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Generative Principles of Musical Thought
Integration of Microstructure with Structure.

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Introduction

We shall describe recently discovered generative principles of musical thought which unify musical microstructure with structure, giving rise to musical integrity (Clynes, 1983, 1985, 1986). These principles appear to describe fundamental aspects of musical thought and are predictive in nature. They show how microstructure unfolds naturally from moment to moment, guided by structure. Their function is not conscious but is systematic; not explicit but secure. Since they may be used in musical synthesis itis readily shown that they can correctly model integral aspects of musical thought and provide good interpretations. (See footnote 1) We are here concerned about what these principles can tell us about musical thought and about thought itself.
Musical thought is a particular kind of thought. It has much in common with non-musical thought and also much that is specific. Non-musical thought involves verbal language and/or non-verbal processes; it is clearly possible to a considerable degree to think without language. Does it make sense to ask what is left of musical thought if one removes musical language from it? In both musical as in non-musical thought, the largest portions of its processes are not conscious, and so this question involves unconsciously operating generative grammars. Evidence for this grammar is found in musical microstructure.

Time and Pattern Recognition

Musical thought is wedded to time - inherently. It is linked with our psychobiological clocks. This gives it special interest for cognitive science in relating meaning to neurophysiologic organization. Music and the perception of time are integral to one another. (See footnote 2) Time enters musical language principally on two rather obvious levels:

(i) as rhythmic or metric generator
(ii) as a frame for expressive entities

In both these modes, pattern recognition is involved of a highly developed kind. Also, potentials for relationship are perceived. Actual relationships that ensue are largely viewed within a context of known potential relationships that are present. Here, as elsewhere, potential relationships ***exist.*** The significance of a given "answer" or event depends not only on itself but also on what it might have been. It is influenced by the total possible communication relationships that can be envisaged at that moment. (See footnote 3)

The obverse of such potentiality is expectation; its significance in music should be considered in relation to potentiality. But we need to talk here not only of the obvious expectations of repeated note patterns, symmetry and other structural aspects, important as they are, but also of expectations engendered by musical thought when musical language is, so to speak, subtracted from it.

Such expectations and potentialities arise in the first instance from the emotional nature and nature of emotion involved in music. Meaning, knowledge and potentiality arise here from the very nature of the emotions involved (Clynes et al, 1986, Clynes, 1977, Meyer, 1950).

Another such source of expectation lies in the continuing identity of the composer's personality, or "point of view" as manifest in the music. This intimate expectation (manifested through the "pulse") can be shown to be distinct from gross stylistic matters, e.g. there are clearly distinct expectations set up by Haydn and by Mozart, Ravel and Debussy, Bach and Handel (Clynes, 1969, 1977, 1983, 1985).

Most musical thinking and listening to music involves the production and recognition of temporal patterns within the context of expectation, surprise and potentiality. In many ways these fashion musical meaning. There may be surprise within known potentiality (for example, the interrupted cadence). But surprise is different from startle. A wrong note is startling but is not felt as a surprise unless it were to give the music a particular unexpected new meaning: with surprise we associate meaning. And interest may be thought of as nourished and sustained by a continuing chain of mild surprises.

Surprise, expectation and potentiality are continuingly weighed in the aware listening to music. Surprise outside of known potentiality may appear as "magic", or as increased insight. New musical meaning enlarges our potentiality. Indeed, listening to and composing music tests our potentiality. We shall describe how specific, unconscious generative properties of musical thought contribute towards these processes.
That intelligent (See footnote 4) thought requires more than merely a data base and storage of relationships between elements of the data base is well known: it also importantly involves the mode of choice of algorithms - the choice of what kinds of programs to use - and the programs that are mentally available among which to choose. Such choice importantly affects outcome (Newell and Simon, 1976, Marr, 1977). Logic is a part of the thought process but probably rather a small part. The main elements of logic (similarity, and choice of either/or) are also used by animals, and not necessarily higher animals. (Without language, most animals can tell whether "A" and "B" are similar or dissimilar, and can make a "logical" choice between alternatives.) Unfortunately, logic does not easily include time, being by nature timeless. Richness of human thought and very likely of animal thought, derives from processes other than just logic. What are some of these processes in music as well as in thought in general? The choice of ***how*** to think about a problem - what kinds of algorithms to use, perhaps the simultaneous calling up and using of several of them is one of these (cf. Minsky's frame concepts). Others compare more recent with less recent events: events placed in a time series, in which the place in time is of consequence. These may involve various time scales. (Note the largely neglected processes of the transformation of time series of memory in dreams.) Serial ordering in the Central Nervous System is still very little understood. Since Lashley (1951) drew attention to this, some progress has been made but we still know only a few aspects about how rhythmic and time-shaping thought is possible. neurophysiologically. But how some of these processes are clearly evident in musical thinking will be described in the following.

Generative Principles of Musical Thought

We have been able in recent work to discover certain unconscious generative principles that apply to musical thought (Clynes, 1983, 1985). The action of these principles transforms the dead skeleton of music preserved in the score into living musical thought. The principles deal with the relation between musical structure and microstructure, unifying microstructure and structure. Their unifying function is of primary importance in music interpretation and performance(See footnote 5) . The principles also have consequence in regard to composing. Expectations generated by the nature of the composer as manifested through these functions can be seen to influence the choices of musical ideas with which he composes, i.e. aspects of the kind of musical themes and their uses that may "come" to him.

The principles apply to three modes in which time partakes of the musical process. In addition to the two rhythmic and expressive modes cited at the beginning of this article, there is a third strongly influential mode we call ***Predictive Amplitude Shaping.*** This concerns the way in which each element of musical thought, the musical tone, is shaped. (We may say that music (except certain avant garde music) is made up of elements, musical tones, each of which has a particular pitch). Those musical tones are a circumscribed subset of all possible tones, which in turn are a subset of all possible sounds. Within the subset of musical tones, a set given by musical language, each tone assumes a particular temporal shape in musical thought, a shape which governs its amplitude contour, i.e. the way in which the tone itself rises and falls in loudness while retaining its pitch (as well as, where feasible,) shaping its timbre contour).

It turns out, importantly, that these amplitude shapes of individual tones are different in musical thought for each tone of music. The various shapes are not random, but are governed by the sequence and temporal relationships of the tones, i.e. the melodic structure, in a specific way that we have discovered. They have a predictive nature and relate the present tone to the tone to follow, so that *without knowing it explicitly* , we anticipate in the present tone what is to follow. This function contributes also to a very considerable part to what we know as musical phrasing, and its musicality.

Individual tone shaping (amplitude, and also timbre) is exercised by great performers on those instruments that permit it such as the voice, string and woodwind instruments but not the piano or harpsichord or organ. When done appropriately, it contributes enormously to the living qualities of the music. It clearly is a powerful aspect of superiority of instruments like the human voice and the violin in shaping melodies.

Microstructure and Information

Unlike the scientific or discursive written word, the musical score intrinsically leaves considerable ambiguity.

The appropriate microstructure greatly reduces the ambiguity and perhaps, ideally, eliminates it altogether. By this is meant that albeit the musical score permits many different interpretations, on choosing one the appropriate microstructure contributes to make it convincing and unambiguous. Once the music is imbued with the microstructure endowing it with living qualities, their execution communicates like qualities in an unambiguous way, clear to the degree that the microstructure is perfected. We shall be concerned then with what make the appropriate microstructure have musical integrity, indeed with *what musical integrity means in this context.*

We may consider that the information of a single tone of music is carried by five independent dimensions: pitch, amplitude, shape, duration and timbre. Of these only pitch is adequately defined in the score, and amplitude and duration are given as a crude approximation, far below the required resolution for thought or performance (which permits meaningful hearing discrimination). Shape is not defined at all by the score, and timbre (and timbre shape, since timbre varies within a tone) only to the extent of the choice of instrument. Microstructure adds the necessary information regarding amplitude, shape, duration, and even partly timbre.

We may consider consecutively that each of these dimensions can independently contribute six bits of information. We may allow for the fact that a musical piece will typically tend to use only a small part of the range available for each variable, say one quarter of its range. Thus we may estimate that each of these variables comprise four bits of information per note, resulting in a total of 20 bits per note. If one considers several voices in the musical texture one typically may be hearing ten tones per second, or a rate of 200 bits per second. ***Two-thirds of this information rate is provided by the microstructure.***

(Table 1).

Table 1

INFORMATION PER TONE
within one voice

Contributions:

	Structure	*Microstructure*
Pitch	5 bits	0 bits
Amplitude	2	4
Changes in Amp. Shape	0	5
Duration	3	4
Timbre Shape	0	4
Total	**10 bits**	**17 bits**

(*Without additional microstructure due to vibrato and expressive intonation*)

The principles which we have found to unify microstructure and structure thus account for a large part of the meaningfulness of music. When the appropriate microstructure is not present we tend to imagine it in our thought when listening to music. It is of course present in the composer's mind when he thinks the music, but the notation system does not permit him to record this microstructure adequately. (See footnote 6)

The fact that two-thirds of the information of the music resides in the microstructure also accounts for the preponderance of poor and meaningless performances. On the other hand, when the microstructure is well shaped, music assumes the power of direct, unambiguous communication present in the greatest performances - it duplicates musical thought.

One of the characteristics of good interpretation is the maintenance of continuity, what is often referred to as integrity of the musical line. The student of interpretation is urged to "keep the musical line going" (though without instruction, in many cases, on how this is to be achieved). Indeed, the listener readily notices interruptions of the musical line, gaps of dullness that interfere with the developing story of the music. Such performer-caused gaps in the attention to the music ruin the enjoyment and understanding of the music. The best music teachers instruct that "every note of the music must have meaning". Moreover, meaning has to be integrated into an overall concept of the piece. But all this is possible only through microstructure.

Generative Principles of Musical Thought: Principle (1) - The Musical Pulse

While we knew of the existence of the pulse phenomenon as early as 1967 and were able to measure it through conducting with finger pressure of musical pieces thought in real time (Clynes, 1969), it was only three years ago that we were able to find out precisely how the pulse affected *each individual tone* of the music (Clynes, 1983). Since then we have been able to synthesize music incorporating the composer's pulse. Further, it became clear that this pulse form could be refined gradually through the efforts of future generations of musicians.

The musical pulse combines specific temporal patterns with amplitude patterns and can be represented by a matrix (see Figure 1(a) and further (1(b)). This matrix is a meta-rhythm for the microstructure of all possible rhythms a composer may produce. It may be described as a specific warping of the notated time values together with synchronized, independently specific warping of the amplitude values (i.e. loudness). Such a combination of time and amplitude warping is specific to a given composer. Moreover, this warping may be active on several hierarchic levels of organization (see Figure 2(a) and (b), respectively. (See Appendix A).

The warping, once begun, becomes expected. Through the property of Time Form Printing we expect such a repetitive warping pattern to be repeated until the end of the piece (Clynes and Walker, 1982, 1986). Automatic repetition continues without specific awareness of its program but one notices it immediately as a kind of stumble, if it should suddenly change (Becking, 1928). The analogy of stumbling is not fortuitious. As a person walks, the pattern of his movements assume a similar automaticity but he immediately notices if it should change. With the musical pulse this pattern is not the notated rhythm of the music - that indeed often varies from bar to bar; yet regardless of the varied nominal durations of the notes, the specific warp of the pulse continues in essentially unaltered form within the piece.

This metarhythm or warp is thought and recognized in the manifold expressions of a particular composer. The pulse sets up an expectation of continuity. Should it be absent from even a small part of the music, say a bar or two, it is noticed and becomes a source of confusion. On the other hand, its continuation is accepted without receiving new information. In this respect it is like the continuing presence of the person who tells a story. The continuing repetition of the pulse may deepen our awareness of the identity of the person that is telling the musical story - the composer. It does not present any novel features, but on the contrary it increasingly penetrates awareness as a stable entity, basic to the perception of the other dimensions of the music. We have also called this phenomenon of music the composer's "point of view", referring to the identity it reveals.
This specific warping should not be confused with rubato. It would not even be correct to call it a micro-rubato; the notion of rubato does not comprise amplitude warping. Moreover this warping is regularly produced, over and over again, while rubato tends to be special. In tempo changes, the relative pulse microstructure is still maintained. This is important for living performance of ritards and other tempo changes, including rubato.

Principle (2) - Predictive Amplitude Shaping

In contrast to the maintained pulse microstructure, the Predictive Amplitude Shaping function output is forever new. Through it no two tones have the same shape. The unfolding, changing story of the music is actively portrayed with the varied shapes of the tones giving eloquence to the melodic structure to which they belong. Through this function we anticipate what is to follow, not repetitiously as in the pulse but uniquely. Not only does it prepare the mind for the next tone, but it may also with each shape confirm the feeling of the phrase and set the emotive tone of the music. And thirdly, quite remarkably, this function very often creates musical phrasing consistent with the composer's where these are given. (It has also recently convincingly provided the necessary detailed phrasing for Bach's 24 Preludes and Fugues of the Well Tempered Clavier).

We may consider that our model of amplitude shaping (see Appendix B) portrays three functions. One simple function consists of the use of the same basic shape regardless of the duration of the note. Thus, unlike with the conventional parameters of rise time, decay, sustain and release which generally do not vary systematically with the duration of the tone (except for sustain) the basic shape is spread over whatever the duration of the tone happens to be. This in itself creates desirable variety and is generally musically appropriate, being an improvement over the mechanical uniformity otherwise encountered. This function provides a modest degree of musicality. It takes some account of the temporal but not of the pitch structure of melody.

The second function is the choice of basic shape from which the dynamic skewing is to take place. This is uniform over the entire piece for a particular voice, in general. The choice of this basic shape is very sensitive in relation to meaning, the composer and coloration of the particular music involved. Different contrasting parts of the music, such as perhaps the Trio section of a Minuet, and certainly different movements of a Sonata would generally use different basic shapes. The overall tempo of the piece also influences the choice of basic shapes. (This is made rather elegantly simple in our method by using beta functions to define the shape. These make it possible with only the choice of two parameters to define a very large and appropriate family of shapes for musical tones and provide a natural way to produce the variously rounded shapes of musical tones as they are thought (Clynes, 1983). (The amplitude shapes used in most commercial synthesizers use parameters derived from the mechanics keyboard instruments: not from the true nature of musical tones as thought).

The third and cardinal function of predictive shaping consists of the *specific skewing* of the basic shape as described above, according to the expected pitch and time of occurrence of the next musical tone. The shape is skewed forward in proportion to the slope of the tangent from the present tone to the next tone on the pitch-time curve of the melody (see Figure 3). The skewing thus takes into account both the pitch of the *next* tone and *when* it is expected to occur. If the pitch of the next tone is lower, then the skewing is correspondingly backwards. As a result of this, downward skips in the melody become more staccato (for a given note duration of the present tone). Upward steps are linked in a more legato way by the same function. With this function, however, performances of virtually infinite gradations of legato and staccato are produced that do in fact give rise to appropriately meaningful phrasing, when combined with a suitable choice of basic shape.

The degree of skewing demanded in relation to the melodic structure appears to be effectively the same for a very large range of music, composers and styles. Its function appears to be an inherent part of musical thought.

The shape of a tone at least in moderate and slow tempo, may reflect the shape of a motoric gesture, and thus relate to the specific dynamic forms of emotional expression we have isolated for various emotions, called essentic forms. It also appears to reflect the sense of motor effort in going up in pitch and relaxing in going down in pitch, corresponding to tensing and relaxing the vocal chords and other vocal apparatus in singing. In these instances the shape of the musical tone is a dynamic model of an expressive gesture or muscular effort. But both the shaped tone and the gesture are likely to be modelled by a common brain program that governs the generation of its shape; and represent different output modalities of the same basic phenomenon.

The sensitivity of the ear to shape of individual tones is considerable. Slight shape changes which are not visually noticeable in graphed representations of the shapes, meaningfully alter the musical tone. When the shapes are really right they, especially the longer tones, appear to lock in on a particular quality of feeling, as saddle-points. Feeling qualities are represented as a number of distinct "eigenvalues" rather than as a continuum in the spectrum of shapes. (Passing the optimum point it does not appear to go into a new feeling but rather through dullness or meaninglessness before approaching another separate feeling quality). This recognition process accordingly requires special mathematical techniques for its description. (Cf. If we gradually transform a letter of the alphabet into another letter, what is the mathematical description of the ability to recognize the letter as the transformation proceeds?) The delight and intensity of the quality experienced appears to be a function of the distance from the saddle-point, i.e. how close it is to the pure form.

Principle 3 - Essentic Forms, the Expressive Forms of Emotions

In addition to the above two functions that affect microstructure, we need to consider the powerful forms of communication of specific emotions which we have called essentic forms. These biologically given dynamic forms have been isolated by us through sentographic experimental studies covering several decades (Clynes, 1969, 1973, 1975, 1977, Clynes and Nettheim, 1982). Essentic forms are embedded into the musical fabric directly by the composer mainly through his choice of melodic lines and motives. They thus are part of musical structure. But they depend on microstructure to render them unambiguous and powerfully communicative. The notes of a melody serve to outline the essentic form as certain key elements (Clynes and Nettheim, 1982). The use of pitch alone embedded in nominal durations insufficiently characterizes the specific quality of feeling. It demands that the other tonal dimensions contributing to the total melodic impact be appropriately shaped in an integral manner. This applies particularly to the amplitudes of the individual notes, and also their shapes. Deviations of the durations of notes from the nominal values also contribute to the characterization of essentic form. Clynes and Nettheim, 1982, show for example, how 28 different melodies that outline the essentic form of grief all express grief. Additionally, variations in timbre may also strongly contribute to the overall eloquence of the form.

Much of the microstructure required by the essentic forms portrayed by the composer's pitch relationships are provided by the functions of pulse and predictive amplitude shaping. These already place the musical phrase in appropriate context. Further refinement may be undertaken in regard to the relative amplitude size of tones within such groups that shape essentic form, to heighten and sharpen the expressiveness of particular emotional meanings.

Recognition of essentic form is facilitated by the biological programming for their production and recognition which we innately share. Its *choiceless* recognition requires no more "intelligence" than to recognize a yawn, say. (No aspect of choice is involved unless the yawn is faultily carried out). In choiceless recognition the choice is made for us by a "hardwired" program - the memory and access is biologically given, not acquired. (In recognition with choice, i.e. intelligent recognition, the memory is acquired and has to be accessed by appropriate choice, i.e. choice of which memory to access, choice of mode of access.) Moreover, like a yawn, these expressive forms in time are contagious. Their contagion is greater the better the forms are realised in the musical edifice. Nevertheless, the listener needs a clue to the mode of expression chosen in the musical structure, a clue to what parameters carry the essentic form information. Music of different cultures can be understood only after the acquisition of such clues. (Although this recognition is choiceless it requires "sensitiveness" to recognize and react to some of the subtler emotional qualities, mixtures and allusions, much like such sensitiveness is called for in recognizing subtle facial expressions that may say much about that person).

The contagion of essentic form in listening to music has a marked effect, however, on cognitive thought and processes of intelligence. This comes about because different emotions have inherent influences on cognition and are in fact linked in their substrates to cognitive thought processes (Clynes, Jurisevic, Rynn, 1989). Essentic forms in music act as modifiers of cognitive thought and as quite systematic modifiers.

Memory, Expectation and Microstructure

We shall now look at different ways in which recognition processes apply to musical thought. The elementary musical unit, the tone, is a perceptual entity which can be imagined, and this imagined entity forms the conventional basis of musical thought. Patterns of tones can be thought and can be arranged in patterns forming musical "lines" as dots can be, visually.

The musical tone has a continuing pitch which is recognized early at the beginning of the tone. Its continuing interest lies in its duration and in the change of shape and timbre which it portrays. While a pattern of dots is readily seen simultaneously as a group, a sequential group of musical tones is thought and heard as a group only by virtue of short-term memory. It is thus subject to its properties and limitations. Moreover, larger constructions of musical patterns involves longer-term memory and even long -term memory. Music in fact is an ideal means for studying the interplay of short-, medium- and long-term memory functions and their gradations. Deutsch (1982) and others have studied aspects of memory for pitch groups without microstructure. Memory for musical thought, however, significantly includes microstructure.

In music, recognition(See footnote 7) occurs involving microstructures in various modes:

1. Recognition of Pulse Microstructure

With regard to the pulse as pointed out previously, the repeated microstructure pattern is expected and is recognized without surprise. This mode of recognition works in a failsafe mode, like the orienting reflex. Attention is triggered mainly when an unexpected change occurs. In this respect it resembles many neurophysiologic sensory processes. Change in the pulse may occur in three ways: the pulse may stop, it may slow down or speed up, or it may change in character. We may call this process of continuing recognition reassuring the hearer of the continuing identity, "identity sensing". In identity sensing, the pattern is well known. We may then speak of a difference threshold with respect to various aspects of this pattern, permitting one to be alerted to a change in it.

Changes in the time scale of the pattern as a whole, such as are encountered in tempo changes, ritards and rubato, are experienced differently from changes in the pattern occurring on the same time scale. The former do not give rise to the impression of a new identity but signal merely a change in the rate of unfolding of the music. We may say that they concern the frame of the music and are of structural significance. They most frequently occur at transitions between sections of a piece, at ends of sections or of the piece itself.

But the specific pulse pattern is more than a simple badge or "flag" for recognizing the composer. It carries with it some meaning regarding the personality of the composer. Perhaps it will suffice to remind the reader of the different patterns of gait encountered in different individuals which are powerful clues for their identification, and can give certain impressions concerning their personality. Handwriting and the brush strokes of painters are other related phenomena.

The pulse is recognized as an identity and an influence. Its manifestation in terms of a systematic warping of durations and amplitudes may be regarded as a particular kind of shadow cast by the composer's personality. Identity sensing in the pulse provides familiarity, even intimacy. A change of identity is disturbing somewhat in the way a tree would be if it began to talk.

The image of identity reinforced throughout the piece may also be compared to the identity of a speaker recognized from his voice. Like an individual's voice, the microstructure of a composer's pulse is conserved in long-term memory. It thus contributes to how we sense that, as Casals put it once, in talking about the way to interpret a "new" Beethoven piece, "Beethoven is an old friend of mine". Even more than the voice, perhaps, the pulse can store an image (shadow) of the character of an individual.

This is what we have in mind calling it the "point of view".

The pulse form matrix represent "eigenvalues" for the specific time and amplitude warping of a particular composer. Pulse forms need to be learnt. It may take years for musicians to be familiar with the pulse form of specific composers(See footnote 8) . It is always an adventure to discover a new composer and to then experience the flash of understanding, to discover the intimacy of his pulse. No matter how many other composers one knows, this is always a new discovery - and having discovered it, that composer "lives in one's heart" from then on. When we say we love that composer, it takes on a special meaning when we know his pulse ("know" is meant as qualitative auditory pattern here, not as a numeric one, of course).

In terms of information processing and cognitive science, the phenomenon of the pulse (and its numeric matrix representation we have discovered) accords a means of identification, of continuity of identity, and those aspects of cognitive influence that belong with an understanding of the individual's character, in short empathy. The relationships the pulse provides need to be included with the database of the musical score. In choosing algorithms of musical thought and performance, the composer's character as manifested in the pulse matrix is an imperative choice. And when we freely think music, and compose, we cannot free ourselves of such microstructure, without killing the very identity of the thought.

Influences of pulse structure on other musical thought processes

Although it is not possible to derive the precise pulse structure from the musical score itself, there are influences and clear hints of it that may be noted. Originally we had thought that it might be possible to obtain the nature of a composer's pulse from the score alone, or from all his scores combined, since it is ultimately only through the score that we know his music (except for living composers). But when in 1983 we first discovered the precise way in which the pulse affects every note of the music, (represented now as the pulse matrix) it became rapidly clear that the pulse parameters are far too precise to ever allow determination from the score. However, we may now look at the music of the composer from the vantage point of the pulse matrix, and ask what it might *predict* concerning how he composes, i.e. how it may act as a constraint on various aspects of composition and point to particular predilections.

Influential aspects of the pulse matrix may be looked for in terms of the specific configuration of loudness and softness, lengthening and shortening of components of the matrix. Loudness combined with duration elongation will certainly lead to emphasis. Conversely, softening combined with shortening will produce disemphasis. But how to regard a shortened loud component or an elongated soft component? Composers may achieve emphasis through accent, through density of notes, through choice of pitch extremes, and through choice of long versus short notes. There is also a commonly believed but often false notion that the first beat of a bar is always especially accented. These are some of the factors (to which must be added instrumentation) which may serve as indicators of special treatment with regard to specific components of the pulse.

We have noted that the elongated second tone of Schubert's pulse is often portrayed by his special attention to this part of the pulse in his compositions both by density of notes and by the choice of pitch extremes melodically. Beethoven's strongly emphasized 4th pulse component is recognizable in his scores through note density. And we may see that his lengthened 4th and 1st tone often correlate with sturdy bass construction (bass tones tend to be longer than treble tones of similar nominal duration). We can also point out the special character of Schumann's 2nd and 4th tone and a strong de-emphasis on the 1st tone. The former may be recognized in special accentuations and syncopated notes and chords and tone densities in his scores. The de-emphasis of the first note tends to give Schumann a characteristic inwardness which indeed was his special contribution to music. (This does not prevent the music from displaying energy, however, in its own characteristic way.) Of course, there is no quantitatively deducible relation possible of required precision from these notated aspects. A statistical analysis could not lead to quantitative predictions required by the ear concerning specific matrix components.

In all this it should be emphasized that these indications in the score are not there pervasively and continually but only some of the time. It will be remembered, however, that if the pulse is forced to behave in certain ways by these constraints at such times, Time Form Printing will carry it through over the other portions of the piece, casting the same microstructure over structures that are neutrally free to accept this (scales, rests, figuration and other parts) (Clynes, 1977, Clynes and Walker, 1982, Clynes, 1983).

It may be possible, knowing the pulse matrix, to predict consequences in the compositional process in the works of the composers concerned. In a later section we shall give an example of this, comparing Haydn's works with Mozart's. On the other hand, going in the opposite direction, we may be able to deduce some characteristics of a person's personality from the pulse structure. In this way, we will show that aspects of the pulse structure of Mozart are consistent with our impression of Mozart's mentality. In the pulse of ethnic music we may substitute a collective character and identity relating to the people of that country for the personality and character's function of the composer. It seems likely that similar ethnic microstructure aspects may be found in the scansion and rhythms of language. These in turn may reflect characteristic ways of movement, inflections that may be seen in dances, as well as in everyday behavior. Such rhythms and their associated microstructures have specific cognitive significance due to the emotional qualities and their cognitive substrates that they involve.

The reader may note that we have not considered cognitive information concerning the nominal metric relations of long and short notes (a la Morse Code), information cognitive largely to musicologists (and those concerned with compositional techniques). This is not to deny the importance of the integers 2, 3 and 4 as universals in musical language, and in communicative time series in the construction of groups. However, only when these entities are embedded in their appropriate time and amplitude warp with its greater information do they acquire their real living significance in music. This significance is inadequately spelled out by single bit descriptions such as accented and unaccented, long and short. (Cooper and Mayer, 1960; Lerdahl and Jackendoff, 1983, who actually go to a 2-bit description of emphasis).

2. Recognition of Tone Shapes

What appeared as the reassurance of continuing identity in the repeated microstructure of the pulse becomes dullness when applied to tone shapes: The process of identity sensing now becomes an error detector. *If two shapes are the same, a flag is produced indicating meaningless* (with occasional deliberate exceptions where the meaninglessness becomes part of the intended meaning). Each shape draws attention to itself in a new way. New itself; but also pointing towards the future. It is literally pregnant with what will occur. Like biologic pregnancy, its signs are covert. It is the change in shape from "neutral" which is significant, and which we notice. That change makes us expect the next tone, when and where we might find it. But the same shape also has emotive overtones. It is one of the marks of integrity of the composer's thought that the emotional meaning of the musical phrase is congruent with the generation of meaningful amplitude shapes as each melodic tone unfolds, born pregnant with the expectation of the next tone - or of silence.

This is then the generative principle: *that the tone shapes predicted by musical structure should themselves predict the melody, in an unconscious manner, and reinforce the emotional quality that gave rise to the thought.* Therein is the essence of this musical integrity. The formulation of this principle we have discovered achieves this natural phenomenon of integral musical thought. It appears to be a good model: it makes the musical thought sound as if it were born in the moment. (See footnote 9)

3. Meaning of slight microstructural differences in repetition of themes and motifs

Recognizing slightly different amplitude shapes and sizes becomes specially important when the same musical phrase or motive is repeated. The ear is very sensitive to relatively slight differences in this respect between a musical phrase or fragment and its repetition. Considerable significance is attached to this slight difference(See footnote 10) . We have elsewhere described (Clynes, 1983) how, for example, in the last movement of Beethoven's violin concerto the first bar of the theme is repeated with slightly greater emphasis, while in another composition by Mozart (e.g. Symph. Concertante K364, 3rd Mvt, Bars 80-83, 88-91, also 24-26, 28-30) such repetition may require a slightly lesser emphasis. Without going into details of what kind of differences may be required and are significant with different composers and different pieces, we may look here at the kind of information that such differences provide. Here is another means of indicating mental attitudes! In the case of the Beethoven example the greater emphasis on the repetition shows an active participation, and increasing engagement, a degree of passion and forcefulness. With the Mozart example, we see on the other hand disengagement, a spectator view that says "Yes, this *is* the phrase we have 'seen before'". This includes a logical process, but more than that, by playing it with a certain lesser emphasis it also indicates a sense of abstraction, of looking at it and considering it. Had the repetition of the fragment been the same, it would not have indicated the attitude of abstraction, of demonstration, it would only have been dull.
Thus, by some slight difference of emphasis - only perhaps 2-3 percent are considered here, not those larger changes described by markings of diminuendo or crescendo - produced by slight changes in amplitude and/or shape of similar musical events to convey attitudes and intellectual thought processes. This is an important function of superior music interpretation that has drawn very little theoretical attention.

Such rather delicate shaping is also involved in the shaping of musical symmetry. The notion of symmetry in music is and extraordinary one. The arrow of time is intrinsically in one direction: how then can two successive events create an impression of symmetry? Memory obviously has to come to the rescue. But then it would seem the earlier event and the later event are not equally favoured. Symmetry may be experienced in music to some degree when A - B is succeeded by B - A in certain parameters. Most commonly, this involves pitch and/or harmonic relationships. But a fast passage is not regarded as the symmetric partner of a slow passage. The arms of symmetry tend to occupy similar time spans. Symmetry is a structural property, and thus largely outside the scope of this essay. Yet amplitude microstructure may add to the "graphic" depiction of symmetry. It adds conviction to its logic - emphasizing that two dissimilar fragments are yet in some inverted way similar, and together comprise a compound entity.

Thesis and antithesis will produce synthesis, even though this happens in a unidirectional time series. For synthesis to occur obviously, memory must keep the earlier instance fresh. At what point do we lose that freshness that we need in order to make the A/B comparison to catch the meaning? Certainly up to 10-15 seconds seems to present little problem, but 1 minute does, and 10 minutes may be quite difficult. But we do not know how such memory fades in the Central Nervous System.

4. *Choiceless Recognition*

Recognition of essentic form
The gripping quality of essentic form

Essentic form inherently has the power to command attention. This gripping fascination is a product of its vivid "livingness" (See footnote 11) incorporated into the musical phrase. A remarkable quality of essentic forms, the dynamic forms of emotional qualities: the truer they are the more they force the hearer to attend. We see this arresting quality, for example, with the special attention a mother gives to the cries of her infant. It lies also at the basis of the phenomenon of charisma. And in the presence of a few tones played by Casals one forgot all other concerns.

A special thing about the recognition of essentic forms is thus its attraction: it is a choiceless recognition, and the mind is attracted more intensely the more perfect the realization of the form. This playing with attractive disembodied essentic forms is a main reason why we like music. The input is not merely recognized, it also overpowers some of the organization of the algorithms. It *forces* us to think in certain ways (non-musical). It appears to be the opposite of a process of intelligence that permits free consideration. The qualities of the emotion engendered by their contagion themselves influence and even direct thought processes. Suddenly we may experience the lightness of joy, the heaviness of grief. Our motor impulses are even modulated by the strange and fascinating inputs. We seem to be captive as well as captivated.

Of course "nature has invented" this very process of communication to permit sexually based reproduction. In the sexual urged "nature has invented and implanted" choiceless recognition. Without a mirror, the primitive organism knows its own species and its mate. Another early invention embodying similar captive information, but without communication, is its "invention" of the psychobiologic entity, hunger. Later "inventions" such as love, joy, anger, grief and so on each incorporate cognitive aspects choicelessly appended to the experiential quality (intuition or instinct were names often used for these). In all of these, serial ordering in time becomes no longer stochastic or subject to "free will", if you will,* (See footnote 12) but follows a characteristic program in terms of thought processes, and even motor behavior.

Escaping the Grip: A Higher Choice - Freedom in Captivity

In being captivated by the essentic form we become subject to further expectations suffused by them. But we are captive only apparently. Like a Houdini, we humans have been given an escape that animals do not seem to have (that may be one reason why animals are not music lovers). This escape is the ability to consider the emotional quality of the essentic form fully, while at the same time being free to contrast it, to compare it, to view it from a point of vantage. This particular escape algorithm is not always used. Some music, notably popular music, is not designed for its use(See footnote 13) . We call such music Dionysian. When it *is* used (in the Apollonian way of thinking and listening to music) it is able to bypass and escape those processes that attach the knowledge inherent to the emotional qualities to ego function. Instead of connecting them to ego functions they become available for synthesis that views the various qualities and their cognitive substrates. This indeed is the understanding and experience of the work of art, and is a largely identical process to that of empathy with another person (using this word as in Clynes, 1977).

This cognitive aspect may be compared with the function of a main program as constrasted with its many subroutines. Thus, while on the subroutine level essentic form holds the mind captive, at the main program level it is completely free to call the subroutines as it chooses. The choice is thus relegated upwards in the aesthetic experience. While we rejoice at the livingness of each essentic form even if it be of negative emotion, such as grief, and are held captive by it, we may view this very captivity from a point of freedom, a source of strength and a focus of knowledge. A parallel processor, you might say. As in this discussion.

5. What the Pulse Structure May Tell Us About the Composer's Mentality

As a short example let us consider the subtle difference in intonation and accent between a real question addressed to another and the same question asked rhetorically. There is a characteristic difference in the dynamic form and accentuation. Recent work (Zajonc, 1984, and others) has emphasized inherent links between gesture and cognitive attitudes. Mozart's phrases at the end of a piece or major section often resemble the dynamics of a rhetorical question (Figure 4). The impression is not like a question asked from someone else, or even a question asked to oneself to which one does not know the answer. Mozart knows the answer and in fact provide it in a complementary phrase. This symmetry of discourse is like "Is that so? That is so.". The two phrases or musical statements combined give symmetry and certitude. The impression of certitude is achieved, however, only with the appropriate microstructure. "Is that so? Yes, that is so.", or, to accommodate some more tones, "Is that not really so? Yes, that is really so.". Between the accents there is a lightness. The words 'not' in the first phrase and 'is' in the second phrase are said very lightly if we are dealing with a question in a logical and intelligent context of thought. Heaviness in these syllables would produce a massive, aggressive, or even threatening effect. Mozart's pulse provides that very intellectual detachment, the unbiased consideration, the looking at matters *as they are.* The intellectual process requires just the kind of scansion, the alternation of lightness and accent that the Mozartian pulse provides. We have previously described the Mozart pulse as being that of a spectator, a cosmic spectator (Clynes, 1969). Phrase structures like the above when executed with the Mozartian pulse contribute to the impression of impartial wisdom and certainty that seems to be implied in much of Mozart's music. The final statements, "Is that not so? Yes, that is so." appear as a seal that certify what has gone before, a frame emphasizing "This is the truth.", (but without "so help me God", which may suit other composers better, perhaps).

It is very easy to perform the same phrase with a microstructure that causes this effect to be lost. One needs to only play it, say, with Beethovian emphasis and it loses all pretension of intellectual consideration. One may play it with a Haydn microstructure and here the relative accentuation, while short, of the fourth tone would produce the effect, somewhat, of a genuine question and give an aspect of playfulness and joviality to the whole.

But even without going so far removed as the Beethoven pulse we may note that even a slightly increased emphasis on these syllables or tones would detract from the elegant, almost mathematical certainty. Instead of certainty the statement becomes merely an estimate. And if you make it too light the certainty evaporates into frivolity. Microstructure provides a very fine line. The remarkable thing of course is that that particular fine line suits only Mozart - it would be out of place for any other composer. Here is an example of how microstructure and structure can link. (See Figures 5 and 6.)

Predicting Compositional Aspects From the Pulse Structure

An interesting comparison may be drawn between the pulse structure of Haydn and that of Mozart: their style is in many ways similar and belongs to the same period. But their pulse structures are considerably different. Using our program, we can readily play a movement of a Haydn sonata with the pulse microstructure of other composers (Clynes, 1986). When such a movement is played with a Mozart pulse it sounds wrong and loses its vitality. (Conversely, a Mozart piece played with a Haydn pulse also sounds unauthentic and false.)
The most salient difference between the Haydn and Mozart pulse microstructure lies in the fourth tone. This tone is much more emphasized in Haydn, yet without being elongated as in Beethoven. How would this difference affect their compositions? Consider the finale movements of Haydn. In some ways Haydn is at his most characteristic in these movements. Frequently in such movements a four note group of eight notes forms a pulse group. The last eighth note of such a group receives the emphasis called for by a Haydn pulse. Emphasis provided only by increased loudness of that tone could become tiresome with a preponderance of four eighth note groups. Another way of providing such emphasis would be by a salient pitch for that note compared with surrounding notes. If that note is an up beat we might expect

a relatively larger pitch interval (downward) between it and the following main tone. This means of emphasizing the pulse component by disjunct or salient pitch could supplement amplitude conditioned emphasis. Accordingly, we might expect that on the whole the finales of Haydn would show a larger proportion of such disjunct pitch progressions in upbeats in the fourth position of groups than finales of Mozart. It would seem likely that such a mode of emphasis would be used by a composer at least some of the time, occasioned by the pulse. Whether this prediction is true or not remains to be ascertained. Here a statistical examination of such movements would provide an answer.

This kind of emphasis also bring out the playful, jovial character of the music typical of Haydn, whose open-hearted, a little naive and innocent humor founded in natural piety is far removed from the wit of Mozart. The spirit of the music, the nature of the composer and aspects of compositional technique convergently touch in that dynamic icon, the precise pulse form - a powerful factor of integrity in musical thought.

New aspects of order in musical thought - summing up

We thus have seen the following ordered processes contributing to musical thought revealed in microstructure:

1. Choiceless recognition of essentic form - essentic form is a window across the mind-body barrier.
2. Identity sensing in the form of the repetitive pulse matrix - a process that unconsciously impregnates our knowledge of the composer and music.
3. Recognition of differences of shapes of individual tones and their integration into larger structures in a systematic way that contributes to meaning: Predictive Amplitude Shaping, a process that defines an aspect of musical integrity by unconsciously foreshadowing continuity of musical thought.
4. The meaningful detection of small differences in emphasis between repeated groups of tones - that allows reflection of mental attitudes.

We are used to associating the word intelligence with only conscious processes. Order is manifest as a result of such conscious processes, we think. However, there is much observable order and design in the universe without evidence of conscious influence. And even when consciousness is used, much of the consequent processes are unconscious.(See footnote 14) .

It is a difficult task to try to combine the conscious and unconscious aspects of thought into a coherent whole. The task involves not only the boundary between the mind and the body, but also between conscious and unconscious, and between the unconscious and the body. Where do unconscious processes end and the body's processes begin? Is there a boundary between the unconscious and the autonomic? Between the unconscious and the neurohormonal production and inhibition processes? We have not yet come to grips with these questions, nor do we know whether they can be posed better in a different form.

In thinking music, as in thinking, the conscious and the unconscious interact. In musical thought there are phenomena of which we are not normally conscious which greatly contribute to its formation and meaning: We have made some of these accessible to consciousness in a way that had not been previously possible. So far there do not seem to have been comparable findings in regard to spoken language. It is possible that some of these findings concerning musical thought may be applicable to other thought processes, and perhaps to spoken language. (Regarding parallel aspects of this work on music with Chomsky's work on language, to which commentators appear to be inevitably drawn, I should like to leave comments on such a comparison - interesting many ways - for another future paper.)

In choiceless recognition the choice has been made for us by nature: the quality of experience and the input are conjoined - there is no freedom to think about this. A yawn cannot be anything but a yawn, an expression of joy an expression of joy, just as green is not green by choice, nor sweet sweet by choice. Further, essentic forms are loaded with cognitive substrates forcing the mind to modify thought processes. Recognizing the pulse becomes almost choiceless when it is repeated enough. Choice is present in the initial selection of the pulse, in interpretation.

Choice is finally present in the synthesis of the entire musical experience. This reflection on the entire work is an option that may be freely carried out in many ways using as material the choiceless recognition experienced.

In the musical experience there is then a combination of choiceless recognition and fee choice. As in other forms of thinking, we may separate the functions of thought into the free and the constrained (as opposite aspects). Without aspects of free thought there can be no conscious intelligence. Insofar as music enjoins free thought, it participates in intelligence; insofar as it partakes of choiceless recognition, it partakes of natural order.

When nature invented hunger, it also invented its way of how to combine the autonomic and unconscious with the conscious. Only, nature did *not* invent hunger. Nature is only a word we use, like instinct, to hide our ignorance. Nature is not a person, nature is not even an entity - there is only the universe and its laws. The illusion of "Nature" is hard to shed. What is left that can combine the conscious with the unconscious? That can become conscious? That can think?

If nature did not create consciousness, since there is no nature, it, like the possibility of a DNA molecule, must originate in the fundamental laws of the Universe.

This is not surprising. The laws themselves appear manifestations of intelligence - built through choice; harmonious, beautiful choice. They are not stochastic events themselves, even though they give rise to such events. They must contain in themselves the potentiality of consciousness, as they do the potentiality of water.

This means it must be possible to predict the advent of consciousness if certain conditions are fulfilled. Some day we may know what these conditions are. We should then be able to tell whether and when a computer may be conscious. But consciousness is not the only way new "intelligent" phenomena appear. Computer answers or responses by themselves inherently will never be able to convince us that the computer is conscious: I cannot, unfortunately, think of any way which a computer that does become conscious could convince us of it. we would never know - everything the computer said could be simply the result of its programming, imitating conscious behavior. Even if it said, yes I enjoyed that joke and laughed, we would not know that it had not simply followed the principle (programmed into it) of suddenly perceived apparent incongruity, that is almost immediately seen to really belong in a larger order. For that is what we do just before we laugh. We laugh consciously, but we do not consciously know clearly what made us laugh. We really know neither "what" is funny nor the nature of funniness. We only know *that* it is funny. Without even knowing "it". So we only know *that.* And *that* may be all we can know, consciously.

But if a computer said it dreamed, then maybe we could believe it.

* * * *

Our computer program plays music so that it is impossible to believe that no human performer is involved. It pays as if it enjoyed the music in the moment. But of course a human performer *is* involved - though not in the moment, as in the conventional way of performing music. Now the performer instills the principles in the appropriate way and lets them do the "thinking" from then on in their computer environment. That they rivet the attention like an old fashioned human performer only shows that the modern performer has applied them properly.

What indeed rivets the attention in music? It is not surprise. It is not expectation. It is that, as in story telling, one is continuously surprised while continuously being expectant - and all the while interchanging things that one expects and things that give one surprise - that too is expected and a surprise - like when we dream. In fact, the greatest performances and experiences in music are so that the music and its feeling makes us think the way the music goes - together with it, not before, and not after - but in thinking together with it, the unconscious processes think with it both before and after, exactly as we do when we dream to ourselves. The music becomes our own dream. And when we know how we dream, which is a long way off, we shall also fully know how music works its wonder.

And the beauty of it is that the expectation and the surprise together retouch our potentiality; as in everyday life, as we wander and explore, it may all come together unexpectedly, and we then see in a moment something timeless that yet endures in us. And that may be the most basic information we can get from music.

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Appendix A

Operation of the Pulse

The pulse may operate on the tones of the music at several hierarchical levels. We will describe the function and structure of the pulse first for its lowest hierarchical level. This level takes as its unit the fastest notes of the music (not considering ornaments). These may generally be grouped as 2, 3 or 4. For example they may consist of four sixteenth notes in an allegro movement in 3/4 time. Microstructure for that level may be written as:-

110	92	100	96	Level 1
1	.53	.75	.87	

where the numbers in the upper row indicate the relative duration modification of the four tones (100 being perfectly even); and the lower row indicates the relative loudness (amplitude) modification of these tones - given on a linear scale here, referred to 1 as the first tone of the group.

If in the music the notes are not all sixteenth notes, and so are notated longer, as is generally the case, the duration of such a note is given by the sum of the duration of its component sixteenth notes. The loudness of such a note, however, is given by the loudness of its *first* sixteenth note component.

In our example the four sixteenth notes of the lowest level of the pulse together constitute a quarter note. The next level of the pulse may then consist of three such quarter notes. This second hierarchical level then may comprise a bar in 3/4 meter.

103	97	102	Level 2
1	.65	.92	

This means that the groups of four sixteenth notes of each of the three quarter notes are all modified i.e. multiplied by these parameters: the durations of the sixteenth notes of the first quarter are multiplied by 103 percent, those of the second quarter by 97 percent, and those of the third quarter by 102 percent. Similarly, the loudness of the first four sixteenth notes are multiplied by 1, the second group of four sixteenth notes are multiplied by .65, and those of the third group are multiplied by .92. The second level microstructure modifies the lowest level in duration and in amplitude, taking each *group* as an element.
Similarly, the highest level acts multiplicatively on all the elements of the lower groups. The microstructure of this level might be, for example,

100	98	98	100	Level 3
1	.80	1.24	.93	

and represents *four bars* of the music in this example. Each element of this third microstructure level modifies a group of twelve sixteenth notes in this example.

The entire "pulse" in this example comprises *4x3x4 or 48 sixteenth notes* , all of which have individual durations and amplitudes.

The lowest two levels determine the general character of the pulse . The highest level allows the phrases to relate to each other in a musically compelling way. In general this level is too slow to be clearly felt as a rhythmic factor - it is felt more as contributing to musical "logic", balance, symmetry and natural ebb and flow of the music, often called "breathing" by musicians.

Composer's Pulse

The composer's characteristic pulse, described initially mainly for a single level (Clynes, 1983), appears to operate on *both* lower hierarchical levels. Depending on the tempo and the construction of the piece, an attenuation factor may be inserted which can soften the influence of the pulse from one level to another to a required degree, producing a partial hierarchy. This factor (one each for duration and for amplitude) operates equally on all component tones, and is useful to avoid exaggerated effects which may sometimes be produced through a full hierarchy. The composer's pulse as determined for 2,3,4, or even 5 tone groups is entered on both levels. In practice the attenuation factor tends to vary in the range from .7 to 1.2 at most.
The highest level generally contains small duration deviations only, but considerable amplitude modifications. Of quite a different nature from the composer's pulse entered on the two lower levels, it is separately determined for each piece, although it may be that further experience will reveal characteristic patterns for different composers also. These patterns would not be expected to have a numerical relation to the pulse entered on the lower two levels.

In applying the pulse to a specific piece, appropriate metrical durations need to be chosen for each level.

Often there is a choice between 2 or 4 as the grouping on the lowest level. This choice influences the choice at the next highest level; and this in turn the metrical duration of the highest level. *It is part of the composition process that in fact only one solution is musically acceptable.* This solution does not necessarily lead to the bar as a unit on the highest level. It may be half a bar, or in fast tempos, even two bars.

The Pulse and bar structure

The three level pulse pattern may comprise 4 bars or some multiple or submultiple of this. However a composition may have a group or groups of 3 bars, or 2 bars inserted between the more usual 4 bar sequences. For such "irregular" bar groups, the pulse may start with its second or third bar pattern respectively, and finish the irregular group withj its "bar 4" pattern, thereby leading into the next 1, of a 4 bar group to follow. It is generally the first bar that is "missing" in a single 3 bar group, not the fourth. (This does not necessarily apply to a continuing pattern such as when Beethoven writes "in ritmo del tre battute".)
In larger pieces one may indicate places or bar numbers where the pulse is to "reset". This often happens at the end of larger sections. Helped in this way, the overall sense of the music is surprisingly well portrayed. Of particular interest for analysis, also, is on what part of the pattern the piece ends - a significant aspect of the composer's ways of thought.

Sensitivity to pulse parameter values

Quite a small change of a single amplitude modifier parameter may change the character of the pulse considerably. A one percent change in a single lower level amplitude parameter is generally noticeable, while a 3-4 percent change may suffice to change the character from "light" to "heavy", or some other quite marked change in character for which words may not readily be found. Changes in a duration parameter resulting in two millisecond duration changes in corresponding tones is quite noticeable, and even finer control would be likely to be effective if it could be instrumented.

Appendix B

Predictive Amplitude Shaping

1. Beta Function for Shaping Tones

The name Beta Function derives form a similar named function used in mathematical statistics, but is not the same function as that used by statisticians. The Beta Function as used here is the argument of integration of the statistician's Beta Function, without the integration. The Beta Function as used here is defined as:

$x^{p_1}(1 - x)^{p_2}$ for $0 < x < 1$

and is normalized for a maximum amplitude of 1 by dividing by a constant N

$$N = \frac{p_1^{p_1} \quad p_2^{p_2}}{(p_1 + p_2)^{p_1 + p_2}}$$

for a particular set of values p_1 and p_2 .

p_1 and p_2 have values > 0

The resulting shape is multiplied by a parameter G to give the amplitude size of the particular tone. The shape stretches over a number of points determined by the duration of the tone. Thus, the amplitude envelope as a function of time, A(t), of a tone of duration T is given by:

$$A(t) = \frac{G}{N} \bullet \left[\frac{t}{T}\right]^{p_1} \bullet \left[1 - \frac{t}{T}\right]^{p_2}$$

2. Predictive Amplitude Shaping using Beta Function parameters p_1 and p_2

Each tone has its own p_1 and p_2 values that determine its shape.

$p_{1(m)}$ and $p_{2(m)}$, the base shape values, are chosen to fit the character of the music.

p_1 and p_2 vary from note to note according to the following equations:

$$p_1 = p_{1(m)}\, e^{\,b\, s\, \exp(-aT)}$$

$$p_2 = p_{2(m)}\, e^{\,-b\, s\, \exp(-aT)}$$

(a and b have small values)

where s = number of semitones to next note (upwards - ve)

b = modulation constant of $p_{1,2}$ by frequency

a = modulation constant of $p_{1,2}$ by duration

T = duration of the present tone in milliseconds

$p_{1(m)}$, $p_{2(m)}$ = base values of p_1 and p_2

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N.B.

FOOTNOTES

(Footnote 1)

With their use it has recently been possible with a computer to generate satisfying performances of the 48 pieces of Bach's Well Tempered Clavier Vol. I, as well as works of Beethoven, Mozart, Haydn, Schubert, Schumann and Mendelssohn. We shall not discuss the merit of these interpretations - considered outstanding by musicians - in this paper. They are available on tapes from the Research Center, N.S.W. Conservatorium of Music and are also being prepared for issue to the public. The exact microscore is also provided for each piece together with these recordings.

(Footnote 2)

A recent study (Clynes, 1986) "Music as Time's Measure" investigated aspects of the psychobiologic clocks involving musical thought and performance, revealing also a quantum-like behavior in the rates of these clocks.

(Footnote 3)

The significance of "It's a good morning" said by one particular person may be judged in relation to a vast number or scope of things that person might have said at that moment, i.e. the total potential of that person in that particular situation, versus a comparatively limited number, say, when said by another person. The experience of music is also a continuing function of potentiality.

(Footnote 4)

What do we mean by "intelligence"? Workers in the field of AI have not arrived at a definition of the word "intelligence". For psychologists, "intelligence" is what intelligence tests measure.

But as a working usage, AI considers pattern recognition, thinking and problem solving as involving "intelligence". We shall not try to stretch this concept for consideratoin in music, but stay within these bounds, uncertain as they are. Instead, musical considerations lead more to a distinction between free and constrained cognitive processes.

(Footnote 5)

They were discovered through synthesis, not analysis (for details, see Clynes, 1983, 1985). Analysis of existing performances is not possible with sufficient accuracy to define the parameters of importance, synthesis makes it readily possible to generate musical structures with any desired microstructure, which may then be evaluated by the ear. Our computer program for this, in FORTRAN, may be obtained by writing to the author. The program also incorporates the principles described herein.

(Footnote 6)

Nor would it be likely to be possible for a composer to sufficiently, accurately estimate the microstructure he intends without synthesizing it (i.e. performing it) so that it corresponds to his thought, although it would become easier to do so with practice.

(Footnote 7)

The word "recognizing" can bear a little closer inspection. Note that we don't use the word "cognizing", and there is no "re-knowing". "Know" in English serves the double function of "savoir" and "connaitre" in French, of "wissen" and "kennen" in German. There is "erkennen" in German, and "wiedererkennen". Somehow savoir got lost in English, nor can the different kennen, erkennen and wiedererkennen be portrayed by single words in English. But in French or in German it is readily possible to connaitre and reconnaitre without the detail of savoir, to kennen and erkennen and wiedererkennen without wissen.

(Footnote 8)

In our early sentographic measurements of the pulse, one of our subjects was Murray Perahia who was then about 20 years old. He provided beautiful examples of the Mozart, Schubert, and Beethoven pulse, but could at that time only provide a "mechanical" version of the Schumann pulse, being less familiar with that composer. Later he became expert at interpreting Schumann: undoubtedly, today he would produce a fine Schumann pulse - we shall soon be able to make that comparison.

(Footnote 9)

"It thinks" said Marvin Minsky on the first hearing of our interpretation by these two principles of Beethoven's Hammerklavier Sonata Op. 106, (last movement). That also applies to the meaning of musicality in performing music.

(Footnote 10)

Minimalism has long been used in the effective interpretation of classical music!

(Footnote 11)

A word used by Susan Langer (1953) - corresponding to the German "Lebendigkeit".

(Footnote 12)

if you will pardon the pun **

** if you will pardon the pun *** etc.

(Footnote 13)

In music specially designed for meditation (such as the "new age" music provided by Steven Halpern), and to an extent also in impressionistic music pioneered by Debussy, thought does not get directed toward larger musical structure as in other music, and does not in the same way involve short-term memory and expectation as in other music. Thus the relative left and right brain function is altered in this kind of music, with greater emphasis on direct associative functions.

(Footnote 14)

Looking at the kinds of order we may find in the universe, even though we don't know *how* such order may have come about, we may note at least four kinds of manifestations:

(1) Design of the universe and its laws, the order of fundamental particles, atoms, molecules.

(2) The development of dynamic functional designs in biologic nature. For example, the weave of the spider's web together with its associated recyclable processes of biochemical production of its material, of securing food supply, of presumable satisfactions of the spider in its production and function. The spider's web provides a visible image of such an ordered process, but innumerable processes exist of this kind, not visible to the eye, like the genetic code, within cells and in larger organisms.

(3) The learning of motor performances such as, for example, riding a bicycle. In this, consciousness plays a role but a very minor one compared with the ordered unconscious processes that have to function in order to accomplish the ordered behavior of riding a bicycle.

(4) The processes of thinking, the processes associated with conventional intelligent thought, and with dreaming. These, too, operate with a very large unconscious component, the conscious input and output being more like the tips of the iceberg.