

PRENATAL EXPERIENCE AND THE ORIGINS OF MUSIC

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Introduction

In this article I advance, and provide tentative support for, a theory of the nature and origins of music based on prenatal experience. Specifically, I speculate that certain cross-cultural features of rhythm, melody, and harmony ultimately stem from sounds produced by walking, blood circulation, and speech, as heard in utero by the human fetus; and that emotional aspects of music have their origin in the mother-fetus relationship.

The theory is motivated primarily by the wealth of literature on prenatal audition that has appeared during the past two or three decades, much of which is cited elsewhere in this volume. The following points may now be regarded as reliably established:

(1) The fetal ear begins to pick up sound some five ~~to six~~ months before birth. Three to four months before birth, the inner, middle, ~~and outer~~ ear of the fetus attain adult size, form and function. The inner ear includes both the cochlea (housing the basilar membrane, the receptor surface of the auditory system) and the vestibular system (the organ of balance, enabling the perception of orientation as well as linear and rotational acceleration).

(2) The amniotic fluid transmits sound to the fetal ear with little damping over most of the audible frequency range. However, high frequencies (above about 2 kHz) are sharply attenuated.

(3) The human fetus responds to sounds during the last four months before birth by moving (e.g., by kicking). During the same period it is possible to measure both heartrate changes and neural responses to sound — the latter by means of electroencephelography (EEG).

(4) Sounds heard before birth influence postnatal behavior. This has been demonstrated for sheep (Vince et al., 1982a) and birds (e.g., Harrer, 1975) as well as humans. Sounds heard before birth by the human fetus, such as the mother's heartbeat and voice, short stories repeatedly read by the mother, or specific pieces of music repeatedly heard during the latter part of pregnancy, have been found to affect aspects of postnatal behavior such as heartrate and breathing. Newborn babies can even distinguish their mother's voice from the voices of other women — an ability that could only be acquired prenatally.

(5) The human fetus is repeatedly exposed to a range of audible (and often quite loud) sounds produced within the mother's body. These sounds may be divided into four main categories (cf. Vince et al., 1982b);

(a) Sounds produced by the mother's cardiovascular system, especially the blood vessels in the uterine wall (Bench, 1968);

(b) Sounds associated with gross bodily movements of the mother, especially walking;

(c) The mother's voice and breath; and

(d) Sounds associated with drinking, eating, and digestion.

Some possible relationships between the first three listed categories (a, b, and c) and aspects of rhythm, melody, and harmony in music are discussed in detail below. Digestive sounds (d), no less important than the other three categories for the fetus, do not appear to have direct musical correlates. This may be due to an absence of simple, recognizable patterns in digestive sounds, or to a lack of positive associations with such sounds. The first three categories of sound have clear positive connotations — the heart as the mother's life-center, the voice as her means of expression and communication, and the pleasureable rocking movements of walking.

At birth, the sensory systems are ready to begin an intensive learning process. It is essential for survival that the infant become familiar with the sights, sounds, textures, tastes, and smells of the world into which it is born, and that this learning process occur as quickly as possible. However it is hardly likely that birth acts as a "switch" that "turns on" perceptual learning. It is more straightforward to hypothesize that perceptual learning begins before birth and accelerates gradually until, at birth, it has reached a rate sufficient to allow the infant to cope with the enormous quantity of new information that it will face in the postnatal world.

In most animals, the auditory system does not begin to function until birth, or soon thereafter. This observation, in conjunction with considerations of cognitive, linguistic, and social aspects of music, is sufficient to explain the relative insensitivity of animals to music. The precocious development of the auditory system in the human fetus may be due to the importance of sensory learning in humans (that is, the relative absence of instinct) and in particular the importance of speech. The early development of the

vestibular system, or organ of balance, also allows the fetus to monitor and control its position in the uterus both before and during birth, and to monitor the mother's movements via linear and rotational accelerations, as detected by the fetal vestibular system.

Cross-cultural aspects of musical structure

The musical cultures of the world are enormously rich and diverse. Ethnomusicology is primarily concerned to explore musical styles and cultures and their many differences — differences that are not surprising in view of the independent development of musical styles in isolated societies and in different countries and continents. These differences initially suggest that musical structure has no universal aspects at all. Even octave equivalence, often cited as an example of a musical universal, appears to be absent from some melodic genres, and manifests itself in very different ways, or to very different degrees, in different musics.

In the absence of clear-cut musical universals, it may be more appropriate to look instead for cross-cultural similarities pertaining to music. The following similarities are striking in the light of the large number of musical cultures to which they apply — cultures that initially developed in isolation from one another.

(1) Most or all human societies include music among their essential cultural activities. No human society has ever been discovered in which music did not play some role.

(2) In most or all societies, specific kinds of music are strongly associated with specific kinds of emotion, and are used to arouse those emotions. Music is chosen for different social functions (entertainment, celebration, mourning, nationalism, and so on) according to the kind of emotions it is supposed to evoke. However the specific mapping between musical structure and emotion differs widely from one culture to another.

(3) With the exception of long-term structures (musical form) and semantic aspects of music such as song texts, virtually all acoustic structures used in world musics may readily be classified as rhythmic, melodic, or harmonic, according to the following tentative definitions:

Rhythm evokes an isochronous (equally-spaced) beat, or pulse sensation. The range and distribution of frequencies covered by rhythmic pulse sensations corresponds approximately to the range and distribution of human heartbeat and walking rates.

Melody involves the rising and falling in pitch of a single voice. The range and distribution of pitches in most music, both instrumental and vocal, is similar to the range and distribution of the pitch in non-musical human vocalizations, especially speech.

Harmony involves the blending of simultaneous voices, such that new timbres are created, and the apparent number of voices is less than the actual number.

How could prenatal experience explain these similarities? There exists considerable anecdotal evidence that an individual's prenatal experience influences that individual's

perception of music. For example, a particular piece played repeatedly before birth may take on particular significance after birth, or be particularly easy to learn (Tomatis, 1981; Verny, 1981). Musicians such as Menuhin and Rubinstein claim that their musical careers began in this way. It is not the intention of the present article to investigate this evidence. Instead, I am primarily interested in sound patterns heard repeatedly by virtually all humans before birth — the internal sounds of the mother's body.

The prenatal auditory environment includes sound patterns remarkably similar to musical structures. These sounds are produced by the maternal cardiovascular system, movements (especially walking), and the voice. Familiarity or conditioning of the auditory system by repeated exposure to such sound patterns before birth could lay the foundation for the development of music in all human societies.

Infants have been found to be remarkably sensitive to elementary musical structures. According to Trehub (1987), infants can distinguish between long and short events in temporal sequences over a wide range of tempi (bases of rhythm), perceive pitch contour and streaming (bases of melody), and detect harmonic pitch intervals such as the octave, fifth, and third (bases of harmony). According to the hypothesis of prenatal experience, infant sensitivity to rhythm is a consequence of prenatal exposure to the sounds produced by the mother's cardiovascular system and footsteps (Parncutt, 1987), and infant sensitivity to melody and harmony develops by prenatal exposure to the mother's voice (Parncutt, 1989):

Rhythm

The maternal heartbeat, as heard by the fetus, has been described by Salk (1962) as an imprinting stimulus. Imprinting stimuli are generally learned quickly during a critical period of development, and strongly affect perception thereafter; a well-known example is the tendency of some new-born animals to treat the first animal they see as their mother. Whether the maternal heartbeat is a stimulus of this kind is arguable, since there is no particular survival value associated with recognition of the maternal heartbeat — at least not by comparison to recognition of the mother's face or voice. Experiments by Salk and others have nevertheless clearly shown that heartbeat-like sounds, played at moderate rates, have a calming effect on new-born babies, causing them to cry less, sleep more, breathe more deeply, digest better, and become ill less often; while faster heartbeat sounds can have the reverse effect. The prenatal learning of heartbeat sounds may also explain why babies are more often fed from the left than the right breast, as confirmed by Lockard et al. (1979).

A possible musical correlate of the maternal heartbeat sound, at least in western music, is *rubato*, or perceptible tempo fluctuations. In most western music — notably, in the romantic music of nineteenth-century Europe (Beethoven, Chopin, Schubert, Brahms, Liszt, etc.) — *rubato* (otherwise known as *agogics*) was an important means by which musical performers communicated emotion to their audiences. The emotional meaning of *rubato* may be linked to variations in the mother's heartrate, as perceived by the fetus. The mother's emotional state is presumably shared by the fetus at some level, due to sharing of hormones. The fetus may also pick up information about the mother's emotional

state via cues such as tactile pressure indicating tension, particular digestive sounds, vocal intonations typical of specific emotions, or even external sounds such as the voice of an angry husband or partner. The fetus could thus learn to associate heartrate changes with specific emotional qualities.

Another prenatal correlate of musical rhythm is the specific combination of sound and movement experienced by the fetus when the mother walks. Bodily movements are perceptible to the fetus due to the early maturation of the vestibular system. Prenatal experience of the mother's walk could underly the soothing effect of cradle-rocking on babies (Clouser, 1971). It could also explain why and how rhythm is linked to dance, in virtually all human cultures.

Musical intuition suggests that the kind of rhythm produced by footstep sounds is qualitatively different from that produced by heartbeats. The time intervals between footfalls in walking are more regular or "metronomic" than the time intervals between heartbeats. This may be confirmed simply by watching people walk down the street, and comparing the subjective impression of regularity with that of one's own pulse as it accelerates and decelerates in response to physiological functions such as inhalation and exhalation. People are generally unaware of the speed with which they walk, but nevertheless maintain a remarkably constant tempo, as this requires the least effort (conservation of momentum).

Prenatal conditioning by sounds associated with the mother's walking may thus underly the experience of rhythm in non-*rubato* styles, such as African drum music and its western descendents, jazz and rock. The hypothesis of a prenatal

association between sound and movement when the mother walks is consistent with the strong dance-like or movement quality of non-rubato musics. By contrast, music in which rubato is an important means of expression, such as western music from the romantic period, was primarily intended to be listened to by seated audiences in concert halls. The use of rubato in some styles of dance music (for example, Viennese waltz) is evidence that both heartbeat and walking rhythms may be combined in the one rhythmic style.

The hypothesis of prenatal origins is supported by more specific aspects of musical rhythm. Consider the case of *ritardando*, or gradual slowing at the end of a piece of music (or section of a piece). *Ritardando* is often used in musical performance to let listeners know that the end of a piece is imminent, and to enhance the feeling of finality experienced when the end finally arrives. Kronman and Sundberg (1987) developed mathematical formulations for the timing of footsteps in the specific case when a walker decelerates and finally comes to a standstill. Calculations according to their model agreed well with measurements of performance timing during *ritardandi* at the end of pieces of music. Given that footsteps are not generally salient in the everyday auditory environment, it is reasonable to hypothesize that sensitivity to the *ritardando*, and in particular the contribution of the *ritardando* to the feeling of finality at the end of a piece of music, may ultimately stem from prenatal experience of maternal footsteps.

Another remarkable property of rhythm is the confinement of rhythmic sensations to the auditory modality. Acoustic rhythms are perceived as more salient or “rhythmic” than rhythms presented in other sense modalities such as vision or touch (Grant & LeCroy, 1986). This is consistent with

prenatal learning, as the most salient prenatally perceptible stimuli with rhythmic properties are acoustic. If rhythm perception originated postnatally, one would expect visual rhythms to be just as strong as acoustic rhythms, given that sound sources in the everyday environment that produce rhythmic sounds (e.g., people walking, performing repetitive physical tasks, or playing musical instruments) are also seen to move in time with the sounds they produce.

Musical experience suggests that, in rhythmic sequences including regular alternations of low and high pitches, lower-pitched sounds are more likely than higher-pitched sounds to function as musical *down*-beats. This observation is consistent with the generally low frequencies of prenatally audible heartbeat and footstep sounds, at least by comparison to other prenatally audible sounds such as the mother’s voice. Examples of low-pitched downbeats from western piano music include the bass/chord alternations in the left hand of ragtimes and waltzes, and octave tremolos in the left hand, which usually begin with the lower note on the downbeat — in spite of the relative weakness of the little finger (which normally plays the lower note) by comparison to the thumb (which plays the upper note). Musical experience suggests that in ensemble music (including music for orchestra, bands, or other groups), the proportion of down-beats played by bass instruments is generally considerably higher than the proportion of down-beats played by melody instruments. In Ghanaian drum music, lower-pitched bells are often used to initiate a rhythmic cycle, whereas higher-pitched bells predominantly provide rhythmic counterpoint at other points in the cycle. In Indian *tabla* music, the lower-pitched drum is used more often than the higher-pitched drum for structurally important events such as the end of a rhythmic group. Of course

higher pitches can and often do fall on downbeats, but not as often as lower pitches; and when they do they tend to produce a feeling of syncopation.

Melody

The meaning of natural speech may be divided into two parts, here called abstract and gestural. The abstract part is that which is preserved when speech is written down. It includes the dictionary meanings of words and phrases, as well as grammatical constructions. The gestural part communicates important additional information such as the emotional state of the speaker, the emotional content of the utterance (beyond conventional or dictionary meanings), and the speaker's true intentions (which do not necessarily correspond to the literal meanings of words). The importance of gestural aspects of speech becomes clear when they are removed, for example when a computer-generated voice speaks on a monotone without rhythmic or melodic variation or emphasis; or, conversely, when abstract aspects are unintelligible but important aspects of emotion and intention are preserved, such as when people with unrelated native languages first try to communicate.

The fetus is regularly exposed to its mother's speech, but of course does not understand the abstract meaning of her words. Only the gestural aspects are likely to have any meaning for the fetus. Speech research has shown that gross changes in fundamental frequency, usually referred to as prosody or speech intonation, carry a large proportion of speech's emotional content (Liberman & Michaels, 1962). The prosody of the mother's speech may thus be one of the fetus's most important sources of information about

the mother's emotional state — an important matter, given that the emotional state of the fetus is primarily dependent on that of the mother. We might therefore expect the fetus to become quite sensitive to speech intonation.

At first glance this observation seems unrelated to the perception of melody in music. Melodies in most musical cultures are defined by successions of specific pitch intervals, and depend for their identity on the precise tuning of these intervals. Indeed, the presence of specific musical intervals in melodies is an important factor distinguishing melody from speech. However research on the perception of melody by both adults (Dowling, 1978) and infants (Trehub, 1987) has questioned the importance of specific pitch intervals in melody. Dowling found that familiar melodies could be identified accurately from their contour alone, that is, from the sequence of ups and downs in pitch, regardless of the exact size of the intervals between successive tones. His experimental findings imply that melodies are remembered primarily on the basis of their contours, and that the exact size of intervals between melodic tones (or the harmonic function of melodic tones in a tonal schema or tonality) play a subordinate role. In a later study, Dowling (1982) found that children learn melodic contour before they learn chromatic interval categories. This is not surprising given the importance of melodic contour in maternal speech or "motherese" (Papusek et al., 1991). It is thus reasonable to conclude that the emotional meaning of a melody is primarily linked to its contour — a conclusion consistent with the idea that melodic perception has prenatal origins.

A sound to which the fetus is almost continuously exposed is that of the mother's breathing. Breathing may be perceived both directly, as periodically repeating quiet bursts of noise,

and indirectly, in the form of regular interruptions to the mother's speech by intakes of breath. In the latter case, the fetus could become sensitive to the following regular pattern: a sequence of vocalizations rising and falling in pitch, then a short pause, then another sequence of vocalizations.

The musical correlate of breathing is phrasing. Music is almost always perceived as divided into phrases. If the music is performed by wind players, phrasing generally corresponds to the breathing of the performers. In other music, phrasing is thought to be determined by "purely musical" requirements. Phrasing is invariably regarded as an essential aspect of musical structure, by performers and theorists alike. Phrasing in music is also an important carrier of emotional information. Musical scores and analyses abound with examples of phrases varying in length and character, from short, "sighing" two-note phrases (about one second long) to long, sustained phrases (of the order of ten seconds).

The nature of the link between phrasing in music and phrasing in speech has always been clear to musicians and music theorists, but the *origin* of the link has not. The idea of a prenatal origin is consistent not only with the temporal characteristics of musical phrasing but also with its strong emotional connotations.

Harmony

One of the well-known functions of the inner ear is to perform a frequency analysis of incoming sounds, encoding information on the frequencies and amplitudes of part-

tones. This task is performed in the cochlea, on the basilar membrane. The spectral information extracted from the incoming signal is then sent to the central auditory system via the auditory nerve.

In the case of typical musical tones and speech vowels, several part-tones, corresponding to the lower five to fifteen harmonics, can be clearly discriminated by the ear. The intervals between the pitches of these part-tones is almost always the same: an octave between the first (lowest) and second, a musical fifth between the second and third, and so on. The pattern of intervals thus forms a recognizable pattern.

Typical complex tones are normally perceived to have a single, well-defined pitch corresponding to their fundamental frequency, or the pitch of the lowest part-tone. According to Terhardt (1974), this pitch is perceived by recognizing the pitch pattern formed by the audible part-tones. Terhardt also hypothesized that the ability to recognize this pattern is acquired from experience of typical complex tones, especially speech vowels, during a learning phase occurring in "early life". Terhardt did not, however, venture to suggest exactly *how* early this process might take place.

The inner ear of the human fetus is fully grown and operational for at least three months before birth. The above-mentioned frequency analysis should thus occur in much the same way for the fetus in the third trimester as it does for adults. So the learning process hypothesized by Terhardt could occur before birth, with the mother's voice as the primary stimulus. The learning process would be limited by the absence of frequencies above about 2kHz,

due to the acoustic filtering properties of the amniotic fluid; however this limitation would remove only a relatively small part of the harmonic and gestural-content of the mother's speech.

If the ability to perceive the pitch of complex tones is indeed acquired prenatally, then new-borns should have no trouble following the pitch of human voices. Prenatal acquisition of harmonic pitch information is consistent with the results of a number of studies on the perceptual abilities of infants, including the ability at the age of one month to categorize speech sounds in much the same way as adults (Eimas et al., 1971); the ability of new-borns to recognize their mother's voices, a feat involving extremely subtle and complex features of speech (Papousek, personal communication); and the sensitivity of infants to the pitch pattern of a major triad, corresponding to the fourth, fifth, and sixth harmonics of a complex tone (Cohen et al., 1987).

If the ability to recognize complex tones as single entities is present at birth, it follows that there is a period before birth when this ability is not yet developed. At some time between the maturation of the auditory system and birth, the mother's voice may be heard not as a single sound but as a simultaneity of different sounds — the audible harmonics of her speech vowels. If this is true, then prenatal experience of the mother's voice may underly not only melody (as suggested above) but also harmony. Harmony in music involves the simultaneous sounding of different tones at different pitches. This may occur without regard for the exact intervals between the tones (e.g., in contrapuntal styles of medieval Europe); or it may involve specific intervals

such as those of the harmonic series (as in most western music since the Renaissance). Both kinds of harmony are to be found in various different human cultures, including cultures that originally developed in isolation from each other. If harmony indeed has prenatal origins, then the strong emotional connotations of western chords and chord progressions, of Indians *thats* performed against bass drones, and of Chinese pentatonic harmonies may be a consequence of prenatal experience of the mother's voice.

Emotion and musical meaning

Gabrielsson (1991) investigated strong experiences of music, as reported verbally by hundreds of western subjects with a range of musical backgrounds, abilities, and preferences. He found that strong musical experiences can strengthen a person's identity, and build self-confidence by enhancing the feeling of affinity with other people; release unconscious barriers or defenses and thereby clarify thoughts and feelings; provide opportunities to act out aggression, frustration, or grief; give consolation, hope, or relief from pain; produce profound feelings of power, freedom, or the joy of simply being alive and existing as a human being; evoke vivid memories (usually happy); and produce altered states of consciousness, enabling contact with parts of oneself that are normally hidden, evoking deep religious experiences or experiences beyond verbal or intellectual comprehension, or allowing glimpses of other realities. In the light of these findings it is not surprising that music has a wide range of therapeutic applications. In music therapy, music is used to improve mood and attitude, reduce tension, reduce heart rate and blood pressure, and alleviate various psychosomatic illnesses. Music therapy is also widely used in the treatment of learning disabilities, especially in children.

The many and striking emotional, spiritual, and therapeutic aspects of musical experience may have their ultimate origin in the bond between mother and fetus, as experienced by the fetus. The mother-fetus bond is without doubt the strongest and most intimate relationship that can occur between two human beings — so close that the fetus is often regarded as part of the mother's body. It is only relatively recently that research in prenatal psychology has provided concrete evidence that the fetus has a life of its own (Gross, 1991; Verny, 1981). Strong human relationships always involve strongly felt emotions, and the mother-fetus bond is doubtless no exception. Gabriellson's research on strong musical experiences suggests that music can, in extreme cases, allow an individual to re-establish contact with prenatal experience. Given that the fetus has no language, it is impossible to describe prenatal experience in any direct or scientific fashion. It is therefore appropriate to resort to poetry and intuition... The prenatal world is a world of feelings, mostly warm and happy (interrupted only occasionally by problems, crises, or accidents on the part of the mother), where hunger, want, pain, responsibility, obligations, and work are practically nonexistent, and where personal identity is taken care of by oneness with another, powerful, wise, loving, and perhaps even immortal being. Postnatal contact with this "paradise lost" could explain the many therapeutic and spiritual aspects of strong musical experiences, as reported by Gabriellson.

According to the hypothesis of prenatal experience, the mother-fetus bond underlies the ability of music to communicate emotion. However prenatal experience does not necessarily determine which emotions will be linked to which musical structures. The complex webs of emotional association that characterize musical cultures typically take

many generations and even centuries to develop. The emotional connotations of particular musical structures as experienced by an individual develop as that individual makes contact with particular aspects of one or more musical cultures, and depend on the specific situations in which these structures are experienced.

Prenatal audition may explain why music has meaning even when it does not refer to known aspects of the human environment. In the visual arts, for example, it is normal for elements of artworks to be related to objects familiar from everyday experience, such as plants, fruit, faces, bodies, and landscapes. Even abstract art forms tend to remind us of real physical objects. This is not necessarily true in the case of music, and especially instrumental music, much of which is abstract — that is, without an explicit program or meaning. Musical rhythms, melodies, and chords do not normally correspond in any direct or obvious way to aspects of the auditory environment familiar from everyday life. Despite this lack of specific semantic meanings, music is vivid and powerful. According to the hypothesis of prenatal origins, the expressive power of music is linked to specific rhythmic, melodic, and harmonic structures, audible within the mother's body and experienced by the fetus.

Discussion

The primary hypothesis advanced in this article is that prenatal experience influences the historical development of musical styles. In a sense, this thesis is hardly surprising, given that all people involved in musical development — performers, audiences, and composers alike — are exposed to much the same battery of prenatal auditory stimuli. Prenatally audible sound patterns may find their way into

music in two different ways. First, prenatal experience may simply enhance sensitivity to certain sound structures, thus increasing the probability that similar structures will find their way into music. Second, it is common experience that particular patterns of sound may arouse rich, deep feelings of mysterious origin. Such feelings could simply be subliminal (and possibly rather distorted) “memories” of prenatal experience, in particular of the link between certain rhythmic, melodic, or harmonic patterns and the mother-fetus bond as experienced by the fetus. Such reminiscences need only occur occasionally in the lives of musicians and audiences for prenatal influences gradually to find their way into musical styles and cultures.

Prenatal experience is of course only one of many forces capable of influencing the development of musical style. The enormous diversity of world musics may be understood in term of the diversity of social functions that music is called upon to fulfill, as well as the range of technical possibilities available for producing sound (musical instruments). Differences between human languages — especially differences between stress, tone, and pitch accent languages — may also play an important role in the diversification of musical style. For example, differences between eastern and western musical styles may depend in part on the use of pitch to communicate abstract meanings in tone and pitch accent languages, but not in stress languages (such as English). The effect of mother tongue may influence music via both pre- and postnatal experience (e.g., mother-infant vocal interactions; see Papousek et al., 1991).

The nature and origins of music are not the same as its *survival value*. The pursuit of musical activities has survival value both for individuals and for societies (Roederer,

1984; Sloboda, 1985). For individuals, musical activities provide a kind of “exercise “ for sensory and cognitive functions such as pattern recognition and hierarchical processing. Music may thus keep the brain in good condition, helping people to deal with unexpected challenges — especially challenges that threaten survival. Music is also capable of strengthening the identity of a society, and thereby increasing the motivation of its members to work for the common good. Societies with musical traditions and customs that involve all their members in regular musical performances or rituals are thus likely to be better organized and more productive than other, less musical societies. According to this reasoning, more musical societies are more likely to survive in times of crisis such as war or famine. The hypothesis that music has prenatal origins does not explain the survival value of music. Instead, it clarifies aspects of the *nature* of music — why music is predominately based on certain rhythmic, melodic, and harmonic structures, and why music is capable of communicating strong emotional messages.

What about consciousness? Does the fetus need to be conscious in order to be influenced by prenatal sounds? Some authors (e.g., Gross, 1991; Tomatis, 1981) assume that the fetus possesses a certain rudimentary kind of consciousness. However this assumption is probably unnecessary for the purpose of the present argument. The fetus may learn about invariances in its auditory environment in a similar way that an animal does — passively and instinctively. After birth, musical structure may be affected by familiarity with prenatally audible sounds, regardless of the specific process by which these sounds became familiar.

Theories of prenatal psychology, and the theory outlined in the present article in particular, are generally difficult to test experimentally. How could one test the hypothesis that music perception is influenced by prenatal experience? One possibility would be to survey the children of mothers who were confined to bed for the latter part of their pregnancy. According to the prenatal hypothesis, such children should be less sensitive than other children to musical rhythm. Another possibility would be to test children who are born deaf, and whose first experience of sound occurs after birth as the result of an operation. Such children might be altogether insensitive to rhythm, melody, and harmony.

As interesting as such results of such studies may be, it is unlikely that they will be able to verify or disprove the influence of prenatal experience on music perception. First, the musical abilities of children born under normal circumstances already vary over a wide range. Second, children may be able to acquire sensitivity to elements of music after birth. Indeed, the influence of postnatal cultural conditioning on music perception may be stronger than the influence of prenatal experience, and the effects of prenatal auditory experience may only reveal themselves over long periods of musical development. If this is true, then the theory of prenatal origins of music may well be untestable, and hence unfalsifiable and unscientific.

According to Popper (1972), this problem is not as severe as it sounds. He argued that, strictly speaking, no scientific theory is provable. Furthermore, falsification of a scientific theory does not necessarily constitute grounds for rejecting it. Newton's theory of classical mechanics is a case in point. Early in the twentieth century, classical

mechanics was shown to be invalid under certain conditions, namely very small dimensions (such as the size of an atom) and very high speeds (approaching the speed of light). In response to these shortcomings of classical theory, theories of quantum mechanics and relativity were developed. Classical mechanics was nevertheless retained to deal with countless everyday situations (e.g., civil engineering), as it is much simpler to apply, and hence more practical, than its modern successors. In general, according to Kuhn (1962), a theory should only be abandoned if evidence against the theory renders it untenable *and* a new and better theory is found to take its place.

It is in this spirit that I propose the present theory of the prenatal origins of music. Presently, this theory would appear to provide the simplest explanation for the presence of rhythm, melody, and harmony in music across cultures, and for the remarkable ability of music to evoke and express emotion. The theory is certainly not perfect; however its imperfections are insufficient to warrant its rejection. Until a better theory of the origins of music is developed, the theory of prenatal experience may remain the most promising option.

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