Locomotion-Encoded Musical Patterns: An Evolutionary Legacy

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Abstract

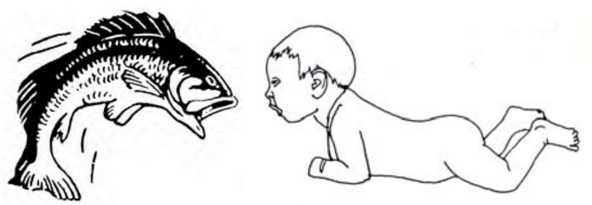
In this paper, I propose a *neurodevelopmental* terminology for the physical actions of musicians, based on the similarities of these actions to the fundamental locomotion patterns of vertebrate species. The terminology describes twenty categories of movements by which musicians produce rhythms and negotiate pitches. The categories themselves, as well as the sonic structures resulting from their interplay, I call Locomotion-Encoded Musical Patterns (LEMPS). I discuss LEMPS as a unique contextualization of neurodevelopmental pattern theory and demonstrate its potential to refer to a vast array of movement possibilities. With examples from scores for piano and other percussion, in which LEMPS are employed as technical descriptors of the human movement content of musical passages, I offer evidence of the uniqueness and significance of individual LEMPS. Audio and video examples illustrate how LEMPS terminology provides distinctive appraisals of musical structure, development, and transformation in improvisational and compositional contexts. On the basis of LEMPS correspondences between musical structures and vertebrate locomotion patterns, I argue for an evolutionary movement legacy inherent to instrumental performance. Finally, I make proposals concerning the usefulness of the terminology in problems of evolutionary musicology: the origins of music, musical processing dispositions, social bonding theories of musical evolution, and memetics.

I. A neurodevelopmental movement taxonomy

Neurodevelopmental movement patterns are locomotive movement strategies used across vertebrate species, generally representative of progressive levels of complexity of an animal's neural organization. They were originally articulated in the early 1940s by Dr. Temple Fay, of the medical faculty of Temple University in Philadelphia. The elements of this taxonomy, refined over decades of use in the fields of physical therapy, movement rehabilitation and movement training, particularly in dance,[1] include the following categories:

[1] My iteration of the neurodevelopmental taxonomy follows Bonnie Bainbridge Cohen (1993), an occupational therapist and theorist of dance training and movement rehabilitation widely acknowledged in the dance field. See Section V.

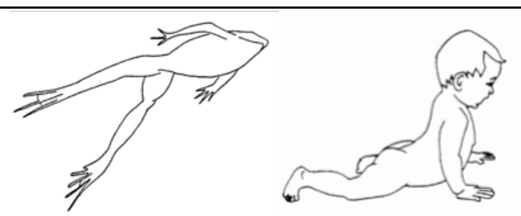
Spinal movement. A progression of movement impulses in the order Mouth-Head-Neck-Spine-Tail. Spinal patterning is exemplified by snakes, fish and other animals with no appendages or minimally significant ones. Spinal patterning is also present in higher-order vertebrates, subsumed in the fuller capabilities of higher-order patterns and used for specialized functions. Spinal patterning is what supports the infant as he lifts his head or the diver as she arcs backwards through space.



SPINAL PATTERNING
Mouth – Head – Neck – Spine – Tail

The diver's Spinal patterning directs her movement.

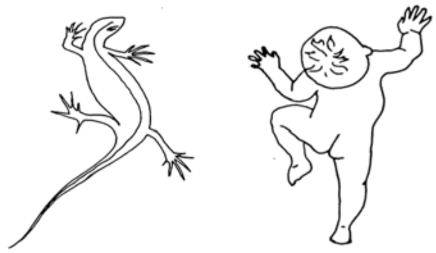
Homologous movement. Involves simultaneous flexion or extension of both upper limbs and/or both lowers. The frog, using homologous movement as a primary mode of locomotion, leaps into space with a symmetrical push through the legs. Higher-order vertebrates such as the dog, the horse, and tiger, when running, push off both lower limbs simultaneously and pull with both uppers, availing themselves of the power and focus of homologous patterns. Infants extend both arms up towards a parent, or move both arms forward to progress from sitting into creeping, "anchoring" in space through homologous reach.



HOMOLOGOUS PATTERNING
Uppers push or reach together; lowers push or reach together.

The Homologous reach supports movement into space.

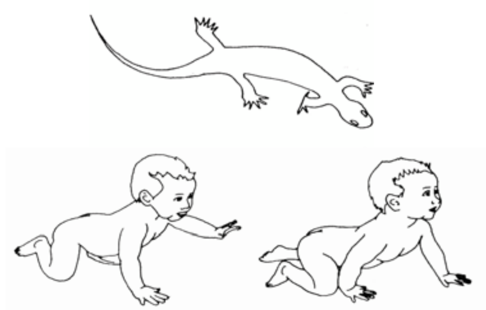
Homolateral movement. In Homolateral movement, same-side limbs, upper and lower, flex or extend together. The sides of the body are clearly differentiated. Although only a few animals (giraffes, camels, some lizards) use the homolateral as a primary locomotion strategy, it appears as a preparatory stage, or an alternative, problem-solving strategy, in many. A baby pulls herself standing by holding on to the couch, then extends same-side arm and leg to "cruise" her way sideways along the couch's length. The archer in this figure uses the support of homolateral patterning to brace her front arm and leg against the force of the drawn bow.



HOMOLATERAL PATTERNING
Same-side upper and lower extremities flex or extend in unison.

Homolateral patterning supports her action.

Contralateral movement. Contralateral patterning links the upper limb on one side of the body with the opposite lower limb. The reach into space of the upper pulls the opposite lower into engagement, catching the forward falling weight of the body. This movement patterning predominates in a great majority of reptiles and mammals, including the runner below.



CONTRALATERAL PATTERNING
Left upper and right lower extremities advance together.

Previous theorization concerning these patterns – their origins and uses – is addressed in Section V. However, we can proceed here on the common sense observation that humans share this small collection of locomotive movement patterns with other vertebrates. Each pattern is consistent in its characteristic features across the groups of vertebrates who have access to it. The patterns seem to be “hard-wired” elements of vertebrate locomotion.[2]

II. The patterns in instrumental music: Strike and Sweep

This account of the role of the patterns in music making begins with an analysis of their function in the production of instrumental music. Percussion instruments, particularly the piano, provide clear examples.[3]

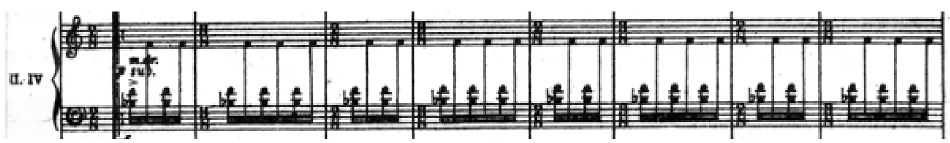
In animal locomotion on the ground, the limbs strike the ground in patterns. When a percussionist plays, his or her limbs strike the surface of an instrument. It does not seem to make a difference, in the experience of musicians attentive to the use of these movement patterns, whether an instrument is in the same plane relative to the body of the player as the ground is to an animal. Whether playing a piano, a marimba, a bass drum in a parade band, or a Taiko drum with hands raised over the head, the act of striking is consistent. Reaching out into space or pulling the limb towards the body, the energetic impulse and the impact of a portion of the vertebrate limb constitutes a *strike* of the instrument.

Applying the vertebrate locomotion patterns to music making: ***Strike patterns*** describe the temporal organization of the impact between the player’s limb and the instrument.

- *Homologous Strike* occurs when both upper limbs (or, in the case of percussionists or organists, both lower limbs) strike the instrument in unison.

- *Homolateral Strike* occurs when strikes from the left and right sides are decisively differentiated from each other. This differentiation may be maintained through either of two kinds of organization:

  The first is strict R/L alternation in the limbs of pianists II and IV at the opening of Stravinsky’s *Les Noces*.[4]



Example 1: Stravinsky, Les Noces, First Tableau, Rehearsal #1, m. 1-7

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[2] By locomotion I mean also brachiation and flight. Neurodevelopmental patterns underlie these movements, too. However, as I have not explored the neurodevelopmental pattern implications, for music making, of either of these modes of locomotion, they get no unique consideration here.

[3] In an unpublished manuscript, *Musical Organization and the Evolutionary Origins of Human Movement*, and in experimentation with string players preparatory to performances, I have extended the application of these patterns to string playing. I anticipate further work articulating the pattern effects of woodwind players, brass players and vocalists.

[4] Strict alternation ceases to *feel* comfortable, or neuromuscularly stable, to a player as he or she approaches a metronome speed of about 120 beats/ minute. At that point, not inconsequentially the approximate speed at which a walking adult would begin to shift into a jog or a run, homolateral patterning becomes difficult to sustain. Impulses having to do with a higher-order pattern - the contralateral (p.5) - begin to emerge in the nervous system and the musical imagery of a player. Players may feel strong impulses to start passing accents between the limbs, in a manner characteristic to contralateral patterning, and introducing contralateral patterning at that tempo relieves the tension of strict alternation at high speed. It is *possible* to perform strict Homolateral Strike organization at high speed, but it is a distinctively tense version of homolaterality. Nonetheless, there are many examples of its usefulness in music. From Kolong Kuma, from the West African Mandinka tradition of *jaliya*, as it appears in transcription in Lynn Jessup’s *The Mandinka Balafon*:

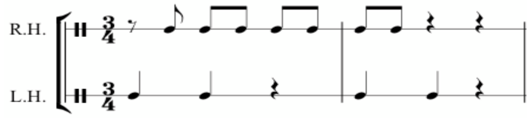
The tension of sustained Homolateral Strike alternation is mitigated by the melodic movement. With no changes of dynamics, and therefore no clear shift to contralateral patterning, there is still the effect of accentuation in the first note of each RH pair. The excerpt plays with ambiguity between the patterns.

The second type of Homolateral Strike is more subtly distributed between the hands. It occurs when one limb[5] strikes (an instrument) in even pulses, while the strikes of the other limb accent (regular, periodic) occurrences of that pulse. As long as accentuation occurs in that one limb only, rather than trading off between the two limbs, and as long as the accentuating limb does not end any phrase on an offbeat,[6] a clear sense is maintained, on the part of the player, of rhythmic patterns on discrete sides of the body.[7] This differentiation gives a homolateral sense.

Example 2: Homolateral Strike

This second type of Homolateral Strike patterning also demonstrates an important principle of locomotion-pattern organization. "Higher" patterns may subsume "lower" patterns and may include incidences of them. In Example 2, a Homolateral Strike instance, are several homologous events as the hands strike in unison.

Should the limb end a phrase on an unaccented beat (an off-beat), as in Example 3, then a successive, answering beat will be supplied (either by the music-maker; or, if the unaccented beat ends a phrase, by the musical imagination of the listener), according to the ongoing pulse of the other hand.



Example 3: Homolateral Strike until last note of LH (reply to RH)

This complicates homolateral differentiation between the hands, creating a distinct form of patterning that will need its own name.

• *Contralateral Strike* patterning occurs when an accent in one limb *passes* to an accent in the other limb. Any syncopated patterning between the limbs results in Contralateral Strike patterning, as do polyrhythms between the hands.[8] A series of strikes in a homolateral context, concluding with a strike on an unaccented beat followed by a strike in the other limb, results in a contralateral event (Example 3).[9] Asymmetrical accentuation (2+2+3, etc.), as in Example 4, is also essentially contralateral, because the agogic accentuation that follows from extra strikes in one hand results in a conversation between the hands -- a reply to the series of extra strikes.[10]

Example 4: Contralateral patterning, as accent moves from L to R at bar

In Contralateral Strike, there will also be subsumed Homolateral and Homologous events. A video file (StrikePatterns) illustrates the three varieties of Strike patterns.

[5] For simplicity's sake the examples are of upper limbs.

[6] "Offbeat" and "on beat" do not, of course, universally describe rhythmic conceptions of musicians. I use the terms in a conventional western sense, confident that their functional analogues in the music of other cultures, including other western music cultures, will consistently yield pattern organization consistent with what is described here.

[7] Offbeat phrase beginnings, however, as in Example 2, initiate limb differentiation, and thus are homolateral events.

[8] A good percussionist can perform polyrhythms so that a sense of homolateral differentiation between the hands, and independent parts, is preserved. Nonetheless, the resultants of combined rhythms will also call to the ear. Polyrhythmic constructions with offbeats in one hand and potential "answering" beats in another are never fully free of the immanent and characteristic conversationality that marks contralateral patterning.

[9] In *Musical Organization and the Evolutionary Origins of Human Movement*, I give a more complete rationale for, and description of, the distinctions between these patterns.

[10] However, a case can be made for homolateral instances of asymmetrical patterns. In a fast 2+3 pattern, where one hand accents the beginning of each group and the other hand fills unaccented beats, the agogic effect and conversational effects seem minimal. All that remains is differentiation between the limbs. In such instances, of course, the accenting hand would have to conclude each section of Homolateral Strike with an "on beat," rather than "offbeat" strike.

Sweep patterns are characterized by the *positioning* of a player's strikes.

The spatial placement and location of strikes of the limbs against the ground, in vertebrate locomotion, helps determine an animal's direction of travel. In music making, rather than indicating direction of travel, the spatial positioning of strikes determines the sound selected for striking. For a drummer, this may be a matter of what drum is being played; for a pianist, it determines what pitch or pitches are sounded.

All neurodevelopmental movement pattern identification follows from the fact that in vertebrate movement the body's midline is a critical reference. Strikes are defined by *temporal* organization on either side of midline. In Homologous Strike, there is *simultaneous* temporal activity on either side of the midline; in Homolateral Strike time is differentiated *independently* on either side of the midline; with Contralateral Strike time is differentiated *interdependently*. With Sweep patterns, the vectors are spatial rather than temporal. Still, they are reckoned relative to midline:

> • *Homologous Sweep* in musicians involves *symmetrical* spatial positioning around the midline of the body.[11] An ideal version of Homologous Sweep in a pianist or drummer means that a musician's limbs either will remain in static symmetry relative to the midline, or will move towards and away from the body's midline in a mirroring fashioning.[12]
>
> • *Homolateral Sweep* requires that each arm remain on its side of midline, but does not dictate symmetrical positioning. One arm may remain anchored in one position while another moves, or the arms may move simultaneously. They may track together up and down the keyboard. They describe spatial patterns in essentially *independent* fashions. As long as neither crosses midline, Sweep remains Homolateral.[13] (Again, the baby reaching along the sofa is a good example.) A great variety of L-R movement of the upper limbs satisfies Homolateral sweep requirements.
>
> • *Contralateral Sweep-by-crossing* occurs whenever either arm crosses the body's midline or crosses over the other arm, thereby *assisting* the other limb in the description of a spatial pattern. Though not every crossing of midline is a contralateral event (a quick, or shallow move of one arm over the midline may not be enough to recruit whatever neurological processes define the pattern), crossovers of one arm above (in the air) or below (tucked underneath) the other arm certainly are Contralateral Sweep instances.

A second category of Contralateral Sweep I call Contralateral Sweep-by-passing.

> *Contralateral Sweep-by-passing* occurs when a sequence of strikes moving in a consistent direction, or in a consistent directional pattern in one limb (a scale, a melodic line, an ascending or descending figure), is continued or taken up by the other limb.

In the video examples (SweepPatterns), the first is Homologous Sweep, the second Homolateral Sweep, the third is Contralateral Sweep-by-crossing, and the last is Contralateral Sweep-by-passing.

III. Characteristic effects of the patterns: Locomotion-encoded musical patterning

An important neurodevelopmental notion, germane to the work of Bonnie Cohen, a preeminent contemporary developer of Temple Fay's ideas, is that all movement patterns involve unique sets of supporting reflexes, sensory pathways and proprioceptive abilities that establish – in the experience of a subject executing them – affective dimensions specific to the movement pattern (1993: 122-156). She calls this combination of psychological and kinesthetic factors the "mind" of a movement pattern (1993: 103).

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[11] In humans, midline is an imaginary line from the apex of the skull, down between the eyes, over the nose, over the sternum and the navel, continuing through the pelvis to the space between the legs.

[12] Vertebrate locomotion, no matter its design, adapts to environmental conditions. Thus, Homologous locomotion does not always feature perfectly symmetrical use of the limbs relative to the midline. Nonetheless, an idealized, symmetrical form represents the essential presentation.

[13] The positioning complexities of Homolateral sweep can be confusing, because many seem to involve a collaboration between the limbs characteristic of Contralateral Strike patterns. However, the execution of Contralateral Strike impulses involves the creation of a coordinated pattern of R and L strikes. In Homolateral Sweep, the actions of L/R positioning are independent. Any Chopin waltz demonstrates this; the player finds LH positions along the keyboard independently of anything the RH does. The strikes of the hands, however, may contain many examples of coordination, opposition, and Contralateral rhythmic play. Such a passage may integrate Contralateral Strike and Homolateral Sweep.

Cohen proposes that vertebrates experience, or more accurately *embody*, aspects of the "mind" of the movement patterns they employ. Pattern-mind can thus be the basis for qualitative distinctions -- distinctions of character, almost of personality – between the patterns. The homologous mind is distinct from the contralateral mind, and so on.[14]

In musical works across cultures, musicians employ specific neurodevelopmental movement patterns in their playing. According to Cohen's version of neurodevelopmental theory, each pattern imparts to its agent, consciously or unconsciously, a specific pattern-mind. If this reckoning of neurodevelopmental pattern experience is broadened to include the (sympathetic) effects of pattern activity on *observers,* or, in this case, auditors[15], then it is no great leap to assert that listening to music includes response to specific organizations of neurodevelopmental patterns. These neurodevelopmental pattern structures in musical activity can be analyzed and described.

Nonetheless, the identification of musical passages as products of neurodevelopmental pattern-activity, even with recognition of distinctive pattern "minds," is still a mechanistic kind of analysis. To identify a musical passage as a "Contralateral Strike passage" is not without interest, but refers only to a narrow and self-referential system of elements. If the terminology is combined with other descriptors, though, a new characterization of musical content is possible. Musical structures executed with particular LEMPS, viewed against structures produced with other LEMPS, can be seen to produce distinctive effects. Thus, LEMPS themselves can be identified as essential components of interesting and meaningful musical structures. The articulated relationships of LEMPS (or, neurodevelopmental pattern artifacts) in a passage of music, a conception for which I suggest the adjective *kinemorphic*, can be useful elements in accounts of musical structure and function.

In Example 5 (StravinskyAudio),

Example 5: Stravinsky, Les Noces, First Tableau, Rehearsal #1, mm. 1-7

[14] Cohen discusses human movement pattern experience with the assumption of a species-wide consistency, but acknowledges that its expressions may vary culturally. An example she gives is an anecdote about Balinese child-raising practices. Carried in their parents' arms from birth, moving almost directly to standing and walking rather than crawling, and thus missing extensive homolateral exercise as infants, most adult Balinese, according to Cohen's report, find hopping on one leg more difficult than do western adults (1993).

[15] Work by Godoy (2003, 2004), especially his motor-mimetic theory, and by Clarke (2001), Cox (2001) and others, though not the subject of discussion here, all contribute to the argument that the physical actions of musicians are intrinsic components of a listener's construction of musical meaning. Supported by theories of ecological listening (Gibson, 1966; Bregman, 1990) that demonstrate how a listener subconsciously accounts for multiple characteristics of a sound source, this body of thought suggests that in listening to any music, the locomotor patterns referred to in the LEMPS terminology would be in constant, mostly unconscious, ideomotor play in the musical imagination of a listener.

Pnos. I and III underline the vocal with powerful and expressive, rhythmically impulsive Homologous patterning. Pnos. II and IV employ a version of Homolateral Strike patterning, in strict alternation, rigid and mechanistic. The direct juxtaposition of these dynamic forces – initiated at the opening beat, with very different figures: one jagged and irregular, the other motoric – helps establish the signal ferocity of Les Noces at its first notes.

In Example 6 (ProkofievAudio),

Prokofiev, Visions Fugitives, Op. 21, No. 3, mm.1-3

regular offbeat chords in the treble suggest Homolateral Strike, with subsumed homologous coincidences on offbeats of 2 and 4. Yet, the LH beat 3 and the RH offbeat of 3 are contralateral answers to the notes preceding. Beat 4 of m.1 seems to restore alternation and homolaterality, but for the successive unison on the offbeat. The pattern character of this passage is deceptive play between homolaterality and contralaterality. The contralaterality is rather demure and smooth, sliding along a trellis of homolateral alternations, sectored by the Homologous Strike that caps m.1, and seems to cap m.2 until the m.3 asserts otherwise.

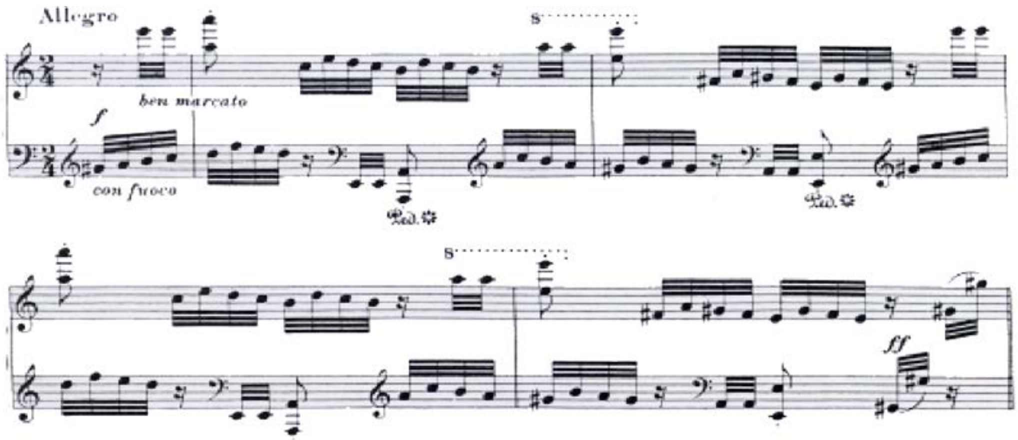
The Beethoven of Example 7 (BeethovenAudio)

Example 7: Beethoven, Op. 13, i, mm. 27-40

illustrates interaction of sweep and strike patterns. Muscular RH descending chords are deployed in stately, symmetrical Homologous Sweep patterning between the hands. Homolateral Strikes – half notes in the RH against a tremolo in the LH – broaden the passage energetically as the melody descends momentously. On the cadence in the penultimate measure, Homolateral Strike activity between the hands is echoed by homolateral alternation in a single hand[16], on the B and C of the last two measures.

In Example 8 (BrahmsAudio),

[16] See Section IV.



Example 8: Brahms, Paganini Variations, Op. 35, Book I, No. 14, mm. 1-5

the nearly maniacal animation of a very square harmonic rhythm is a function of Contralateral-sweep-by-passing, the mostly stepwise middle voice exchanged from hand to hand. The whirling Contralateral Sweep activity is turned virtuosic by integration with the Homolateral Sweep gestures of alternating stabs into extreme octaves, further pixilated by small Homologous Strikes, in rapid sixteenth note unisons, between the hands.

IV. Scope of the LEMPS Terms

All three Strike and all three Sweep patterns result from relationships between the limbs. It is also possible to identify pattern events in a single limb. This notion depends upon two concepts. The first is the validity, neurologically speaking, of the attribution of two-limbed neurodevelopmental pattern *effects* to single-limbed movements; second is the delineation of single-limbed movements into neurodevelopmental locomotion categories.

Both questions can be addressed through the concept of *motor equivalence*, as summarized by Godoy (2004) from research by Deecke (1995) and others. Motor equivalence involves alternative executions, using alternative parts of the body, of "motor programmes . . . mental image[s] of an action or sequence of actions."[17]

As there is no empirical research correlating single-limb movement *or* two-limbed locomotion with the neurodevelopmental taxonomy, it is left to common sense to recognize that some single-limb movements involve motoric and affective experiences with a kind of equivalence to two-limbed pattern movement. For the listener and for the musician (also a listener), single-limb sound patterns often evoke two-limbed locomotion-pattern imagery. In fact, the "two-limbedness" of the musical image may be remarkably congruent, in the experience of listener and player, with its one-limbed execution.

In Example 9 the LH pattern might be played with one-limb or two. Either would be syncopated, thus contralateral, upon successive strikes in the higher registers in m. 2.

Example 9. Bartok, Suite Op 14, I, mm. 15-18

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[17] Motor equivalence is also the basis for the representation of the four-limbed developmental movement patterns as two-limbed patterns in the upper or lower limbs of musicians,

Such equivalences are, anatomically speaking, no accident. There is an uncanny likeness, in the anatomy of the single upper limb, to the agents of neurodevelopmental locomotion -- right-side/left-side arms and legs. The two bones of the forearm, the radius and ulna, although anatomically spiraling around each other, create a left-ness and right-ness within the arm[18] that can be used to identify motor equivalences of Homologous, Homolateral, and Contralateral patterns in a single limb. That these equivalences are persuasive to players, as well as to listeners, is an assertion that depends, for the moment, on the cumulative perceptions of those musicians and auditors who have examined this theory and its examples.

Systematic descriptions of the principles defining strike and sweep characteristics of Homologous, Homolateral and Contralateral patterns at the level of a single limb (which in pianists, string players and hand drummers extend to activity at the levels of the fingers as well) are beyond the scope of this article.[19] However, for the purposes of illustration and for the sake of several musical examples here, a few elements of single-limb-pattern identification at the keyboard will be helpful.

a. Pattern definition in a single hand at the keyboard is contingent on L/R differentiation within the forearm. "Sides" of the hand are figured according to the relationship of fingers with the radial and ulnar bones of the forearm: the thumb, index and middle fingers indicating the radial side of the hand; the fourth and fifth fingers the ulnar. (The sidedness of the middle finger can be ambiguous.)

b. Homologous Strike in a single hand involves simultaneous strikes through fingers on *both* radial and ulnar sides. Homologous Sweep involves successive single-hand Homologous Strikes through fingers combinations symmetrical with respect to the middle finger (1/5 moving to 2/4, 3 moving to 2/4, etc.)

c. Homolateral Strike in a single hand involves finger patterns that preserve L/R differentiation in the hand. These include tremolos, trills, or repeated strikes of the same note, executed on strictly alternating sides of the hand or a single side of the hand; also, a pulsing finger or fingers on one side of the hand against a finger or finger on the other side, accentuating pulses with no phrases on an offbeat. Homolateral Sweep would include stepwise or arpeggiated passages whose fingers strokes either do not cross midline of the hand, or if they do cross the midline, alternate *arrays* of strikes in a way the preserves differentiation. Such arrays might move back and forth symmetrically across the two sides of the hand, in L-to-R-then-R-to-L patterns evenly distributed across the fingers. Additionally, Homolateral Strike and Sweep configurations in one hand may be moved along the keyboard to new locations, avoiding contralateral techniques in all positions, and thus sustain homolateral organization over wide ranges of pitches.

d. Contralateral Strike in a single hand results from "conversation" of the fingers across the middle finger (other than strict alternation), including polyrhythmic or polyphonic play. Contralateral Sweep involves cross-over or cross-under of fingers; "passing" notes across the midline of the hand; and reversals of direction, within a stepwise or arpeggiated line, that disrupt symmetrical L-to-R-then-R-to-L patterns.

Here are three examples of Individual Hand LEMPS:

Example 10 is Homologous strike at the level of the fingers, with each finger striking simultaneously with the others:

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[18] More precisely: supination and pronation of the forearm. Relative to the rest of the body, with palms turned down in an approximation of animal locomotion, these rotations prefigure "left-ness" and "right-ness" in a single limb.

[19] Pattern incidences are not necessarily the same at the levels of bilateral coordination and single-limb coordination. For instance, Homolateral Strike between the limbs, in common practice literature, is ubiquitous and largely stable in its appearances, but at the single limb level is likely to turn Contralateral at any point in a passage. In all but the shortest or most stable of contexts, melodic lines tend towards Contralateral Strike patterning in single-limb strike patterning. This may reflect the neurological sophistication of the human brain in relation to other animal brains: with the fingers the predominant agents of hand movement, a corresponding shift, in neural support and processing, for the increased refinement of limb movement that contralaterally agile digits facilitate.

Example 10. Shostakovich, Twenty-Four Preludes and Fugues, Prelude I, mm. 1-6

Example 11 uses Homolateral Strike in the fingers of the RH. The R and L sides of the RH execute a motor-equivalence of clearly differentiated L and R limbs:

Example 11. Bach, Prelude XXI, Bk. 1, Well-Tempered Clavichord

Example 9 deserves a second look, now that principles for pattern differentiation in one limb have been articulated. The alternation of the sides of the LH is at the beginning Homolateral Strike, then turns Contralateral with the syncopation in m. 2:

Example 9. Bartok, Suite Op 14, I, mm. 15-18

The six types of Strike and Sweep patterns created by the use of the hands together, the six types of Strike and Sweep in a single limb, and Strike and Sweep versions of the Spinal pattern (although not discussed here), total fourteen patterns that can be used in musical contexts. However, single-limb limb patterns can sometimes be analyzed with greater refinement upon consideration of the movements of individual fingers.[20] This level of detail is not technically necessary for this presentation of applications in the field of evolutionary musicology, so it not covered here in any depth. Nonetheless, it is important to recognize that locomotor pattern expression is possible at many levels of musical expression. Finger Strike is expressed in both Strike and Sweep patterns, so six more categories are sometimes needed (Homologous Finger Strike, Homologous Finger Sweep, etc.).[21]

Overall, there are 20 possible categories of patterning available for use as LEMPS:
3 Strike patterns, 3 Sweep patterns of the **hands together**
3 Strike patterns, 3 Sweep patterns in **single limbs**
2 Spinal patterns: Strike and Sweep
3 Strike patterns in the **fingers**
3 Sweep patterns in the **fingers**

[20] See description of Homolateral Strike in a single limb, p. 10, for instance.
[21] Alternatively, strike and sweep in the fingers can be analyzed as a variant of strike and sweep in the individual limb (or hand); but both possibilities occur.

V. Previous contextualization of neurodevelopmental patterns

The chief purpose of this paper is to explore how the LEMPS terminology pertains to evolutionary musicology. This involves ways in which Locomotion-Encoded Movement Patterning has been a factor in shaping the evolution of musical behavior; it also concerns the application of LEMPS to problems of ongoing "evolutionary" activity in music. The broad objective is to explore the usefulness of the LEMPS patterns in as wide a range of evolutionary problems as possible.[22] Before turning to these issues, however, it will be worthwhile to summarize and contextualize previous theorizations of these neuromuscular pattern movements.

Temple Fay's original formulations of vertebrate movement patterns arose from his search for effective approaches to physical therapy with cerebral palsy patients. All suffered movement impairments associated with lesions of the "high-brain" cerebral cortex. Fay thought these patients might be able, through use of movement patterns established over the course of vertebrate evolution, to utilize "low-brain" centers to enlist movement in place of that which the high-brain lesions have compromised (Fay, 1947). As low-brain centers are, evolutionarily speaking, older structures, he hypothesized that movement patterns associated with relatively primitive stages of vertebrate nervous systems might correspond with neural activation in the older, low-brain structures. He reasoned that the performance of movement patterns of the appropriate evolutionary stage might gradually stimulate corresponding low-brain controls.

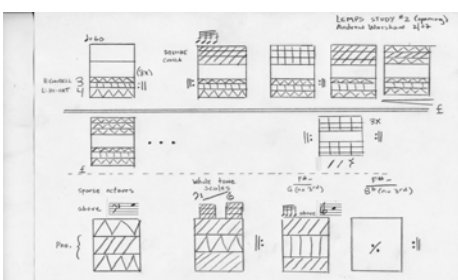
After extensive observation of animal movement, Fay identified a progression of "evolutionary" stages of vertebrate movement that he correlated with "types" of neurological deficits identified clinically in patients with cerebral palsy or traumatic brain injury (Wolf, 1963). At the

[22] It may be helpful to briefly survey a number of ongoing or future applications of the LEMPS terminology involving research I have done personally with musicians. These are of only indirect concern to issues of evolutionary musicology, but other investigators of this taxonomy may make evolutionary connections that go beyond my own:

1. Extension of locomotion pattern analysis to other instrument morphologies.
Some work has been done for cello, theoretically and in performance.
Theorization of voice and woodwinds forthcoming.

2. **Description and Analysis.**
Theorization of juxtapositions, transitions (upshifting/downshifting) and transformations of patterns.
Kinemorphic descriptions.

3. **Composition/Improvisation/Notation**
Pattern terminology learned by small ensemble.
Performances of structured improvisations using pattern notation.
Beginning efforts with notational system.



Opens with Perc. improvising ¾ figure in feet using Contralateral Strike and Homologous Sweep.
Next figure (reading to the right): Perc. adds hands on djembe and conga.
Piano enters in second section (bottom line) with patterns scored in limbs, then limbs and fingers.

4. Research.
Examination of Bach Cello suites for pattern options in bowings.
Ergonomics-of-drumming.
Typology of metaphors: variations in correspondences between movement patterns and sounds generated by them.

5. Future projects.
MRI investigation of musicians performing LEMPS.
Motion Capture of movement for pattern-analysis and dance/music collaborations.

Neuro-Physical Rehabilitation Clinic he founded in 1943, Fay experimented with positioning and manipulating patients according to a variety of vertebrate patterns. The therapy involved "recruiting" movement reflexes in a cerebral palsy patient, to elicit and support locomotive movement patterns that patients found difficult to attain (Page, 1967). An indication of the manner of results Fay obtained appears in a speech to the Institute of Psychiatry and Neurology of the V.A. Hospital of Lyons, N.J. (1954). "Who is to complain," he said, "when spastic hemiplegia coordinates like a dinosaur and leaves his bed or chair for greater freedom of action, or feeds like an amphibian, if it releases another to join society again and makes the patient less dependent?"

Fay wrote numerous professional articles describing his theories, clinical practices, and results, and gave many presentations at professional conferences over the decade and a half between the early 40s and late 50s (Wolf, 1963). By the early 1960s, however, medical interest in Fay's techniques had crested and waned along with his political fortunes as one of the founders of the Cerebral Palsy Association. The most visible promulgators of his approach were, by then, his former students Glenn Doman and Carl Delacato, for whom Fay acted as mentor and consultant until 1957 (Wolf, 1963).

In 1955, Doman and Delacato founded the Institutes for the Achievement of Human Potential (IAHP), where they explored Fay's neurological concepts. Eventually, the IAHP would make broad claims for the efficacy of "repatterning" the brains of neurologically unimpaired, as well as brain-injured, children using movements derived from Fay's neurodevelopmental categories. However, the Doman-Delacato "patterning" techniques received vociferous early criticism from the American Academy of Pediatrics and others (Cohen et al., 1970; Neman et al., 1975; Zeigler, 1975). A number of studies failed to demonstrate that the patterning of (passive) subjects produced evidence of superior learning abilities in unimpaired children, or produced signal improvements in the cognitive performance of brain-injured children. The AAP position was most recently reiterated in a 1999 statement (Ziring, et al) and was reaffirmed by the organization in 2002 and 2005.

Though the IAHP has thrived for fifty years, its reputation is mixed. Its intensive approach to the optimization of early childhood learning, as well as its work with brain-injured children, has been profiled on Nightline, national news broadcasts and in national publications. Its website lists branches in Italy, Brazil, and Japan, as well as offices in Japan, Mexico, Spain and France. A research/education partnership with NASA appears, according to the IAHP website's citations, substantive, though not necessarily current. Extensive clinical successes are reported in IAHP in-house publications, though not in independent, peer-reviewed journals, nor as the results of controlled studies. It is not hard to find vivid, inspiring and intelligent testimonials to the successes of patterning as a therapeutic approach, particularly as a modality used in conjunction with other somatic therapies (McGehee, 2003). However, critics of patterning respond that many gains attributed to patterning would have occurred without it, as developmentally delayed brains mature in a normal, though delayed, style. To this, patterning's many adherents might reply that movement's effect on the brain is not yet well understood, and that in the future, verification of patterning effects will appear. In any event, it is clear that Fay's ideas have been extensively exploited in this arena.

However, the IAHP represents a less important factor in Fay's neurodevelopmental pattern legacy than might be supposed. Fay himself was not much in control of the development of patterning work after the closing of his clinic (Wolf, 1963). His work in the years before his death covered a broad spectrum of concerns in addition to patterning.[23] Moreover, the IAHP was not the sole avenue of advancement of his ideas. Several other organizations started by associates of Fay's, such as Bette Lamont's Developmental Movement Center in Seattle and Florence Scott's Northwest Neurodevelopmental Movement Center in Eugene, Oregon, still operate today. All use a form of "patterning" based on the Fay/Doman-Delacato approach. A number of physicians, of Fay's era and after (Page, 1967), associated themselves with his approach, and mainstream occupational and physical therapists including Margaret Rood,

[23] In 1959 he became Vice-President of the Cerebral Palsy Association, which he had helped to found. At his death, Fay was dismayed by the lack of controlled studies of his methods. He was similarly chagrined about the insufficient number of controlled studies of the effects of *any* physical therapy on cerebral palsy patients (Wolf, 1963).

Dean of the UCLA School of Physical Therapy during the 60s and 70s,[24] reflected elements of Fay's work in creating *neurofacilitation* approaches to movement pathologies. To the current day, even neurodevelopmental therapy approaches that do not explicitly use patterning based on evolutionary sequences acknowledge Fay's significance as a theoretician of reflex-oriented physical therapy. [25]

The legacy of Fay's movement pattern work in the medical and therapeutic field may be hard to assess, but its effect in another field – dance and movement education – is not. Cohen, an Occupational Therapist, Registered Movement Therapist, dancer and dance educator whose iteration of Fay's patterns is employed here, was exposed to Fay's ideas through his writings and through Rood in the early 60s. She has refined Fay's ideas about neurodevelopmental locomotion patterns and recast them as elements of a broader scheme of physiological organization she calls Basic Neurological Patterns (BNPs) (Cohen, 1993). Cohen has applied the BNPs in the rehabilitation of children and adults with an array of movement and cognitive difficulties, but she has also brought them to bear on the movement training of dancers and other performers.

In this respect, she has aligned herself with some of the most notable twentieth century traditions of movement theory and analysis. The pre-eminent figure in the analysis of modern dance movement is probably Rudolph Laban, the inventor of a broadly used system of movement notation and the originator of Effort-Shape analysis, a critical model in the field. Laban left no single authoritative publication of his ideas, but one of his prime students and interpreters, the teacher and movement theoretician Irmgard Bartenieff, writes:

> The developmental stages in the achievement of full postural locomotion can be correlated with the discovery by Magnus and Rademacher (in the 1920s) that postural reflexes use four levels of the brain. These are: (1) spinal, (2) brainstem, (3) midbrain, and (4) cortical. The stages of development of postural locomotion, brought to light through the application of the concept of postural reflexes and their [brain] levels, show a marked parallel to the degrees of complexity of movement identified by Laban. . . . The analysis of both Laban and neurophysiology agree that the degrees of complexity of postural locomotion in space proceed from simple constellations of limb movement to a differentiation of right and left, then, with emphasis on the vertical axes, to the full, final use of the cross of the vertical and diagonal axes in space (Bartenieff, 1974).

Bartenieff herself originated a training system called Fundamentals, whose descriptions of "Body Part Relationships" include striking parallels to Fay's taxonomy. Bartenieff identifies a *Head-Tail* organization, parallel to Fay's Ocular-Head-Neck-Trunk-Tail pattern. Her *Upper-Lower* is Fay's Homologous; her *Body Halves* is Fay's Homolateral; her *Diagonal* is Fay's Cross-Diagonal and Cohen's Contralateral.

Dr. Rima Faber, Program Director of the National Dance Education Organization, the premiere national advocacy organization for dance education, writes that Cohen's work "has, indeed, been transformative for dance education and in understanding the relationship between early motor development and cognitive development. The National Dance Education Organization has embedded [Cohen's] Evolutionary Movement progression into the 'Standards for Dance in Early Childhood' and 'Standards for Learning and Teaching Dance Education in the Arts, ages 5-18' (NDEO, 2005) published in 2005 to outline what students should know and be able to do in dance."[26]

Cohen's *School for Body Mind Centering* has produced several hundred practitioners and teachers, all certified in the developmental movement taxonomy that is central to the BMC approach. Through her students, and through her students' tens of thousands of students, and

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[24] Bonnie Cohen, Personal Conversation, 2007. Her viewpoint is supported by such evidence as the February 1967 issue of the American Journal of Physical Medicine, titled *An Exploratory and Analytical Survey of Therapeutic Exercise*, in which articles on the Fay Method, the Rood approach, and on the Proprioceptive Neuromuscular Facilitation (PNF) approach of Kabat, stress similar themes of manipulation according to developmental recapitulation.

[25] These approaches, which can be investigated under the rubric Neuro Developmental Therapy (NDT) are more likely to use a form of therapy aimed at inhibiting primitive reflexes that interfere with the postural reactions necessary for unimpaired movement, and thus lead to developmental delays. The work of those who practice NDT ultimately involves eliciting and coordinating effective reflexes and righting-reactions, but without Fay's concept of evolutionarily-delineated neural "wiring" that distinctively integrates collections of reflex actions into pattern movements.

[26] Personal correspondence, July 16, 2007.

by the broad adoption of her “evolutionary movement” sequences in the dance community, Cohen has widely disseminated Fay’s ideas.[27]

Cohen’s presentation of an evolutionary scheme of neurodevelopmental movement has been more broadly convincing in the dance field than Doman-Delacato’s in the therapeutic; however, they are subject to similar forms of scrutiny. With the past century’s widespread rejection of Haeckel’s “Law,”[28] “Ontogeny Recapitulates Phylogeny,” there has developed the tendency to broadly devalue correlations of individual characteristics and species-wide characteristics. Stephen Novello, for example, in scathing commentaries on patterning, correctly cautions that embryos do not literally pass through stages of a vertebrate legacy (1999) and rejects patterning on the grounds that there is "no theoretical basis for the belief that [therapeutic movement] patterns can be impressed upon the developing cortex" (1996). This however, does not speak to the notion that therapeutic or otherwise useful movement patterns might be at once elements of a vertebrate legacy and inherent elements of neural structures. Patterning may represent a legitimate attempt to interact with those elements.

A critical point, in review of the theorization of the neurodevelopmental patterns, is that there has been no direct experimentation aimed at validating the neurological correlations at the heart of Fay’s work. There are no fMRI scans of subjects engaged in one or another neurodevelopmental pattern. Though one study was designed to investigate "claims . . . regarding neurological activation during the performance of developmental movement patterns" (Eddy, 2000), no experimentation occurred. A current clinical trial titled *Brain Reorganization in Cerebral Palsy* is recruiting subjects to examine brain lateralization in CP sufferers[29], but there exist no imaging studies of cerebral palsy patients correlating neural lesions with pattern-movement impairments. Ultimately, there is no experimental record on correspondences between neural activity and the movement patterns named by Fay. The patterns have not been scientifically evaluated in a manner commensurate with their widespread use over six decades.

Controversy over these patterns has been, more precisely, controversy over claims for the efficacy of their uses, rather than over the nature of scientific, or pseudo-scientific, correlation of movement patterns to neural substrates. It may seem plausible that such categories of movement, so salient in their significance to professional dancers, should have distinct and specific neural substrates (either of structure or of processing). However, little is known, empirically, about Fay’s central hypothesis: that there exist whole-body, hard-wired movement patterns that reflect the neural organizations of our phylogenesis. All that clearly stands is a working hypothesis, shared by Fay, Cohen, Doman-Delacato and others: that a set of inherited locomotive movement patterns, of a taxonomy shared with those of other vertebrates, are fundamental elements in the motor development and movement vocabulary of humans.

What is important about Fay's ideas, for issues of evolutionary musicality, is that they provide a basis – *that may prove to be neurological* – for dividing music-making movement into interesting and significant categories reflecting our phylogenetic heritage.[30]

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[27] An incomplete list of dance training institutions that have offered, or sponsored, classes based on neurodevelopmental pattern concepts: The Laban Center (London), Center for Kinesthetic Education (NYC), Movement Research (NYC), The State Theaterschool (Amsterdam), Dartington College (Great Britain), New York University Dept. of Dance, Tricia Brown Dance Company (NYC), American Dance Festival, Five College Dance Department (Western Mass, USA), The Moving On Center (San Francisco), Naropa Institute (Boulder, Colorado), and hundreds, if not thousands, of other universities, festivals, dance studios in the U.S., Europe, Asia, and South America.

[28] Haeckel’s Law, or The Biogenetic Law, or *Recapitulationism*, applied to humans, holds that the development of humans’ structures from conception to maturity (the entire process is called *ontogeny*) follows, closely or exactly, the chronological evolution of the structures of our (phylogenetic) ancestors. It has been long discredited. However, it is today more accurate to say that Haeckel’s Law has been modified, rather than rejected. All credible commentators acknowledge similarities between the embryologies of different species (as observed by Baer prior to Haeckel), as well as the fact that ontogeny does indeed refer to phylogeny, though inexactly. For an example of science that acknowledges the general validity of the Biogenetic Law, while energetically limiting its application, see Medicus (1992).

[29] National Institutes of Health, Bethesda, Maryland, study numbers #01-N-0260, #04-N-0098, or #05-N-0066

[30] The significance of a theory of movement patterning, at least for modeling the evolutionary significance of any action that involves cognition (and music making certainly fits this bill), may be underlined by surprising sources. Rodney Brooks, a noted theoretician of Artificial Intelligence systems, writes in *Cambrian Intelligence*, an investigation of the basis of symbolic thought, that “problem-solving behavior, language, expert knowledge . . . and reason” are “pretty simple once

Poignant differences between the Cohen and Doman-Delacato approaches point the way towards the most effective application of these patterns to issues in evolutionary musicology. Contrast the following passages, characterizing the IAHP and Cohen's different approaches to "patterning." First, Glen Doman (1974) describes his work with a child

> . . . with a midbrain injury, who could not move his arms and legs . . . in the exact pattern that the midbrain was designed for. . . . We decided to "pattern" him. . . . The patterns were administered by three adults, and were to be performed smoothly and rhythmically. One adult turned the head, while the adult on the side toward which the head was turned flexed the arm and extended the leg. The adult on the opposite side extended the arm and flexed the leg. When the head was turned the other way, the position of the limbs was reversed. Through the years [of "patterning" therapy at IAHP] the basic pattern has remained the same, with only slight modifications. We found eventually that when this patterning was done often enough, consistently enough and in a time pattern, which we made more rigid as time went on, then indeed many a child with a hurt midbrain would begin to creep and, indeed, once creeping began, walking followed since it was normal to his well cortex.

Here is Cohen's orientation, as described in a 1984 interview:

Q: What do you mean when you say you're "patterning" someone?

Cohen: First of all, when I just put my hands on, I can tell where the force [of the patient's effort] is, and if I feel the force going perpendicular to the axis of [desired] movement, then I might do any number of things to eventually direct the force. But I rarely move perpendicular to their force. I always try to join it and swing it around. Like yesterday, I wanted one of the children to walk along the couch. But I didn't want to *make* the child do it. Instead, what I did was try to entice her, so that she *wanted* to walk along the couch and then I could work with her. I tried to stimulate her attention and intention in this activity, and then worked within her framework (Cohen, 1993: 110).

Cohen's approach reflects a "Dynamic Systems" orientation to motor development (Thelen, 1995). Such a view declaims any 'essence' of a movement behavior, but considers all movement behavior multi-causal, emerging as a series of solutions to tasks in an ever-changing environment. Doman's investment in a highly specified performance of a neurodevelopmental pattern movement is of a different spirit. It signals a belief that the movement represents an essential expression of "midbrain" motor activity. But in an ecological framework such as Cohen's, movements that meet the precise criteria of taxonomic categories are neither ideal movements, nor engines of motor development; they are superbly efficient, evolutionarily tested movement strategies that suit us so well, humans ubiquitously employ them. The neurodevelopmental patterns deserve, on that basis, to be reference points in movement training and rehabilitation. However, no single individual's optimal use of this movement repertoire can be reliably proscribed. It must evolve in situ.

Likewise, the role of these patterns in musical activity, if one follows Cohen's presentation, should be expected to reveal itself most fully with an ecological approach. An investigation of the use of these patterns in musical contexts should focus on their evolutionary values as solutions to the specifics of social and environmental, as well as purely auditory, problems and opportunities.

VI. LEMPS in an evolutionary perspective

In the video clip GiraffeMozart, a giraffe walks the savanna to a few measures of Mozart's Sonata in Bb K. 333, i. The giraffe is a homolateral walker; she anchors both limbs on one side, front leg and back, before the next step can be taken. On the alternating, asymmetrical supports of this coordination, she is exquisitely balanced.

The Mozart has many homolateralities, too, though first one must listen *through* the twists and turns of the melody in the treble. These are Contralateral Sweep effects, expressed at the

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the essence of being and reacting are available. That essence is the ability to move around in a dynamic environment, sensing the surroundings to a degree useful to achieve the necessary maintenance of life" (1999). This suggests that musical cognition, on the basis of its problem-solving behavior and expert knowledge alone, not to mention its design components, its hierarchically ordered elements, and more, is also built upon the foundation of perceptual and locomotive abilities, the "essence of being and reacting."

level of the fingers. For homolateral effects, attend to each phrase ending: they alight precisely on quarter notes as prescribed in Homolateral Strike. Listen to the rhythmic relationships between the treble and bass hands – how cleanly the lines differentiate and how distinctly their rhythms sound, also the result of Homolateral Strike patterning. The movement in the bass passes evenly through the intervals of arpeggiated chords (Homolateral Sweep), then it settles on one pitch, a C, trolling out away from C on every other note and returning to it – one venturing note for each anchoring note – so that anchor and explorer are at every point equally poised. These are all musical effects of Homolateral locomotion patterns. K. 333 is animated by traces of homolateral vertebrate locomotion.

In every phrase of this (and other) piano music, locomotion patterns are present. Some pattern declarations are so common as to become cliché, but this should be no surprise; when movements are habituated, they can easily be elicited with little, or weak, motivation. Nonetheless, musical impulses long ago emerged from locomotion patterns; then music began to be made from these patterns, and now it cannot cease to express them.

The following are a number of ideas regarding the potential, for the field of evolutionary musicology, of the neurodevelopmental pattern concepts. These are offered primarily as provocations, rather than as any kinds of findings, intended to suggest a wide-ranging potential of the LEMPS terminology as a musicological tool.

1. The full range of neurodevelopmental movement patterning was a necessary precondition to the development of musical activity in the EEA (Environment of Evolutionary Adaptation).

The neurodevelopmental patterns are not unique to humans, nor are they specific to musical tasks. Obviously, they did not evolve to facilitate musical activity. Nonetheless, music could not have evolved the way it has, but for hard-wired neurodevelopmental movement behaviors.

Upright locomotion has been previously theorized as a precondition for metrical cognition (Trainor, 2007; Merker, 2001). Trainor suggests that preferred tempos of children and adults, as well as preferred entrainments to a pulse, may vary according to previous physical experiences: the gait of the listener, or in the case of a child, the gait of a caregiver, who provides an infant with early movement experiences. Merker, in advancing a theory of sexual selection advantages in hominids, argues that upright locomotion helped early male hominids entrain to pulses together while synchronously chorusing, for the group purposes of attracting females: "Our ancestors paced and coordinated their calling bouts with the help of associated bodily movements derived from the repertoire of walking and running" (Merker, 319). However, these scholars are hardly the only ones to speculate that humans learned to sing together while dancing.

In the early evolution of metrical or rhythmic experience, any skill or repertoire of skills built upon the capacity for entrainment, especially those proceeding from upright locomotion, would have had as a foundation not some abstract metronomic type of walking or running, but movement-life as lived. All locomotive experience – walking, running, pacing, changing direction, synchronizing movement with others -- is rich with variation, counterpoint, transition, accommodation, and development. If the experiences of locomotion are cited as prerequisites to the capacity for entrainment and the development of metrical and rhythmic skill, then the importance of a great variety of experiences of upright locomotion is implied. These might include locomotion in many environments and circumstances, under many conditions, at many stages of physical maturation and ability; or for many purposes, with adaptations of posture or level; or with mimetic elements, referring to specific actions or species; or with objects held in hand or otherwise on the body.

Varieties of hominid locomotion at all stages of evolution would have included dynamic relationships within the body in support of locomotion, including reflexes and righting systems to establish and maintain upright locomotion. Even if long-ago establishment of metrical and rhythmic behavior centered upon highly repetitive and refined movement patterns, the full complement of neurodevelopmental patterns would have been active in supporting roles, representing basic strategies of balance and propulsion available for an individual. It is difficult to imagine how human metrical experience, a system of dynamic tensions[31] that parallels the dynamic tensions of human locomotion, could have evolved upon less than the full spectrum of neurodevelopmental pattern experience.

Musicality includes phenomena beyond locomotion patterns or their physical counterpoints. Nonetheless, “ghosts” of locomotion patterns are widespread in the physical acts of music-making. Representations of locomotion by motor equivalence, or other processes of analogy and metaphor, are accomplished by “non-locomoting” parts of the body (fingers, tongue, the upper limbs of upright vertebrates) and are available upon motivations that have little or nothing to do with locomotion. These second-order appearances of locomotion patterns seem so widespread as to offer fundamental support for expressive aims.

Even the voice has mechanisms that directly involve, and effectively imply, physical ranges of motion, including locomotion. From the sudden and extreme shifts in register that mark yodeling, or the register-hopping vocalizations of peoples of the Central African rainforest, to the incremental pitch changes of bel canto scalar movement, the vocal chords tighten and loosen along a binary continuum[32] reminiscent of R/L alternation in locomotion. Consider the difference between the effect of simply clapping the rhythm and singing the melody of Example 12. How much more vividly does the pitched version suggest dance, its gestures and the means and patterns of its locomotion? It is hard to imagine that singers, as melodies were invented, were not subconsciously sensitive to such shadows of locomotive movement – the metaphorical “near” and “far” – in the movements of the vocal cords.[33]

Example 12: Sto Mi E Milo, mm. 1-8. The Laduvane Songbook (Ed. by Graetz, Buchholz, Peppler, 1981)

2. LEMPS embedded in musical structures hint at a processing disposition: towards the sensory and cognitive tracking of locomotive movement.

Infants’ interest in gestural movement is well documented (Trevarthan, 1999; Trehub 2001). Trehub also describes several forms of preferred *musical* experience in infants, calling these “processing dispositions,” because each implies preferred organizations of sensory data. Examples include preferences towards consonant rather than dissonant intervals; towards the

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[31] The dynamic tensions of meter: a downbeat is accented, separated from the other beats, yet it is also one and the same with those other beats; the last beat of a measure both ends a period and provides the transition to another; the right foot sets off the left, yet leads to it.

[32] By “binary continuum,” I mean open/closed, though at the same time, the positioning of the vocal cords by the muscles attaching to the arytenoid cartilages are somewhat more varied than that.

[33] Consideration of the perceived phenomena of musical motion of pitches might include this insight.

significance of melodic contour rather than specific notes; towards scalar arrangements of steps of unequal size; and towards rhythms that exemplify "gestalt-grouping" principles.

The notion of processing dispositions can be applied to neurodevelopmental movement pattern perceptions as well. Trehub notes that entities for which there are processing predispositions[34] function as "perceptual anchors, facilitating encoding and retention . . . " (2001). Such are the functions of numerous pattern effects in music, where saliences of locomotive-pattern organization in canonical works mark events of primary importance. The saliences suggest that there may be widespread processing dispositions aimed at detecting "locomotive" activity in musical structures.

Taking Beethoven as an example (his centrality in the canon, as well as the breadth of his appeal, being the argument for this; but many other composers would serve just as well), numerous tropes of his work are quintessentially pattern-movement events. Two examples: abundant reliance on Homologous Strike patterns to deliver the sense of an ending (Example 13); and a reliance upon Homologous Strike/Contralateral Strike "upshifts" to develop ideas (Examples 14 and 15).

Both cases exploit the characteristic effects of pattern *upshifts* and *downshifts*, two of several analytical constructs that may be enlisted to describe relationships among LEMPS.[35] A pattern upshift (Homologous pattern evolving in the direction of Homolateral and/or Contralateral patterns; and/or Homolateral changing in the direction of Contralateral) has the effect of emergence and development. A downshift (Contralateral changing in the direction of Homolateral and/or Homologous; and/or Homolateral changing in the direction of Homologous) gives the effect of consolidation and concentration.[36]

In Example 13, the Homologous Strike ending, at the penultimate measure of the second system, consolidates and concentrates the energy of the Homolateral strike passage before it.

Example 13. Beethoven, Op. 7, i, end of exposition.

Similar examples of Homologous Strike endings are too ubiquitous to list.

The use of shifts (up or down) as arresting devices at important formal junctures (Examples 14-16) is offered as evidence of a predisposition to focus attention on such events. In Example 14, the contralateral texture introduced at the last beat of m. 9 initiates a B statement in contrast with the two-phrase Homologous Strike A statement.

[34] Her example is of pitches related by small-integer ratios.

[35] Others include: stability and volatility of individual LEMPS in regard of pattern transitions; out-of-phase and attractor LEMPS; mutation of one LEMP into another; vertical and horizontal juxtapositions of LEMPS; hierarchical nestings, warpings, and insertions of LEMPS. Any and all of these may result from the dynamism of the kinemorphic forms and structures of LEMPS activity. Accounts of some constructs appear in *Musical Organization and the Evolutionary Origins of Human Movement.*

[36] Pattern upshift and its musical effects makes a neat parallel with species-wide evolutionary development, in which upright posture and locomotion accompany more expansive exploration of the environment,

Example 14. Beethoven, Op. 27, No. 1, ii, mm. 1-25

In Example 15, at the beginning of the second system, there is a Contralateral Strike variation on a theme that has ended solidly and homologously.

Example 15. Beethoven, Op. 14, No. 2, ii

At m. 24 of Example 16, Contralateral patterning begins an extended presentation of an Ab major chord, that Beethoven contrasts with the preceding section's cadence in Cm at m. 21.

Example 16. Beethoven, Op. 27, No. 1, i

Often, in Beethoven's piano writing and indeed in much other piano writing, Homologous Strike appearances refresh and focus the ear. Passages of Contralateral Strike complexity or Homolateral Strike lucidity climax with octave unisons between the hands. Transitional passages employ unison scalar materials. In each, a decisive shift in strike patterning commands the listener's attention.

It is not difficult to imagine evolutionary contexts in which it would have been adaptive for humans (and animals) to notice decisive shifts in locomotion patterns. In fact, the recognition and production of changes in locomotion patterns, in salient and contrasting effects, may be related to what is quintessentially human. For example: chimpanzees and several other primates drum on their chests and on tree buttresses (Arcadi, et al., 1998). In the EEA, with primates and early hominids sharing an interest in the identification of characteristic locomotive movement around them, locomotion awareness -- demonstrated in some form of mimesis -- might be expected to have evolved. However, drumming primates apparently make none of the characteristic adaptations of locomotion patterns that humans do. Arcadi discusses primate shaping of pulses into "two-beat" patterns according to handedness, but observes nothing further. No alternations of handedness, no transitions in handedness or flexibility of handedness is indicated. (Certainly, reversals of handedness, or even simultaneities of strikes, would have been worth noting.)

It is also interesting to consider whether processing dispositions involving locomotion patterns could contribute, through the imposition of cognitive constraints on forms of musical organization, to the development of compositional practices.[37] For instance: could a disposition toward locomotive interpretation of rhythmic activity help explain how humans hear, and thus understand and create, polyrhythmic constructs? For instance, the European model of four-voiced contrapuntal writing is usually attributed to the existence of four vocal registers. However, humans have also learned to coordinate the actions of four limbs; could this coordination have provided models for contrapuntal constructs?

3. To social bonding theories of the origins of music, LEMPS provide a flexible and coherent set of symbols for signaling traits relevant to relational potentialities.

Hagen and Bryant's (2002) "coalition-signaling" theory proposes that an important adaptive function of music and dance in the EEA is the ritualistic signaling, between tribes and peoples, of traits important to groups when attracting and selecting coalition partner-groups. Forming strong coalitions with other groups, essentially for "political" alliances in an environment in which warfare was common, but also for sexual selection, provides a distinct evolutionary advantage. For effective "coalition-signaling," the traits that need to be signaled include:

a. the ability of a potential partner group to perform complex maneuvers in time and space – the sine qua non of music and dance
b. the ability of a group to internally command from its members energy, reliability, and commitment over time – traits requisite for the creation and rehearsal of music and dance
c. unanimity of motivation and commitment - as evidenced by the shared emotionality of group music-dance structures
d. a varied repertoire of performances - demonstrating versatility
e. the featuring of "soloists" as exemplary group members - such that they may be offered up by the group in significant marriages

Locomotion-encoded musical and movement structures would provide relevant content for many messages with coalition-signaling purposes. Mastery, in the musical sphere, of the performance, juxtaposition, transitioning and transformation of locomotive patterns indicates:

a. mental discrimination and bodily skill consistent with discipline and maneuverability
b. group capacities for endurance and versatility
c. emotional intensity, insofar as it is exemplified by controlled and abandoned treatment of tempo, the incongruence and juxtaposition of sound images, and the full range and variety of movement patterning, from the difficult and labored to the flowing and continuous.
d. the presence of individuals of exemplary fitness and virtuosity

[37] Trehub (2001) cites cognitive constraints as an explanation for the ubiquity of five and seven-tone scales.

Locomotive pattern use in music (LEMPS) advances multiple aims of a coalition-signaling group.

A second body of social-bonding theories focuses on the adaptive functions of music, along with dance, in producing transcendent experiences of group entrainment. Freeman, in noting that the design of human perception and processing – *learning* – culminates in concepts "entirely constructed within [our brains] . . . without direct transfer of information from outside" argues that group entrainment to pulses is "a human technology for passing the solipsistic gulf" (2001: 420). With the flood of neuropeptides released during "exhaustive dancing and drumming" (as during "copulation to orgasm"), humans have unique opportunities to learn trust and cooperation. These include "new understanding through behavioral actions that are shared with others, including cooperative caring for the infant and the other parent," and "succor . . . by other, older members of the tribe . . . [with] . . . admission to new . . . status." Similar constructs are articulated by Roederer (1984), when he cites "the value of music as a means of establishing behavioral coherency in groups larger than nuclear families."

Without undercutting the importance of neurochemically-induced ecstasy, it is worth remembering that the vertebrate movement legacy contains multiple, parallel mechanisms for producing cohesion within groups. Locomotion itself provides a primary experience of group unity in the movements of herding, flocking, stampeding, swimming in schools, and so on. If the artifacts of locomotor impulses are indeed part of what provides cohesion in a musical ensemble, do we understand anything more about what people are doing when they make music?

The musical importance of the neurological vestiges of vertebrate group locomotion is intriguing. Once the ability to entrain was established, and music began developing within the context of human culture, did reference in sound and music to locomotion patterns serve to refresh a group's identification with common and ancient experiences? The shifting accent patterns of contralateral coordination: do they say to a group "now is our time to dodge and evade, to shake off predators?" Did group enactment of contralateral locomotion lay the groundwork for syncopation? Do homolateral musical signals communicate anything about the experiences of amphibian life? Are unison homologous strikes a means to demonstrate corporate force and power? Shared dominance? Symbolic power-sharing?

4a. Several commentators have found applications in music for the notion of a *meme*, a "unit of cultural transmission" (Dawkins, 1989), as opposed to a gene, a unit of biological transmission.[38] Here it is observed that after hominid evolution had established the full complement of locomotive movement capabilities, the replication and adaptation of locomotion-encoded musical content (including locomotion-encoded musical memes) was a *cultural* rather than biological process.

Compare the chest-thumping, left-hand/right-hand two-beat "buttress drumming" of bonobo chimpanzees (Arcadi, et al., 1998) to Example 16, two-handed human music from *Sunjata* (SunjataAudio), one of the oldest pieces of the Mandinka balafon repertoire, circa 1250, Kingdom of Mali, West Africa (Jessup, 1983). (At bottom of example: L is Left Hand, R is Right Hand, B is Both Hands.)

[38] Memes evolve within the context of their appearances in the acts of specific individuals (often, intentional acts), rather than by biological development or mutation.

Example 16. *Sunjata* – donkilo (basic ostinato)

Music of *Sunjata's* contralateral complexity surely represents wholesale changes in the "mental modules" (Molino, 2000: 167) of humans, as compared with chimps. A few such mental modules, novel in comparison to chimpanzees and at issue in Example 17, are: 1.) the capacity for entrainment and 2.) neuromuscular control of contralateral movement patterning, making the 2 v. 3 polyrhythm attainable physically and conceptually.

These abilities represent evolutionary changes accomplished many years before *Sunjata* was created. Additional abilities, implicit in the interplay of melody and polyrhythm of *Sunjata*, may also have a history that is evolutionary in the Darwinian sense: in that they are dependent upon critical "mental modules" developed through processes of biological changes in the species. These might include the ability to recognize and create melodies, to give salience to important intervals in the melody, and the ability to interestingly position melodic vectors within rhythmic material. Further: the recognition and creation of symmetries, asymmetries and variations of rhythmic and pitch organization, as well as the ability to sing vocal lines in counterpoint with patterns such as the ostinato here.

An alternative, though not mutually exclusive, possibility is that the evolution of such features took place in a shorter time span than the establishment of mental modules require – in tens, rather than hundreds, of thousands of relatively recent years. In this alternate explanation, the musical products (songs, rhythms, emblems, fragments, calls, signals) of such "modular" abilities themselves underwent processes of combination, recombination, mutation, cross-fertilization, and development to produce the musical object *Sunjata*.[39] This kind of evolution, which may logically be expected to have included instrumental (percussive) phrases characteristic of locomotion-encoded musical patterning, would have been, as Molino points out, Lamarckian. It would have been "dependent on the biological evolution of mental modules produced through environmental adaptation, [but proceeded] with objects that are susceptible to the partly autonomous process of directed evolution (2000)." In this manner, the body of musical phrases expressive of locomotion patterning may have quickly grown more complex and varied.

4b. Numerous configurations of musical ideas, offered in the work of other commentators as examples of musical *memes,* have locomotor-movement components. These locomotor-movement components can be helpful in identifying the path of a meme's evolutionary appearances.

Steven Jans, applying the concept of musical memes to the development of musical style (1999), describes a broad canvas of memetic activities. Citing Meyer's discussion of pattern replication as an element of musical style, Jans observes that musical memetics may take place within a variety of hierarchical levels and musical/conceptual frameworks. This may be illustrated with the example of a representative human music-maker: again, Beethoven makes a fine example. A meme in one of Beethoven's works might appear: elsewhere in that work of

[39] To speak of Sunjata as a musical object is not to ignore the fact that with respect to many properties of its composition and performance, it departs from musical objects of the European tradition.

Beethoven's; elsewhere within the whole body of Beethoven's work; elsewhere in the (Classical) idiom of Beethoven and his contemporaries; and elsewhere within the musical works of cultures and times other than Beethoven’s. Some appearances of a single meme may even need to be considered within the context of all possible music-making principles and approaches – including but not limited to those involving the human body.

Jan’s approach includes many roles for memes in a composition. A meme may incorporate any elements (pitches, rhythms, timbres, etc.) on any structural level. Jan claims memetic relationships on Schenkerian “foreground/middle-ground/background” levels and in “memeplexes” linking memes of diverse art forms and cultures.

Locomotion-pattern elements, then, might also be considered when comparing units (Jan calls them *particles*) of musical meme replication. These may reveal unexpected or interesting dimensions of musical transformation. For example, Jan focuses a meme that appears in Mozart (Example 17b), after the model of J.C. Bach (Example 17a):

Example 17a, Bach, J.C.,
Keyboard Concerto in E-flat Major, Op. 7, No 5, mm. 54-55

Example 17b. Mozart, W.A.,
Die Entfuhrung aus dem Serail, KV 384, No. 11, 14-15 (strings only)

If LEMPS elements are included in a comparison of memes in these passages, they add a novel dimension to the account. The Bach begins with LH/RH alternation on the second, third and fourth beats of the first measure, employing hand alternation (essentially homolateral) in a contralateral manner: as the m. 1 RH beat two is held, as the LH strikes on beat three, the player’s attention moves across the body’s midline while the note is held. Then, with beat one of the next measure, against the expectation of a LH strike on that downbeat, the successive RH strikes create *syncopation* in movement patterns terms (if not in metrical terms). This also suggests contralaterality. Measure 2 then continues and concludes homolaterally. The overall impression is that of a weak homolaterality colored liberally with contralaterality.

In the Mozart, a different overall affect prevails, the result of a key shift and a timbral change to strings. Altered as well is the movement pattern information transmitted. Though principles for analyzing pattern-encoding in string passages have not been detailed in this paper, it is not difficult to understand that simultaneous applications and releases of pressure of the LH on the fingerboard and the RH through the bow would constitute Homologous Strikes. Patterns of initiation of action between the hands (with the bow, or on the fingerboard), *or in a single hand*, that are not syncopated, and that contain no "conversation" of accents between the hands or between the sides of one hand, are usually Homolateral Strike patterns. Therefore, the F-G-C sequence in the violas begins with a Homologous Strike but turns Homolateral once the G and the C, bowed on open strings, are struck with one limb only. As the Bach's (keyboard) homolaterality was tinged with contralaterity in the RH strikes at the beginning of m.15, Mozart gently echoes that effect with the violas’ homolateral string pattern: two single strokes of the bow, both with the RH, with no action on the fingerboard.

Whether these strokes are taken with one up-bow, one down-bow, or one of each, the three strokes of the three pitches are sure to have at least one reversal of direction, producing an element of either asymmetry, or incompleteness, in L/R alternation *in a single hand*. This suggests contralaterality, but in such a brief occurrence stops short of strongly asserting it. In the violins, all bowings produce homolaterality across both measures (though the last two notes of m. 14 contain subsumed Homologous Strikes).

So, Bach's version of the meme is marginally homolateral with a strong coloration of contralaterality, but Mozart's version is predominantly homolateral with slight homologous coloring and a clever reference to contralaterality across the bar line.

4c. The basic LEMPS categories -- abstract templates of motor coordination without specific realizations in particular tones -- can themselves function as memes. Within a variety of musical/conceptual contexts, the categories' own evolutionary histories provide examples of memetic development.

LEMPS can link significant structural and stylistic formations across a range of conceptual frameworks. In the broadest terms, LEMPS are archetypal movement patterns, rather than specific configurations of tones. Their variety of applications and therefore their specific characteristics evolve through their deployments in various works. An example is Beethoven's previously cited use of Homologous Strike to decisively conclude formal sections (Example 13). That same practice characterizes sectional endings of keyboard works from the Fitzwilliam Virginal Book to the present, from gamelan ensembles to Ghanaian drummers.

If an equally expansive claim cannot be made for the Homologous/Contralateral *upshifts* of Examples 14-16, then at the least these examples speak to stylistic evolution within the framework of Beethoven's keyboard works. However, such upshifts also mark hundreds, if not thousands, of works of all eras, so that each of Beethoven's upshift or downshift maneuvers could be contextualized within the overall history of LEMPS upshift and downshift maneuvers. Each conceivable typology of an upshift or downshift maneuver, however reckoned, might have initial appearances, periods of greater or lesser popularity, etc. All would be instances of archetypal movement patterns used in such fashion that their types and their functions acquire, over time, histories of development and change -- evolutionary histories.

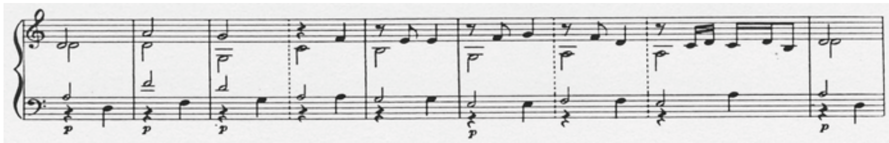
Panoramic accounts of the emergence of specific LEMPS characteristics may be possible uses. For instance, LEMPS may help describe innovations in instrumental technique and composition in keyboard playing. In the following citations (1997),[40] note the gradual emergence of Contralateral Strike coordination in the LH.

a. In this 14th century excerpt of the Robertsbridge fragment, Example 18, the strike patterning is chiefly distinguished by alternation of sides of the hand – a homolateral characteristic – except for the repetition in m.2 and the descent from m.4 to m.5. The passage's overall LH contralaterality is mild; at most, attributable to mixed note durations, more than the passage of accents that marks contralateral conversation.

Example 18. Robertsbridge fragment.

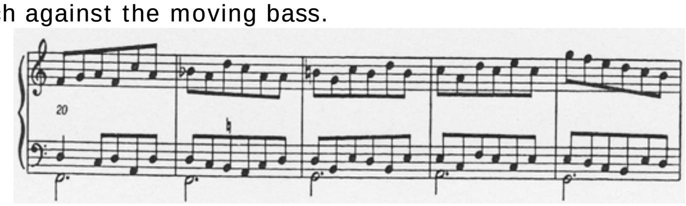
b. This 15th century excerpt, Example 19, introduces contralaterality as an outgrowth of activity between the hands, rather than in a single hand alone, as the second LH beat of the first three measures seems to answer the half note that begins each measure. (The RH part, polyphonic, does use individual contralateral patterning.)

[40] These examples, from sources related by little more than chronological order, are broadly aimed. More focused studies would, ostensibly, generate more nuanced pictures of memetic development.



Example 19. Buxheim Organ Book

c. In the 16th Century Examples 20, we find Contralateral Strike patterns in the LH by virtue of polyphony, as at the crossing of each bar line the acrobatic tenor voice stays on one pitch against the moving bass.

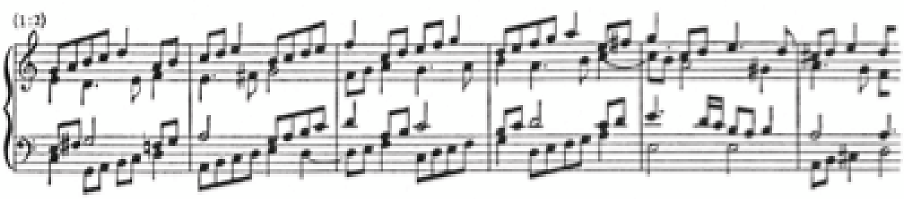


Example 20: O lux in the faburden

The contralaterality in the LH of Example 21 involves accentuation across the two sides – radial and ulnar – of the LH. Notice the syncopated rhythm resulting from roots and fifths alone in the first measure.

Example 21. Tallis: Felix Namque II

By the 17th Century, with Example 22, LH strike contralaterality is complex and polyphonic. It involves some finger crossovers and some syncopation across the bar line. As well, its Contralateral Strike patterns are underlined by the Contralateral *Sweep* characteristic of melody passed between R and L sides – in this case the radial and ulnar sides of one hand.



Example 22. Gibbons, Fantasy (No. 11) (Glyn IV, No 6)

Although Examples 16-22 represent a highly selective overview of changes in keyboard practice over four centuries, the progressive enrichment of LH activity does suggest that innovations in motor action can be important links to stylistic change. If the LEMPS categories themselves are considered memes (that is, as pattern-movement tendencies, rather than as specific instances of these tendencies, encoded in the pitches of specific pieces), then they have perpetuated their own survival over centuries of stylistic change.

4d. In all the above cases – LEMPS elements in memes otherwise described; or, evolutionary appearances of a LEMPS category itself – a similar mechanism of movement-pattern replication and transmission may be involved, accomplished by processes such as Baily describes using the concept of "motor grammars."

Ethnomusicologists Baily and Driver (1977, 1992) suggest a mechanism by which this manner of style development might occur. Their work describes the significance of instrumental "motor grammars," musical structures that come spontaneously into existence at the intersection of an instrument's morphology and the explorative and investigative impulses of a player's hands. For two string instruments of diverse cultural origins, they argue for the importance of "spatio-motor thinking" during the processes of musical invention. They argue that the creative value of physically *playing* an instrument is underrated. Looking closely at players of the Afghan Herati *dutar* and the folk-blues guitar, they argue that motor patterns and mutations of motor patterns, both accidental and deliberate, are critical elements in the processes of composition and improvisation. "Motor grammars" are, according to Baily and Driver, foundational to the vocabulary and cumulative repertoire of an instrument. As such, they are also symbols and forms of instrumental creativity, the musical "creatures" through which LEMPS-type memes replicate.

5. The primary rhythmic units of *1, 2* and *3* have elegant analogues in the LEMPS patterns, as demonstrated by the gaits of various vertebrates. This argues for the impact of evolutionary stages of locomotive experience on human rhythmic organization.

A cliché of musical training holds that all rhythms reduce to combinations of one, two, or three impulses. Whether this is technically true or not (it isn't; not every interpretation of a 2-vs.-5 polyrhythm is limited to cognition based on whole-number units) is less important than that the cliché seems widely and intuitively cited. Many polyrhythms and many mixed and asymmetical meters will divide neatly into units of 1, 2 and 3 for easier execution. As well, much syncopation becomes intelligible once its components have been parsed into these tiny units. If 1, 2, and 3 are not musical universals, it is doubtful any other numbers have better claims.

So, why should this be the case? Vertebrate locomotion provides some clues.

If one counts the number, type, and sequences of sounding-impulses made by animals' limbs in locomotion against the ground, then compares these to the three primary locomotor patterns discussed here – the Homologous, the Homolateral, and the Contralateral, some possible answers emerge:

One is the number of primary sound-impulses in homologous locomotion: one push of the lower limbs and the body flies through space. (Not to say the corresponding reach into space of the upper limbs is unimportant, but it doesn't necessarily mean they will strike against the ground). A body pushes off two legs (counted out loud: "*One*"); upon landing, the knees bend, gathering energy for another push (counted: "*and*"). The sound of homologous locomotion: *One-and-one-and-one*, etc.

Two is the grouping of sound-impulses in homolateral locomotion. The lower leg on one side initiates and the upper is pushed along into action: *a-one.* The other side's limbs move in their turn: *a-two*. *A-one, a-two.* Two are the number of the sides of the vertebrate body, the essence of this variety of locomotive capabilities.

Three is the sound-template of contralateral locomotion. The lion's upper limb on one side reaches forward ("*one*"); the body suspends momentarily in space ("*and*"); the opposite lower leg swings forward and lands ("*uh*"). The sequence begins again with the other side's initiation. *One-and-uh, two-and-uh, one-and-uh, two-and-uh.*

The animals in video example 1-2-3, demonstrating this more clearly than words can, close this account of the locomotive origins of several phenomena of musical perception and organization.

Acknowledgments.

1. Musicians in videos: Damien Bassman, percussion; William Moulton, piano.
2. Neurodevelopmental Movement Pattern images: Janice Geller (in Cohen, B. 1993. *Sensing, Feeling, and Action*. Northampton: Contact Editions), by permission of Contact Collaborations, Inc.
3. Balafon transcriptions, pp. 4, 23 (Jessup, L. 1983. *The Mandinka Balafon*. La Mesa, Calif:

Xylo Publications) by permission of author.
3. Examples 17a-22 (Apel, W. 1972. *History of Keyboard Music to 1700*. Bloomington, London: Indiana University Press) by permission of Indiana University Press.
4. *Sto Mi E Milo* (Eds. Graetz, Buchholz, & Peppler, 1981. *The Laduvane Songbook.* Cambridge, Mass: self-published.) arranged by Ethel Raim and the Pennywhistlers.
5. Animal videos: *Mutual of Omaha's Adventures in the Wild Box Set*. DVD (Brentwood Home Video/Sunset Home Visual Entertainment, 2005).

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