us clarify this subtle mathematical point, which may escape the non-professional. Lewin's theory uses classical transformations and then, in Klumpenhouwer's networks, diagrams of transformations.

We have shown in [719] that Klumpenhouwer's and Lewin's transformational networks are typically points of projective limits of diagrams of affine transformations in musical standard spaces (pitch class spaces, for example). This is a giant step ahead, since projective (and inductive) limits are related to processes, namely the underlying diagrams. Diagrams are systems of transformations between a set of spaces and they relate points in those spaces by determined transformations, see Figure 60.7. But they are not identical with the point systems generated by the so-called limit construction. An intuitive, and incidentally mathematically correct, way of characterizing diagrams is as generalized equations, whereas the objects from the limits are solutions of such equations. So the diagrams play the role of industrial plants, producing facts (*factum*, what is made), namely Klumpenhouwer's K-nets. So the Lewinian digression from cartesian facticity (or extensionality) is the step to processes, but not to gestures.—We have to discuss this difference more precisely in order to understand the missing processes and gestures. In a diagram of transformations, these arrows, which encode transformations, are intuitive graphemes. They are used everywhere in mathematics to denote functions, transformations, or homomorphisms. In category theory, such arrows are called morphisms, and their meaning is absolutely abstract. But already in the classical language as framed by set theory, arrows denote functions f in the sense of Gottlob Frege.

What is such a function? It is (together with its domain X and codomain Y) a set f of ordered pairs (x, y), where the second component y is denoted by $f(x)$. So these two components have nothing more in common than their being part of a set f of ordered pairs. There is no interior relation beyond this association. Coming back to the arrow notation $f : X \to Y$ for such a function, the arrow has absolutely no relation to the interior of its shaft. One could as well write $f : X \diamond Y$. This is a dramatic fact: Arrows suggest a movement, but this is merely illusory. Nothing moves. This has been observed by the French philosopher and mathematician Gilles Châtelet [190]. For example, if we take the matricial representation of a rotation R in three-space, the matrix has no relation to the rotational movement. Matrices are functional objects and do

not imply any continuous displacement of points whatsoever. The only relation of matrices to real movements is created by the calculation of so-called eigenvectors, which may eventually help define a rotational axis, and then an angle or rotation, and finally (!) give the option to realize this rotation by successively increasing the rotational angle from zero to the actual value.
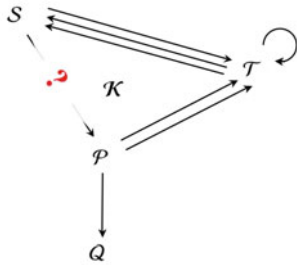

Fig. 60.7. A diagram $\mathcal{K}$ of transformations between spaces $\mathcal{S}, \mathcal{T}, \mathcal{P}$, and $\mathcal{Q}$.

It should be clear by now that the arrow notation for functions is intuitively associated with movements, but does not correspond to any movement at all. Coming back to Lewin's transformational theory, this means that his language that refers to moving from one point to another, and *a fortiori* his suggestion of a gesture relating point s to point t, are different from the reality of his mathematical formalism. He speaks about gestures, but writes about processes. In short: his theory is processual, half way between facts and gestures in terms of the axis of embodiment. It would be very interesting to investigate Lewin's text with that subtext of gestural thinking in mind, since he repeatedly uses this metaphor in a speaking way. With regard to his question about the movement of s to t, he adds [605, p.159]: "This attitude is by and large the attitude of someone *inside* the music, as idealized dancer and/or singer. No external observer (analyst, listener) is needed."

This is a remarkable statement, which leads to the question set forth by music theorist Robert S. Hatten in his book with the now explicitly gesture-related title *Interpreting Musical Gestures, Topics, and Tropes* [446]: "Given the importance of gesture to interpretation, why do we not have a comprehensive theory of gesture in music?" For Hatten gesturality became a core topic when he learned that performance of classical piano music, Mozart, Beethoven, Schubert, is strongly determined by gestural attitudes. This is best exemplified when comparing Glenn Gould's interpretation of Beethoven's op. 57, *Appassionata*, to Vladimir Horowitz's version. Gould's performance completely lacks gesturality. His so-called "analytical' reading is the opposite of what Adorno had recommended, and amounts to Beethoven minus gestures, a substantial negation given the strongly gestural nature of Beethoven's music. Hatten confirms this in theory, as does Gould by his contrafactual experiment.

Fig. 60.8. Robert S. Hatten.

Hatten's definition of a gesture reads as follows: "Gesture is most generally defined as communicative (whether intended or not), expressive, energetic shaping through time (including characteristic features of musicality such as beat, rhythm, timing of exchanges, contour, intensity), regardless of medium (channel) or sensory-motor source (intermodal or cross-modal)." He distinguishes his understanding of gestures from the school of Adam Kendon and David McNeill in that (1) semantic aspects are not characteristic and (2) he stresses "energetic shaping through time", an interesting wording, since the main subject is "shaping", an action, not shaping of something, but pure action. The making in itself becomes a central feature, not the resulting facts generated by the making! And he adds, in remarkable congruence with Wieland's abstract geometry of gestures, that: "at a higher, more symbolic cognitive level, the representation of gesture may be considered amodal, in that it is not restricted to any particular modality."

This shift away from the conservative semiotic perspective on gestures can also be observed in psychology. In Susan Goldin-Meadow's book *Hearing gesture: How our hands help us think* [377], a title reminiscent of Paul Valéry's phrase at the head of this chapter, she investigates the role of gestures in the development of a child's ability to reason mathematically. She writes: "Advances in mathematical reasoning are very likely to come first in gesture—and they do. (...) Do new ideas always come first in gesture, regardless of domain?"

Coming back to the context of musical gestures, the question of semiotics of gestures arises when we display the overall image of traditional Western musical performance; see Figure 60.9. This process starts from the score, which is a text of more or less analyzed symbols. The score symbols are then "thawed" and unfold in gestures, which interact with the interface of an instrument and thusly induce sounding events. (The reversed process of freezing gestures is concretely taking place in a MIDI recording session.) The meaning of music is thereby guaranteed by the dominant role of the score. The entire process is only produced in order to rhetorically communicate the given meaning that was recognized in the score's symbolic code. This canon is
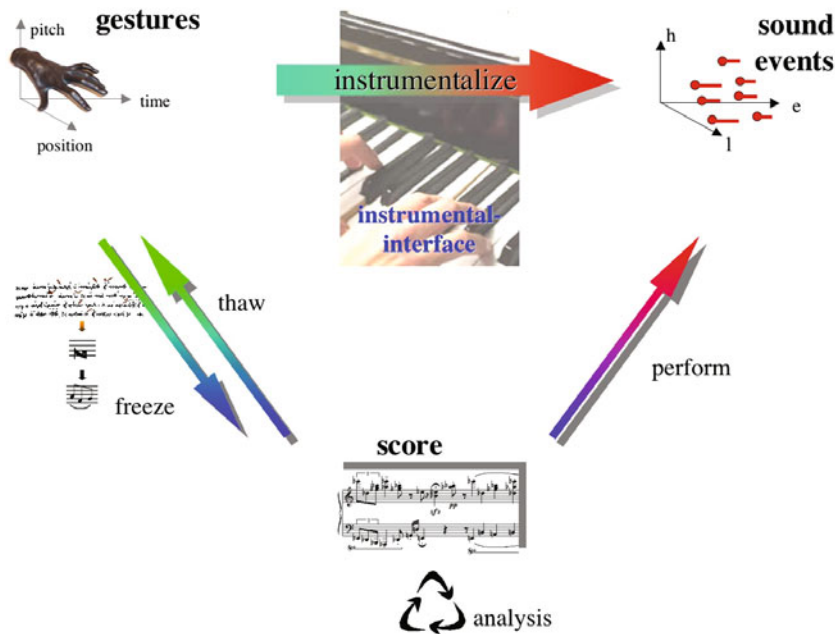
Fig. 60.9. The triangle of Western musical performance.

broken up once the lower vertex of the triangle, the score, is not present. It is not a general truth that music must be produced starting from a given abstract score text. It could as well start from the gestural utterance and its interaction with the instrumental interface that acts like a dance floor for a gestural dance. In other words, the semiotic approach to gestures in music is traditionally related to the score-driven production of music.

But there are many musics that are not score-driven, and free jazz is one of them, while (standard) jazz is not; it is framed in the scores of song forms, lead sheets, and similar ready-mades. It was a dramatic insight in Mazzola's own development as a pianist and as a theorist in mathematical music theory for him to learn that his free jazz playing had nothing to do with score-driven logic and meaning (see [718] for that affair).

Once making music has been freed from the interpretational task of classical Western performance, the question of meaning becomes secondary, making music is no longer just an expression of given meaning. Semantics is no longer the core business, and, as Ornette Coleman states: it is no longer a question of playing the background of other things, such as meaning, symbols, calculations, everything but music.

To summarize, gestures have been recognized as essential to music. The layer of semiotic musical functions has been recognized as being unimportant, or only important in relation to gesture. The background of score-driven rhetoric has been abolished by free jazz and other gesture-oriented music, liberating the musician to freely dance on the instrumental interface. A wonderful example of free jazz without any reference to score or associated semiotics is the double LP *Mu* [195] by Don Cherry, on pocket trumpet, piano, bells, flute, percussion, and voice, and Ed Blackwell, on drums, percussion and bells. The music here is completely free of global strategies. Nobody tells Don and Ed where to go. They just throw gestures at each other and play a game of free gestural dialogs without pre-meditated meaning and significance, creating new sounds that facilitate a gestural dance by maintaining a sonic equilibrium. Although there is a strong reference to something like folk sound, the music is not following any specific ethnic tradition, it is just free playing. Blackwell's percussion is not bound by strict rhythmic frames, and often utilizes the more loose concept of "phase shifting" heard in many varieties of African drumming. Often, he abruptly stops patterns and lets the empty space of time go by, and then takes up another germ of time without any reference, without any

obligation to mean anything. The freshness of this music is exactly rooted in its independence from given semantics. It "don't mean a thing," but it has got so much swing.

60.5 Marcelo Wanderley and Claude Cadoz, Rolf Inge Godøy and Marc Leman

Summary. This section describes more technologically oriented conceptualizations of gestures. Refer to [168] and [371].

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In [168], Claude Cadoz and Marcelo Wanderley give a summary of the gesture concept and its specific structure for the performing musician. Their discourse is based on a list of definitions of a gesture that can be found in dictionaries and gesture research resources. All these definitions are stated in common language and share the following two characteristics:

- Gestures are defined as human body movements that
- carry information or, in other words, are expressive.

This implies that all these definitions interpret gestures as a special type of signs, semiotic instances that express some content or meaning. Carrying information is however arcane: how is information present in a gesture, and where in the movement's anatomy is this information located? Also, the more contemporary concept of information is not defined. And what information is considered relevant?

Cadoz and Wanderley however take a typically French turn and propose a definition that is not semiotic: In [168, p.73], we read: "We consider that the word gesture (or the French equivalent geste) necessarily makes reference to a human being and to its body behavior—whether they be useful or not, significant or meaningless, expressive or inexpressive, conscious or not, intentional or automatic/reflex, completely controlled or not, applied or not to a physical object, effective or ineffective, or suggested."

The main point of their paper is—following their own words [168, p.74]—to discuss human-human and/or human-machine communication through gestures in a musical context. When moving to the concept of a musical gesture, they recognize that theirs may be quite different from the general concept. In fact, one of the musical gesture definitions states that "the notion of a musical gesture that at the time it occurs involves no actual human movement but merely *refers* to it is quite common."

Although they refrain from presenting a universally valid definition of the gesture concept, they admit [168, p.74] that "in essence, the direct or indirect reference to human physical behavior tends to be the common denominator to all the notions."

After the general exposition of the gestural concepts, the authors proceed to a more detailed typology of musical gestures. They refer to Christophe Ramstein's [878] methodology for analyzing instrumental gestures [168, p.74]:

- a *phenomenological* approach, i.e., a descriptive analysis;
- a *functional* approach, referring to the possible functions a gesture may perform in a specific situation;
- an *intrinsic* approach (from the musician's point of view), it is based on the conditions of gesture production by the performer.

In the phenomenological approach, they propose the classification that uses gestural primitives. Following Insook Choi [196], *gestural primitives* are "fundamental human movements that relate the human subject to dynamic responses in an environment." Choi proposes three types of gestural primitives, both device- and signal-independent:

- Trajectory-based primitives: e.g. changes of orientation;
- Force-based primitives: e.g. gradient movements;
- Pattern-based primitives: e.g. quasi-periodic movements.

In the functional approach,[2] following Cadoz's proposal [169], they identify three different functions (complementary and dependent on each other):

- material action, modification and transformation of the environment—the *ergotic* function;
- perception of the environment—the *epistemic* function;
- communication of information towards the environment—the *semiotic* function.

In view of the French generalization to non-semiotic gestures, it is remarkable, if not quite strange, that in the following discussion of an instrumental gesture the authors state [168, p.79]: "Instrumental gesture is considered as a "communication modality" complementary to empty-handed gestures. They are therefore singular in that they possess, *à la fois,* all three characteristics of the gestural channel: ergotic, epistemic and semiotic."

They then focus on gesture typology with this rationale [168, p.82]: "The importance of gesture typologies is then not to completely describe acoustic musical instruments but to provide general guidelines for the design of gestural input devices, mostly regarding the presence of different types of feedback related to different gestures." In the their typology of instrumental gestures, they distinguish between three types:

- *Excitation* gesture; it can be instantaneous (percussive or picking) or continuous.
- *Modification* gesture; it can be parametric (continuous variation of a parameter, such as vibrato) or structural (when the modification is related to categorical differences, such as the insertion/removal of an extra part, e.g. a mute in the case of the trumpet, or a register in an organ).
- *Selection* gesture (a choice among multiple similar elements in an instrument).

The system is then illustrated by a number of case studies, involving different instruments, such as cello, clarinet, and bagpipe.

Godøy's and Leman's book [371] is an edited volume that recollects a number of contributions around the topic of musical gestures, meaning gestures that arise while producing or perceiving music. The contributors include well-known researchers in that field, such as Marcelo Wanderley, Frédéric Bevilacqua, Roberto Bresin, Antonio Camurri, and Albrecht Schneider, for example. The initiative for this book came from a European research project, COST87—ConGAS—Gesture Controlled Audio Systems, running from 2003 to 2007. The book is conceived as a representation of a highly interdisciplinary collaboration, however without aiming at a final discussion of the book's topic.

The book is divided into three parts. Part I, " Gestures in Music", introduces definitions, examples, and a history of gestures in music. Part II, "Gestural Signification", provides a theoretical framework for the formation of signification in gesture in music. Part III, "Gesture Generation and Control", concerns the processing and control of gesture in music.

Answering the question "Why Study Musical Gestures" (title of Chapter 1), it is stated that "we believe that musical experience is inseparable from the sensation of movement, and hence, that studying theses gestures, what we call *musical gestures*, ought to be a high priority task in music research."

In Chapter 2, besides categorizing gestures as poietic or aesthetic utterances, it is stated that the core role of gestures is to provide a "bridge between movement and meaning", it "surpasses the cartesian divide between physics and mind." This is a clear conceptualization of "gesture" as a semiotic entity: it has meaning, although its production is different from meaning that we deal with in linguistic systems: gestures "demonstrate", while languages "say" or "denote". And accordingly, Part II deals with the semantic aspect of this gesture concept.

The definitions of "gesture" are taken from three perspectives: communication, control, and metaphor. Communication happens when gestures are vehicles for meaning in social interaction, control when gestures are elements of computational and interactive systems, and metaphor when gestures work as concepts that project physical movements on cultural topics. Summarizing, they define "musical gesture as an action pattern that produces music, is encoded in music, or is made in response to music." They distinguish between four types of functional aspects of musical gestures: sound-producing, communicative, sound-facilitating, and sound-accompanying, and they represent these four characteristics quantitatively in the 2D plane with two

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[2] The intrinsic approach is not explicitly discussed in this paper.

axes, one spanned by the couple "sound producing/sound-accompanying" , the other by the couple "sound-facilitating/communicative". This representation is used to position musicians as opposed to dancers at their musical gesture values; see Figure 60.10.
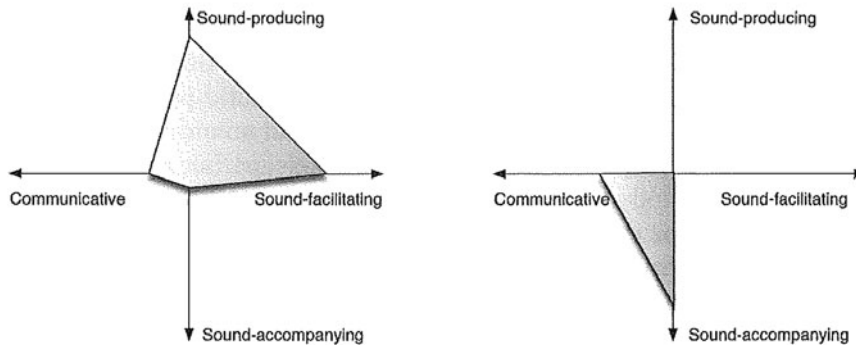

Fig. 60.10. Four types of functional aspects of musical gestures. Left: Musicians, right: dancers.

Chapter 2 concludes stating that "Up until now, there is no single unequivocal definition of gesture, although most authors seem to agree that gestures involve both body movement and meaning." Chapter 3 discusses gestures in performance for a number of classical and electronic musical instruments. Chapter 4 is a historical overview and, after an interesting survey, starting with Aristoteles and Platon, concludes: "The motional and gestural qualities of music have been known since antiquity, and have been developed in various musical styles and genres." However, the reference to Jean-Claude Schmitt's important book about medieval gesture theory is missing, and also the reference to the French gesture philosophy, which is unfortunately completely absent (except for Maurice Merleau-Ponty) in this book.

The gestural production of embodied meaning is addressed in Chapter 6 of Part II. Meaning results from a chain of transformations (synaestetic, kinesthetic, cenaesthetic) from sonic features to cognitive strata. The third, "canaestetic transformation can be seen as a precondition for a fully symbolized type of meaning formation." This confirms the initial principle that "gestures can be understood as close to body movements and close to meaning." "Gesture can be considered as a hierarchically structured action pattern to which we can have mental access."

The concept of "gesture" is differentiated according to the three personal dimensions of "I", "You", "He/She/It". The first person shows a gestural ontology that relates to the concepts of flow, presence, and cause-effect. The second person shows that gestures are more than isolated phenomena, they pertain to a dialogical dimension (also stressed by Émile Benveniste's theory of pronouns; see also Sections 57.9 and 59.1), and this is also confirmed by neuroscience (as made evident by the mirror neuron phenomenon to which this text does not refer). The third person perspective deals with the objectively measurable traces of gestures.

The chapter terminates with the "question to what extent music *is* gesture." It is concluded that music contains gesture but music is also (auto)referential: its internal gestures refer to one-another. As a final conclusion, gestures are characterized as *multi-modal* (audio, motor, etc.), *multi-level* (space-time hierarchies), and *monistic* (bridging the cartesian divide) phenomena. The last Section 7 of this part deals with basic bio-kinetics in activation and signification.

The third part of that book deals with more technical topics: gesture generation and control, discussing gesture and timbre or the conductor's gestures and their mapping to sound synthesis.