Prenatal and infant conditioning, the mother schema, and the origins of music and religion

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Abstract

Existing theories of the origins of music and religion fail to account directly and convincingly for their universal emotional power and behavioural costliness. The theory of prenatal origins is based on empirically observable phenomena and involves prenatal classical conditioning, postnatal operant conditioning and the adaptive value of mother-infant bonding. The human fetus can perceive sound and acceleration from gestational week 20. The most salient sounds for the fetus are internal to the mother's body and associated with vocalisation, blood circulation, movement, and digestion. The protomusical sensitivity of infants may be based on prenatal associations between the mother's changing physical and emotional state and concomitant changes in both hormone levels in the placental blood and prenatally audible sound/movement patterns. Protomusical aspects of motherese, play and ritual may have emerged during a multigenerational process of operational conditioning on the basis of prenatally established associations among sound, movement and emotion. The infant's multimodal cognitive representation of its mother (*mother schema*) begins to develop before birth and may underlie music's personal qualities, religion's supernatural agents, and the link between the two. Prenatal theory can contribute to an explanation of musical universals such as specific features of rhythm and melody and associations between music and body movement, as well as universal commonalities of musical and religious behaviour and experience such as meaning, fulfilment, and altered states of consciousness.

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Introduction

What might be the adaptive value of music? The literature that addresses this issue (*e.g.* Cross, 1999; Huron, 2003; Pinker, 1997) is inconsistent. On the one hand, if music and art emerged in parallel during a *cultural explosion* between 60,000 and 30,000 years ago (Mithen, 1996), they cannot be adaptive, since even a period of thousands of generations is too short to allow biological evolution to significantly affect behaviour - the "human nature" that evolutionary psychology aims to explain (Curry, 2003). But a period of the order of a thousand generations is certainly long enough for new exaptations (evolutionary parasites: Buss *et al*., 1988) to emerge, as old adaptations are carried forward into a new context. On the other hand, the extensive literature on music's functions (*e.g.* Hargreaves & North, 1997; DeNora, 2000) and neural substrates (Falk, 2000; Peretz & Coltheart, 2003) suggests that music may, in some direct or indirect way, promote the survival of humans, either individually or in groups. In the face of this complexity, one might regard adaptation and exaptation as the ends of a continuum upon which music and art lie, perhaps somewhere near the middle.

For similar reasons, one might also place religion somewhere near the middle of the adaptation-exaptation continuum. Alcorta and Sosis (2005) argue that religion is adaptive because, like music, it promotes individual health, maintains social order, and is costly: rituals engage considerable resources, and the characteristics of supernatural agents are typically strongly counterintuitive. Both musical and religious behaviours can strengthen the immune system (Koenig, 2000; Kreutz *et al*., 2004; Kuhn, 2002) and generally promote health (Lipe, 2002; Seybold & Hill, 2001). But these points do not necessarily suffice to elevate religious and musical behaviours to the status of evolutionary adaptations. It is not clear that religion or music solved a specific adaptive problem in the ancestral environment, such as the negative effect of free-riders on social or individual survival, that was not solved in another way. Moreover, the underlying mechanism whereby religion and music might *directly* promote health is unclear. Is the effect merely due to the typical social behaviours that accompany religion and music?

There can be little doubt that the emotionally powerful symbolic systems of both the arts (including music) and religion emerged in the context of ritual (Alcorta & Sosis 2005; Dissanayake, 1988; Rappaport, 1999). Ritual is a behaviourally costly phenomenon with non-human origins (Rogers & Kaplan, 2000). It often involves structural features that are also found in music, such as formalization and sequencing, repetition and elaboration (development, variation) of thematic elements, and exaggeration (Dissanayake, in press). Both music and religion also involve emotionally charged symbols (specific musical fragments; religious icons) whose meanings are created or maintained in ritual contexts (Alcorta & Sosis, 2005).

I will sidestep the question of music's adaptive value and instead take a new look at the old question of why humans are *motivated* to engage with music. In other words, where do musical emotions come from - *originally*? Listeners in studies of strong musical experiences (*e.g.* Gabrielsson & Lindström Wik, 2003) report extraordinary powerful experiences. Why is music so emotional, even though - unlike other behaviours and experiences such as love, pain and hunger - it is not critical for human survival? One of music's many functions is to bring people together and give them a common identity (*e.g.* Huron, 2003), which evidently helps social groups to function efficiently. In this regard, it is not surprising that music is also emotional. But a theory of music as social glue, in which evolutionarily costly musical activities contribute to survival via social cohesion, seems unable to account for the *strength* and *specific nature* of musical emotions. Nor can it easily account for the universal association between music and spirituality and its ability to induce altered states of consciousness, or for that matter why musicians spend such enormous amounts of time and effort learning their instruments and non-musicians spend such enormous amounts of time and money simply enjoying music. Such behaviours become all the more remarkable when we imagine them, as Huron (2003) did, from the point of view of an imaginary interplanetary psychologist or anthropologist that has no idea of music.

Existing theories of the origins of music

The present volume of *Musicae Scientiae* presents may different theories of the origins of music. My purpose is not to contradict other theories, since it would appear most theories that have been repeatedly presented in scientific contexts contain considerably more than a grain of truth. Instead, I aim to complement them, assuming that music may have several origins in the sense that it emerged in parallel with a number of changes in the human and pre-human condition over a long period.

A leading current theory of the origin of music is based on *motherese*[1] - the audible and visible, gestural and linguistic behaviours of infant-mother dyads (or infant-carer dyads) in all human societies (Dissanayake, 2000a, b). I consider this theory to be particularly promising, and take it as the starting point for my argument, for the following reasons.

Dissanayake's theory can explain many of music's basic properties or universals. Many theories of the origins of music seem to regard music primarily as melody and rhythm, and shed light on music's origins by documenting animal and bird sounds that modern humans perceive as melodic or rhythmic (Wallin *et al*., 2000). Of course, motherese includes melodic and rhythmic elements - but there is much more to music than that. Music may be defined as an acoustic signal that evokes recognizable patterns (segments, structures *etc*.) of sound, involves or implies bodily movement, involves social interaction, is created intentionally, and is accepted and valued by most members of a given cultural group. Moreover, music differs from language in that its meanings are non-lexical. All the points in this tentative definition (which was inspired by various sources, including Cross, 2001; Dissanayake, in press) may be regarded as musical universals - at least from a western viewpoint, which is unavoidable since the concept of music itself is not

[1] In this paper I use the term *motherese* for any protomusical communication between infants and carers, regardless of whether the carer is the biological mother or some other carer, male or female. My preference for a term that refers to the biological mother is based on the assumption that when "music" (as defined here) was "emerging", motherese was primarily or solely the domain of biological mothers.

universal. And this definition of music might just as well be a definition of "motherese". That motherese and music are so similar is unlikely to be a coincidence.

Dissanayake's theory involves behaviours that can be observed here and now. Most other research into the origins of music is *data-poor* (*cf*. Huron, 1999): we have little information about human behaviour at the time when music was presumably emerging. In the absence of a time machine, many assumptions about early human behaviours can never be confirmed. We simply do not know, and perhaps will never know, how prehistoric humans attracted sexual partners (Darwin, 1871), how their "minds" were constructed (Mithen, 1996, 2005) - whatever that means exactly – or whether there was a direct link between repetitive manual activities such as threshing wheat and the emergence and development of music (Bücher, 1896; Hornbostel, 1912).

There is a concrete link between motherese and adult life, namely children's *play*. Dissayake criticized theories that art is an extension of play (*e.g.* Freud, 1908), "because they isolate one strand in the total phenomenon and neglect or ignore the rest" (1988, p. 204). She nevertheless stressed the resemblance among motherese, children's play and *ritual*. Since children's play often involves the imitation of adult behaviours, it is not hard to imagine how the protomusical vocabulary of motherese, in which infants imitate adults and vice-versa, may have found its way into children's play and, from there (or perhaps directly), into adult ritual. In the following, I will refer to this process as Dissanayake's scenario for the origins of music.

If the musical-affective vocabulary of music is based on that of motherese, what is that based on? Papousek (1996, p. 95) observed that specific melodic contours in infant-directed speech may have specific meanings such as arousing, eliciting attention, encouraging a turn, or soothing. This vocabulary may be primarily learned from the pitch contours of regular speech, and the learning process may occur both before and after birth. How exactly might that occur?

In an evolutionary scenario, the syntax and semantics of motherese might gradually develop over many generations by a process of trial and error. During the creative exploration that characterises motherese (Trevarthen, 1999/2000), mothers might have introduced patterns of sound and movement that – for some unspecified reason - evoke emotional responses. Initially, this might have happened more or less by accident; the actions that lead to the patterns would then have been reinforced by the infant's response. In that way, extensions to the gestural vocabulary of motherese that improve mother-infant bonding might have been either naturally selected or culturally transmitted. The observed cross-cultural commonalities in motherese could be explained if this process had been well developed before the exodus of modern humans from Africa roughly 100,000 years ago (Mithen, 1996).

In this paper, I will consider another possibility: that the foundation for the musical-affective vocabulary of motherese is laid before birth. I will present a scenario for the origins of the emotional connotations of sound and movement patterns as they occur in music, speech and any other gestural, affective or regulatory communication. Both prenatal psychology (perception, cognition, emotion) and motherese play a central role in the theory.

The psychological relevance of prenatal perception and development

Why look for musical origins in the prenatal period? The following arguments of Smotherman and Robinson (1990) refer to research on behavioural development in fetal rats:

> The existence of behavioural organization in the mammalian fetus implies that many of the motor, sensory, and learning abilities that are typically associated with the behaviour of mature mammals have their origins in the prenatal period. However, the behavioural literature is replete with examples of experimental design, reasoning, and conclusions that convey the implicit assumption that the prenatal period is irrelevant to the postnatal expression, function, or development of behaviour. Efforts to replace simplistic

> dichotomies in the study of behaviour, such as the everlasting distinction between nature and nurture, with a more sophisticated perspective of behavioural epigenesis (Oyama, 1985) seem continually thwarted by the widespread lack of appreciation for the early development of behaviour. For no portion of the life history of an animal is this lack of appreciation more evident than for the prenatal period. (p. 97)

The implications of this statement for music are considerable. Of the “motor, sensory, and learning abilities” referred to, music involves all three: music performance involves all motor, somatosensory and auditory areas of the brain (Altenmüller & Gruhn, 2002). But the extensive research on motherese (*e.g.* Trevarthen, 1999/2000) largely ignores the possible role of prenatal development. Nature-nurture debates in music psychology tend to avoid any serious consideration of the prenatal period, in which nature and nurture are difficult to separate. Smotherman and Robinson (1990) continue:

> Viewing fetal behaviour under (…) naturalistic conditions has revealed that the fetus is more than a passive passenger during gestation, it is an active organism responsive to changes within its intrauterine environment. Certain features of the fetal environment can facilitate the expression of organized behaviour, other features constrain or inhibit behavioural production. Further, the behaviour expressed by the fetus can have functional consequences. (…) These facts imply that the behaviour of the fetus is inextricably connected to the environment in which it has developed, to the environment in which it currently exists, and to the succession of predictable environments that will follow in the course of its life history. (p. 97)

A few years later, Smotherman & Robinson (1998) remarked:

> (Y)oung animals eventually become adults, so differences in the mechanisms that govern behaviour at one age must ultimately be transformed or replaced by mechanisms that govern behaviour later in development. Understanding the emergence of behavioural competence in immature mammals that dwell in very different ontogenetic niches (such as

> the fetus in utero) bears an indisputable relevance for the more familiar and complex behavioural processes expressed by adults. (p. 587)

The present contribution aims to expand this research philosophy to encompass the complex human behaviours associated with music and religion.

A scenario for the origins of music

The following scenario for the origin of music is divided into separate steps that are supported by convergent empirical and theoretical evidence from a range of research disciplines.

Internal bodily sounds and movements. The main sounds to which the human fetus is repeatedly exposed are the internal sounds of the mother's body. These include vocalizations (usually, but not only, speaking), breathing (air entering and leaving the lungs and associated interruptions to vocalizations), heartbeat (or pulsating blood vessels), body movements (including friction within the body and between the body and other surfaces including clothes); impact sounds (especially footfalls); and digestion (*e.g.* Abrams *et al*., 1995; Busnel & Granier-Deferre, 1983; Lecanuet, 1996). Of these, the voice is the most consistently audible (Fifer & Moon, 1994). The internal sounds of the mother's body tend to be louder *in utero* than sounds that originate from outside (Richards *et al*., 1992); since external sounds are quieter, less predictable, and more dependent on culture and environment, they play no role in the present theory. The fetus is also exposed to patterns of movement, such as rocking when the mother walks. These movement patterns are often coordinated with sound patterns.

Prenatal perception. All human sensory systems begin to function before birth (Hepper, 1992). The main adaptive value of prenatal perception is evidently its role in infant-maternal bonding (Roth & Sullivan, 2006; Smotherman & Robinson, 1990): the more the infant "knows" about the mother before birth, the better it can adjust its postnatal behaviour to optimize maternal care.

The cochlea and vestibular system in the inner ear begin to function near the middle of the human gestation period. Bibas *et al*. (2007) and Hepper & Shahidullah (1994) observed that cochlear functioning begins as early as 20 weeks gestational age (*i.e.* 18 weeks after conception); Pujol and Lavigne-Rebillard (1995) estimated that functioning begins at 18 weeks gestational age. During gestation, the frequency response of the cochlea gradually expands from a narrow range near 300 Hz to almost the full adult range (Hepper & Shahidullah, 1994). The neurocognitive processing of sound and movement improves with myelinization at around week 28 (Morre *et al*., 1995; Moore *et al*., 1996). Thus, sound and movement are perceived for some 12-20 weeks preceding a typical birth at 40 weeks.[2]

The sound that is transmitted to the fetal cochlea via the amniotic fluid and the middle ear is impeded in various ways (Abrams *et al.*, 1995), but the wealth and diversity of published evidence on prenatal responses to sound and transnatal auditory learning (Moon & Fifer, 2000) suggest that none of these impediments is serious. First, the amniotic fluid filters out (muffles) higher frequencies, so that pure tones or partials above about 500 Hz are significantly attenuated and almost nothing is audible above about 2000 Hz. Second, the critical bandwidth of the developing cochlea is broader than that of the mature cochlea (*cf*. Hepper & Shahidullah, 1994; Lavigne-Rebillard & Pujol, 1986). Third, the mucous that fills the fetal middle ear causes some attenuation (Abrams *et al*., 1995; Keith, 1975). While the combination of these three hindrances significantly reduces intrauterine speech intelligibility (Smith *et al*., 2003), the fetus can nevertheless distinguish among the phonemes of maternal speech to some extent (Decasper *et al*., 1994). Based on these various sources, we may safely assume that the fetus can discriminate up to about five harmonics in the mother's voice near f_o = 200 Hz.

Fetal movements begin during the first trimester and develop throughout pregnancy. Robinson & Kleven (2005) demonstrated that the fetus can adjust its

[2] Twelve weeks is a long time by comparison to the mere five days between gestational days 16 and 21 (birth) during which fetal rats exhibit spontaneous movement, the ability to coordinate simultaneous movements of different limbs or body regions, and the ability to learn in response to intrauterine sensory stimulation (Smotherman & Robinson, 1990).

movements in response to external stimuli and constraints, suggesting that it has a sense of the relative position of parts of the body (proprioception).

Classical conditioning. I assumed in Parncutt (1989, 1993) that the human fetus can associate stimuli with each other by classical conditioning. Pavlov's (1906) concept still plays an important role in memory research because of its conceptual and procedural clarity and simplicity, its generality (virtually any animal can be classically conditioned), its strength and robustness (classical conditioning can even modify evolutionarily adaptive reflexes: Schreurs, 2003), and the long tradition of human and non-human research literature that supports it.

Published demonstrations of human fetal classical conditioning (Spelt, 1948; see also Hepper, 1992) were methodogically problematic (Moon & Fifer, 2000). In principle, however, any animal can habituate to a stimulus (Thompson & Spencer, 1966) and any animal can associate stimuli with each other by classical conditioning - regardless of whether the involved stimuli are presented before or after birth, or whether they are ecologically relevant (Robinson & Smotherman, 1995). Classical conditioning can be demonstrated in the rat fetus after just four pairings of chemosensory stimuli, even when many of the brain structures involved in sensory processing and learning in older animals are physiologically immature (Smotherman & Robinson, 1991). Thus, there is no reason to suppose that the human fetus in the third trimester might be incapable of classical conditioning. It is more plausible to suppose that both human and non-human fetuses are finely tuned to a specialized intrauterine *ontogenetic niche* (West & King, 1987); they sense it and respond to it, and in that sense interact with it (Oppenheim, 1982; Smotherman & Robinson, 1990). "Fetal learning thus is not a curiosity, but an active area of research in the fields of developmental psychobiology, neurobiology, and child development" (Robinson & Smotherman, 1995, p. 297).[3]

[3] Incidentally, this statement also implies that ontogeny is not homologous to phylogeny. The specific series of events that marked the prehistoric emergence of music are not necessarily related to the specific series of events that mark the emergence of protomusical abilities and behaviours in individual fetuses and infants.

Classical conditioning allows patterns of sound and movement to be associated with emotions. The process might be best understood within the ecological paradigms of *perceptual learning* (E. J. Gibson & Pick, 2000) and *direct perception* (J. J. Gibson, 1979). Like any other organism, the fetus constantly interacts with its environment. In the course of this interaction, which involves all functioning sensory and motor systems, the internal microstructure of the brain is in a constant state of flux, as the strength of synaptic connections change according to Hebb's law: the brain "resonates" to the environment. When the brain changes in such a way that the organism's future response to an environmental situation changes, we may say that the organism has *learned*. Learning often has a limited duration, that is, the future effect of a present event can be overridden by later events. The duration of learning is increased if a given situation happens repeatedly, which allows the organism to learn the perceptual invariants corresponding to the event or object in question and, on that basis, to subsequently recognize the event or object. These invariants include temporal regularities of the kind "stimulus A is generally followed by stimulus B" to which the theory of classical conditioning refers.

The ecological approach to understanding musical behaviour and meaning of Clarke (2005) contrasts with the cognitive approach to the origins of music, based on cognitive structures and mental modules, of Mithen (1996, 2005) and Cross (1999). The advantage of the ecological approach, from a scientific point of view, is firstly that its basis – the physical environment, which includes the perceiving organism and is also affected by it - is concrete rather than abstract and directly observable rather than the subject of theoretical debate (Someya, 2006). Second, the physical environment is highly complex and includes a wealth of relevant information or affordances. Third, behaviour in the ancestral environment before the cultural explosion may have depended more on environmental than on cognitive constraints, at least by comparison to later behaviours such as music and religion.

Physiological emotional communication. Everyone experiences emotional changes in the course of a typical day. When the emotional state of a pregnant woman changes, some of the hormonal correlates of that change reach the fetus via the umbilical blood. The hormones involved in stress and the hypothalamo-pituitary-adrenal (HPA) axis (van den Bergh, 1992) pass, or are transported across, two semipermeable interfaces that separate the maternal circulation from the fetal brain: the *placental barrier* (Burrow, 1997; Morreale de Escobar *et al*., 1988) and the *blood-brain barrier* (Rapoport, 1976; Saunders *et al*., 2000); the latter begins to form toward the end of the first trimester in humans (Johanson, 1989). In that way, changes in the mother's physical and emotional state (such as stress or relaxation) can affect observable fetal behaviours such as heart rate, heartrate variability, body movements, and breathing movements (van den Bergh, 1992). Transplacental transfer can take seconds, minutes or hours (Bajoria *et al*., 1996, 1998). The number of involved hormones is high (D. G. Porter *et al*., 1982) and their various physiological and psychological functions and interactions are not well understood (Burrow, 1997). In an evolutionary approach, hormonal communication between mother and fetus also involves fetal-maternal conflict (Trivers, 1974), in which the fetus (via the placenta) manipulates maternal investment by secreting hormones (Haig, 1996).

Human emotions have behavioural, physiological, and experiential aspects (Strongman, 2003), of which only behavioural and physiological aspects can be studied (or can be said to exist) in the fetus (van den Bergh, 1992). In an ecological approach (J. J. Gibson, 1979; E. J. Gibson & Pick, 2000), perception involves actively and selectively seeking out relevant information (exploratory perceptual learning) and usually does not involve reflective consciousness. Phenomenal experience (including reflection) may be regarded as a byproduct of direct interactions in the physical world that include the organism's physiology, its active perceptual behaviours, and the affordances of environmental objects. Although children and adults have the ability to reflect upon their perceptual activity, they do not need to reflect for learning of any kind, including classical or operant conditioning, to occur.

On this basis, we may assume that the emotional physiology and behaviour of the fetus influence the development of its neural networks, which in turn influences its later, postnatal emotional behaviour and physiology, and hence its experience as child and adult. That later experience is dependent on reflective consciousness, as demonstrated by such behaviours as mirror recognition, personal pronoun use, pretend play, meta-representation of self, and theory of mind. Reflective consciousness emerges during the second and subsequent postnatal years and is promoted by imitative social interactions with caretakers (Asendorpf, 2002; Lewis & Ramsay, 2004). Thus, childhood experiences can be influenced retrospectively by prelinguistic and even prenatal events, even though those events were not "experienced" in real time.

Behavioural emotional communication. The internal patterns of sound and movement to which the fetus is repeatedly exposed – those produced by the mother's voice, heart, stomach, footfalls, and body movements - depend in consistent ways on her physical and emotional state (Mastropieri and Turkewitz, 1999). Because the transmission of sound is limited only by its speed, sound patterns can transmit information about the mother's state more quickly than hormones.

Patterns of sound and movement can be associated with hormonal changes by classical conditioning. Since the behavioural correlates of a change in maternal emotion (sound and movement patterns) are perceived *before* the physiological correlates (which take time to pass the placenta), the behavioural correlates *predict* the physiological correlates – just as in Pavlov's famous example, footsteps predicted the appearance of dogfood. After many repetitions of this pattern in a given context, the fetus must, according to the theory of classical conditioning, begin to respond emotionally (*conditioned response*) to changes in sound and movement patterns (*conditioned stimulus*) that occur in a similar context – that is, to anticipate the corresponding hormonal changes.

Transnatal memory. Several studies of postnatal responses to prenatally audible sound patterns (*e.g.* Hepper, 1991) have provided evidence for transnatal long-term memory lasting for at least five weeks (Lecanuet *et al*., 2003). Lamont's unpublished data (Jones, 2001) suggested that transnatal memory lasts as long as one year. While not all of the published studies have been methodologically sound (Moon & Fifer, 2000), there is considerable convergent evidence for long-term transnatal memory. If infants possess long-term memory for relatively complex music (Trehub *et al*., 1997), it is reasonable to assume that the fetus does so too, since there is no empirical evidence that birth acts like a switch that turns on learning or affects memory. A complete account of development that accounts for later behaviour and experience in terms of earlier behaviour and experience must therefore begin prenatally (Slater & Bremner, 2003). From an evolutionary viewpoint, prenatal perception, including the auditory, vestibular and proprioceptive senses, has adaptive value as preparation for sensory perception, language, motor control, and/or bonding (Parncutt, 2006); but prenatal perception can only contribute to postnatal survival if supported by transnatal memory.

The limited duration of transnatal memory does not pose a serious problem for a theory of the prenatal origins of music. First, transnatal memory for maternal sound-movement-emotion associations is presumably stronger and more durable than memories for sounds heard in experiments, because the fetus is exposed to the maternal stimuli more often and over a longer period. Second, the repetition of sound and movement patterns in motherese, play, work and ritual can presumably prolong, but also modify, prenatal memory traces (see *motherese* below).

The theory that I have outlined in no way assumes the existence of *episodic prenatal memory*. I reject claims of psychotherapists (*e.g.* Chamberlain, 1999) that it is possible to remember the events of one's birth or even before - not only because the evidence is problematic, but because birth only happens once. For episodic or single-trial memory to exist in the absence of reflective consciousness, that memory would have to directly promote survival. For example, birds may remember the location of a flower and the time they visited it in order to avoid revisiting emptied flowers (Henderson *et al*., 2006).

Instead, I assume that a *specific combination of stimuli* must be *repeated many times* before it can leave a lasting trace in the fetal brain. Implicit learning, whether fetal or otherwise, is *statistical* – the more often a given pattern happens, the more likely it is to be learned, or the more salient is the memory trace (*cf*. Krumhansl's 1990 account of the origin of the major and minor key profiles). Statistical learning has been demonstrated in the case of the 8-month-old infants as they learn to segment words from fluent speech (Saffran, Aslin & Newport, 1996), and there is no reason to suppose that earlier learning is any different. Since statistical learning requires no conscious reflection, a theory of musical origins based on implicit fetal memory is consistent with the failure of both early and modern humans to trace the origins of (proto-) musical emotions.[4]

Brain size, bipedalism and altriciality. Between 2.0 and 1.5 million years ago, there was a notable increase in brain size of hominids (Falk, 2000; Mithen, 1996, p. 11). The process of giving birth (*parturition*) became more difficult for two reasons: infants had larger brains, and bipedality narrowed the birth canal. Consequently, infants that were born earlier were more likely to survive - as were their mothers, upon whom their postnatal survival depended. As the gestation period became shorter, newborns became increasingly helpless (*altricial*) and dependent for longer than other primates on their parents.

Precursors of motherese have been observed in non-human primates (Whitham *et al*., 2007). Infant gorillas participate more actively in mother-infant interactions than do their mothers (Maestripieri & Ross, 2002). With the advent of human infant altriciality, mothers presumably became more active, newborns more passive, and motherese more complex and costly (Falk, 2005). Dissanayake (2000 b) commented that "The trend toward increasingly helpless infants surely created intense selective pressure for proximate physiological and cognitive mechanisms to ensure longer and better maternal care" (p. 390). Consistent with this claim, today's premature infants with low birth-weight participate actively in mother-infant interactions by opening and closing their eyes and grimacing - behaviours that are more pronounced for infants with higher biological risk (Eckerman *et al*., 1994). Along similar lines, Falk (2005) speculated that "hominin mothers adopted new foraging strategies that entailed maternal silencing, reassuring, and controlling of the behaviours of physically removed infants (*i.e.* that shared human infants' inability to cling to their mothers' bodies). As mothers increasingly used prosodic and gestural markings to encourage juveniles to behave and to follow, the meanings of certain utterances (words) became conventionalised" (abstract).

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[4] Another factor that could impede the acceptance of such a theory is its positioning of women at the centre of musical creation, which contradicts the familiar androcentric view (Parncutt & Kessler, 2006).

On the basis of these observations, one may assume that human motherese is at least 1.5 million years old. It was well developed for a long time before the "cultural explosion", during which intentional, socially accepted music – music as we know it today, corresponding to the above definition – presumably emerged. Since the basic semantic code of motherese differs little from one modern culture to the next (Dissanayake, 2000 a, b; Kuhl *et al*., 1997; Papousek, 1996), it is hardly likely to have changed fundamentally in the past 100,000 years.

Bonding and infant/mother schemata. A schema is a cognitive representation of an object or situation. Bartlett (1932) defined schemata as knowledge structures or maps that are stored in long-term memory; they develop and function actively, unconsciously and holistically. In cognitive psychology, schemata are the result of unconscious inferences, computations, and reasoning, whereas in ecological psychology, they are held to involve the invariants that allow a situation, concept or object to be recognized, are acquired during active interaction with the environment, and represent the result of selective perceptual learning (*cf*. Ben-Zeev, 1988).

Lorenz's (1943) *infant schema* (*Kleinkindschema*) refers to adults' perceptual representations of typical infants, and corresponds in both function and detailed content to the word *cute*.[5] Infants, adults, animals and cartoon characters are perceived as cute if they have round faces, large heads by comparison to their body, large eyes and small noses by comparison to their face, and so on. The infant schema is holistic and multimodal: it includes not only the typical visual characteristics of infants but also the typical sounds that they make, the ways in which they behave and so on. The evolutionary function of the infant schema is to enhance both the infant's survival and its parents' reproductive success by motivating adults to love, nurture and protect their infants. Although the infant schema is a perceptual universal, it also has a learned component that is different

[5] Politically, Lorenz is a problematic figure. He was a member of the Nazi party and a professor at a German University during the Second World War. The extent to which his research contributed to Nazi ideology is unclear (Föger & Taschwer, 2001; Taschwer & Föger, 2003).

for every mother-infant dyad and influences the infant's development (Rosenblum *et al.*, 2002).

By analogy to the infant schema, Lorenz also coined the idea of a *mother schema*. The mother schema is a representation of the mother from the point of view of the infant – a cognitive structure that enables and motivates the active role of the infant in the infant-carer relationships. It brings together adult attributes that typically evoke infant trust, and includes infants' innate knowledge of faces and facial expressions (such as the three categories of facial expression in motherese identified by Chong *et al*., 2003) and the gestural-emotional vocabulary of motherese (as outlined by Papousek, 1996).

Motherese may be regarded as an interaction between the infant's mother schema and the adult's infant schema. Studies of motherese such as Trevarthen (1999/2000) have highlighted the mutual, two-way nature of carer-infant bonding, to which both partners contribute actively. Mothers and other carers respond to infants whose appearance and behaviour corresponds to the infant schema by nurturing, protecting and paying attention to them. Infants respond to adults whose appearance and behaviour correspond to the mother schema, drawing on both innate and acquired knowledge about the kind of behaviours in the presence of mothers or other carers that will optimize their chances of survival. Infants prefer proto-musical behaviours (mother schema) over normal speech (Fernald, 1985) and, after a few weeks, begin to reward their mothers or carers with facial expressions and vocal/physical gestures (infant schema).

Like the infant schema, the mother schema has a universal and a specific aspect. The latter allows the infant to distinguish its mother from other mothers on the basis of sound, sight, smell and so on. Observations of the development of infant cry (Wermke & Friederici, 2004) suggest that both the infant's specific mother schema and the mother's specific infant schema develop as the mother-infant relationship develops. Infants' sensitivity to the emotional states of their mother can be demonstrated from the age of a few weeks: the infant reacts to the emotional state of the mother, and the mother to the infant (Trevarthen, 1999/2000; Trevarthen & Aitken, 2001). In an experiment by Cohn and Tronick (1983), mothers were asked to simulate depression for three minutes – to “speak in a monotone, to keep their faces flat and expressionless, to slouch back in their chair, to minimize touch, and to imagine they felt tired and blue” (Weinberg & Tronick, 1998, p. 54); the infants responded by looking away and becoming distressed (*cf*. the Still Face procedure of Rosenblum *et al*., 2002).

Phylogenetically, infant and mother schemas developed in a context of high infant mortality. Since infant mortality is high in modern societies with poor medicinal infrastructures (including hunter-gatherer or nomadic societies), it must also have been high (>50%) in early human societies (Gage, 2005). Since an infant is primarily dependent on its mother, any improvement in maternal care will increase the probability that an infant will survive to reproductive age.

Does the mother schema begin to develop before birth? The evolutionary theory of parent-offspring conflict predicts that it does. Offspring demand more contact, attention and nourishment from their parents than their parents are willing or able to give them (Trivers, 1974). The *begging* of offspring is *costly* in the sense that it can endanger the survival of both parent and offspring by wasting energy and attracting predators. Both human and non-human offspring can learn to adjust their begging behaviour to maximize begging success (Kedar *et al*., 2000). In humans, crying behaviours change as the relationship between infant and carer(s) develops (Wermke & Friederici, 2004). Ancestral infants that adjusted their crying behaviours and sleep-wake cycles to accommodate changes in the physical or emotional state of their mothers were more likely to survive. For this strategy to be successful, the infant must monitor its mother’s physical and emotional state on the basis of available signals such as visible maternal movements and the audible prosody of her voice. Since the human infant is in a position to begin to acquire the latter skill before birth, and this skill can improve its postnatal chances of survival, it is under evolutionary pressure to do so.

The *prenatal mother schema* [6] is a multimodal cognitive representation of the mother, or a mental structure or set of invariants corresponding to what the fetus "knows" - either innately or from perceptual learning - about its mother. It brings together all available sources of information about the mother that may help the fetus or infant to survive, including information about her changing physical and emotional state. If birth marks the end of a *critical period* during which information must be acquired about the mother in order to enhance infant survival, prenatal classical conditioning may be regarded as kind of *imprinting* (Lorenz, 1943), and the prenatal mother schema as its manifestation.

From the point of view of the fetus, the mother is a poorly defined environmental object whose salient features are its *size* (the whole world) and its tendency to *move* (Oberhoff, 2005). To these main points may be added associations among sound, movement and emotions, and information about the mother's characteristic taste and smell. The latter plays a role in infant-mother bonding (R. H. Porter, 1991) and can in part be learned before birth (Hepper, 1992; Varendi *et al*., 1996). The prenatal mother schema may in part explain universal human desires to be nurtured and protected, to take refuge from the stresses of everyday life, to allow natural healing processes to take their course, and to revere supernatural agents. A link between prenatal immaturity and mature reflective consciousness may be created by a long-term process of cultural learning that involves motherese, play and ritual. Such a link may contribute to an explanation of the universal belief in supernatural agents and of universal commonalities of such agents, but not to the details of beliefs held in specific cultures.

Although Bartlett (1932) developed the idea of schemata in a quite different context (*e.g.* memory for stories), the prenatal mother schema nevertheless corresponds

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[6] Here, I use the term "mother schema" only in the psychological sense, from the point of view of the fetus or infant. It may also be used in the following two sociological senses, from the point of view of adults. The *patriarchal mother schema* is a sexist concept of maternal roles according to which mothers should stay at home, look after the children, cook, wash, correct their husbands' research articles, and so on. The *theological mother schema* compares the monotheistic god with a mother figure that loves, accepts, nourishes, protects and educates all those who believe in her/him.

well to his concept. It is assumed to be *active* and *direct* (non-reflective) in the Gibsonian sense. It is *holistic* in that it does not analyse or discriminate specific inputs from different sense modalities. Once developed, schemata show emergent properties; the prenatal mother schema not only promotes infant survival (adaptation), but also facilitates the development of musicality and spirituality in infancy and childhood (exaptation).

For the 6-month-old infant, the most salient (or even defining) property of the mother schema may be her breasts. From that age, infants begin to use the word “mama” (or similar words in other languages) to refer to their mother, which may be an important stage in both the ontogeny and the phylogeny of language (Tincoff & Jusczyk, 1999). To produce the word “mama”, the infant must close and open its lips, as it does when breastfeeding. Before birth, the signal that most consistently provides the fetus with information about the mother’s state is presumably her voice (Moon & Fifer, 2000). The (muffled) maternal voice may therefore be the most salient (or even defining) feature of the prenatal mother schema – consistent, in the present concept, with the central role of the voice and singing, and with the vocal character of instrumental melody, in world musics.

Protomusicality of newborns. Infants are sensitive to sound patterns that adults perceive as “musical” such as the contour of a melody and the lower intervals of the harmonic series such as the perfect fifth; they can also recognize tone sequences in different transpositions and tempos (Trehub, 2003). Their sensitivity to melody in the form of lullabies (Trehub & Trainor, 1998) and to rhythm in the form of heartbeat sounds (DeCasper & Sigafoos, 1983) is well documented. The present theory provides a partial explanation for infant protomusical sensitivity: some of this “knowledge” about the relationship among emotions, sound and movement may be acquired prenatally. That can explain why infants are so sensitive to the emotional connotations of musical sound and movement patterns (Trehub, 2003). Their prenatal development may also predispose infants to quickly learn new, similar associations and in that way to rapidly expand their protomusical or musical vocabulary. It may be unnecessary to posit the existence of innate musical abilities (Trehub & Trainor, 1993) or the “biologically hard-wired nature of musical responsivity” (Kogan, 1997, abstract). While innate factors presumably play an important role, they are difficult to identify and investigate directly.

Operant conditioning. The above scenario sets the stage for a return to Dissanayake’s theory (or my interpretation of it) of the origins of music. Not only infants (*e.g.* in motherese), but also children (*e.g.* in play) and adults (*e.g.* in communal work, long-distance communication, or ritual) are repeatedly exposed to patterns of sound and movement that are more or less similar to patterns to which they were exposed prenatally. In such situations, the corresponding emotion may be evoked, regardless of whether the pattern of sound happens by accident in creative exploratory play or is deliberately created. Such sound or movement patterns may prime the prenatal mother schema and evoke its detailed contents. The strength of priming would depend on context; one of the functions of ritual may be to create an environment in which the mother schema is likely to be primed.

A comprehensive account of the origins of music should explain why humans are strongly *motivated* to make and experience music. A possible theoretical basis is Skinner’s (1938) theory of operant (or instrumental) conditioning. Behaviours that produce stimuli similar to those perceived before birth evoke the corresponding emotions. These then act as rewards, increasing the frequency of occurrence of the behaviours.

Infants are remarkably susceptible to operant conditioning. Moon and Fifer (2000) reviewed numerous experiments, beginning with Siqueland and Lipsitt (1966), and concluded that “infants less than 4 days old can learn in less than an hour that headturning or sucking on a tube is rewarded with a sweet taste” and - more relevant for the origins of music - “2-day-olds can learn within 15 minutes to initiate sucking bursts during auditory signals for the availability of preferred sounds” (p. S44). These findings have been repeatedly confirmed in empirical studies by DeCasper, Fifer, Moon and Spence.

Like Pavlov’s theory of classical conditioning, Skinner’s theory ignores the internal structure of the organism - the ways in which it processes input information and organizes its behaviour, and the ways in which that internal structure developed under the dual influence of genes and environment (Chomsky, 1959). Like classical conditioning, however, operant conditioning may produce consistently observable effects that are independent of the specific ways in which an organism processes information. Those processes may include reflective consciousness, language or culture. Consider a rat that receives sugar if it presses a lever: the sugar acts as a reward that increases the probability that the rat will repeat the associated actions. Neurobiologically, rewards involve dopamine neurons and pathways (Berridge & Robinson, 1998; Schultz, 1998) and, in humans, cortico-limbic interplay (Roederer, 2004). In the present scenario of the origins of music, the emotions associated with a given sound or movement pattern are rewards that lead to an increase in the frequency of occurrence of the actions that produced them – regardless of the specific cognitive mechanisms that process this information. For the moment, I am assuming that such actions are not *intentional* in the way that music is intentional – just as the rat does not *intentionally* press the lever (in the sense of reflective awareness or planning). In other words, the sound patterns produced in this phase of the scenario are *protomusical*.

Operant conditioning involving prenatally established associations among sound, movement and emotion might happen at any time and in any situation, including motherese, exploratory childplay, and the diverse working, recreational and spiritual activities of children and adults. In this way, prenatally established associations might influence behaviour either directly or indirectly at a range of levels. For example, infant-directed speech in motherese may "remind" the infant of prenatally heard speech. These two stimuli differ in two important respects: prenatally audible speech is low-pass filtered, and motherese has exaggerated pitch contours (Cooper & Aslin, 1990). But the low-pass filtering does not affect the fundamental frequency contour, and the exaggeration may simply make it easier for the infant to recognize the pattern and its associated emotional meaning.

Motherese. Motherese is carer-infant vocal-gestural interaction. Typically, the carer produces vocal and physical gestures that communicate and exaggerate positive emotions, which tells the infant that the carer is available to fulfil its needs. This behaviour is rewarded and reinforced if the infant produces similar gestures in return, which it begins to do at the age of several weeks.

The main evolutionary function of motherese is presumably to strengthen *bonding*, that is, to motivate the carer to nurture and protect the infant (Hepper, 1992; Trevarthen, 1999/2000). A further function is to promote language development, which may help the child to survive in social situations (Falk, 2005). If motherese played a central role in the early development of music, the emphasis on positive emotions in motherese is consistent with the predominance of positive emotions in world musics (Becker, 2001, p. 145).

If motherese played a role in the origins of music, it did so between 100,000 and 2,000,000 years ago. We can only guess what the prosodic-semantic vocabulary of motherese was like and how it developed during that long period (Falk, 2005). But if creative exploration was as important for motherese then as it is now, both mother and child would easily and regularly have created sound patterns that were similar to patterns of sound that had been repeatedly heard during the prenatal period (mother's voice, heartbeat and footsteps). The present theory predicts that these would then have evoked emotional associations according to the principle of operant conditioning. By trial and error, prenatal sound and movement patterns would have gradually found their way into the vocabulary and repertoire of motherese.

That in turn would have reinforced prenatally established associations among emotion, sound and movement and thereby extended the effective duration of transnatal memory for such associations. For example, the prenatal association between rhythmic sounds and movement that is created when the mother walks may be prolonged in an infant's transnatal memory every time it is picked up and carried. Moreover, the infant can actively bring about this prolongation if it cries until it is picked up or cries again when the adult stops walking.

Since adults' and infants' repertoires of sounds and gestures are limited by their anatomy and physiology, their ability to imitate prenatal sound and movement patterns is also limited. For this reason, motherese not only *prolongs* but also *modifies* prenatally formed associations among emotion, sound and movement, in a process akin to Piaget's (1952) *assimilation* and *accommodation*. Motherese projects protomusical patterns of prenatal origin into the postnatal world of human culture, while at the same time distorting them.

Play. Children and adults play for many reasons, such as recovery from concentrated exertion, stress relief, renewal of optimism and creativity, and preparing for unexpected challenges (Lancy, 1980; Marano, 1999). From an evolutionary viewpoint, the most important functions of play are to equip children with the physical and social skills that they need to survive to sexual maturity (Bjorklund & Pellegrini, 2000). The play of children, as of all social mammals, may be regarded as adaptive insofar as the abilities that children acquire while playing (*e.g.* interaction with the physical and social environment, development of cognitive and social abilities including theory of mind) contribute to their subsequent survival and reproductive success. In the present approach, play - like motherese - may contribute to the consolidation and reinforcement of prenatally established associations among emotion, sound and movement, extending the effective duration of transnatal memory. As in motherese, the detailed nature of these associations may be distorted by physical constraints in different environments and by oral traditions in different cultural contexts.

Reflective consciousness and culture. Both Noble and Davidson (1996) and Mithen (1996) assumed that reflective consciousness emerged during the human "cultural explosion" some 60,000 to 30,000 years ago, but explained its emergence in different ways. Since that time, adult humans have been in a position to *deliberately* create patterns of sound and movement with the *intention* of evoking the associated emotions. Music as we know it today – intentional, socially acceptable, emotional patterns of sound and movement – may have been born in this deliberate act of emotional manipulation.

Conclusions

Cross (2001) remarked that "For Pinker, Sperber and Barrow, music exists simply because of the pleasure that is affords; its basis is purely hedonic" (p. 33). Although music clearly involves more than superficial pleasure, it is interesting to systematically consider that aspect. What is the *ultimate origin* of musical emotion?

In this article, I have proposed that the complex web of associations among patterns of sound, movement and emotion that characterise music may ultimately be of prenatal origin. One possibility is that the fetus acquires information about these relationships by passive exposure (classical conditioning). Another is that it actively creates a mother schema that includes information of this kind and promotes its postnatal survival. In both cases, protomusic can be created postnatally when the patterns of sound and movement produced in motherese, play, communal work or ritual resemble patterns of sound and movement that had been heard before birth. The emotions evoked by such associations may then function as Skinnerian rewards, leading to an increase in the frequency of occurrence of behaviours that produce them. Finally, these behaviours may have evolved from protomusic into music during the cultural explosion that began when humans acquired reflective language and consciousness.

Strong emotions are generally associated with instinctive behaviours such as eating, fight/flight and sex (Tinbergen, 1989). Music is puzzling because it evokes strong emotions in spite of its unclear adaptive value. This problem can be solved in two ways: either demonstrate that music does, in fact, have adaptive value, or demonstrate that music's strong emotions are explicable in the absence of adaptive value. The above scenario realises the second possibility without denying the first.

The present theory is consistent with many published observations about the *strongly* emotional nature of music such as those made by contributors to Juslin and Sloboda (2001). The following points do not *directly* support the theory that music has prenatal origins, but they are so often consistent with it as to raise the question of how so many consistencies might have arisen coincidentally. Davies (2001) remarked that music is expressive in a way that sentient beings are expressive; that even sad music is interesting; that listeners often do not separate their feelings from the music; that music represents "gaits, carriages, or comportments that are typically expressive of human occurrent emotions" (p. 35), and that music is often regarded as a universal language of emotions. Cook and Dibben (2001) noted that "the idea that music expresses emotion through somehow mirroring the dynamics or our inner life has become commonplace" (p.

58), citing Langner (1942) as an example, and continued: “When we said that music ‘somehow’ mirrors the dynamic of inner life, however, we meant to signal a crucial vagueness in such thinking: without entering into details, the problem lies in specifying what sort of entity the ‘dynamics of our inner life’ might actually be, or how it might be measured” (p. 58). Sloboda and Juslin (2001, p. 81) pointed out that musical emotions differ from other emotions (p. 81); that recognition of iconic emotional meaning in music does not require musical training (p. 94); that sources of musical emotion are often associative; that music has three main social functions - the formation and expression of identity, the establishment and maintenance of personal relationships, and mood management; and that musicians and musicologists have tended to idealise great composers and to remove them from their specific social and historical context. The role of associations in generating powerful musical emotions was also discussed in the context of music therapy by Bunt and Pavlicevic (2001), who raised questions such as why musical emotions are so strongly associative and where the chain of associations began. DeNora (2001) described how music is used to create and regulate mood, energy, feeling and stress, and Simonton (2001) wondered how instrumental music evokes emotion.

The qualitative data of Gabrielsson and Lindström Wik (2003) on strong experiences of music are often consistent with a prenatal theory of music’s origins, although again they do not constitute direct proof of it. Their participants reported, for example, ”hard-to-describe experiences” (p. 170); pronounced physiological and behavioural reactions including out-of-body experiences; a feeling of intimate physical contact with music; altered states of consciousness including trance, flow, and loss of awareness of self, body, time or space; an experience of entering into a private world along with loss of contact with the outside world and a feeling of being surrounded by music; an impression of highly focussed attention or living in the here and now; an experience of wholeness with, being embedded in, or merging with music; an experience of being seized by music and not being able to defend oneself against it; a feeling of being directly addressed by music as if it were a person with a message; as a performer, the feeling that someone or something else is in control of hand and finger movements; associations with childhood experiences; positive emotions such as internal peace, harmony, safety, warmth; feelings of humility, wonder, admiration, reverence, respect, joy, love, perfection, rapture; negative emotions such as loneliness, abandonment, longing, melancholy, embarrassment; existential and transcendental thoughts about the meaning of life and existence; and feelings of ecstasy, totality, and merging with something greater. Participants even reported “experience of other dimensions, other worlds” (p. 182), “vision of heaven, of a life after this” (p. 182), and “contact/meeting with the divine/the sacred” (p. 182).

The prenatal mother-schema concept has the potential to contribute to an explanation not only of music, but also of spirituality and supernatural agents. Like music, supernatural agents are held to exist in all human cultures, and both presumably emerged in the context of ritual (Alcorta & Sosis, 2005; Dissanayake, 1988). The prenatal mother schema can account for some of the most salient universal features of music: its robust personal qualities, its strong link to dance and movement, and its connection with religion (Parncutt & Kessler, 2006). It is also consistent with the social omniscience of supernatural agents in world religions and the developmental predisposition of children to believe in such agents (Bering & Bjorklund, 2004; Kelemen, 2004). A detailed analysis of the religious aspect is beyond the present scope.

The theory presented here refers to, and is situated among, a large number of academic disciplines. Among these are musicology (historical, ethnological, theoretical, cultural), psychology (developmental, prenatal, evolutionary, cognitive, ecological, behavioural), neuroscience (developmental, cognitive), life sciences (biology, biochemistry, physiology), medicine (endocrinology, gynaecology, embryology, audiology, otology), psychoacoustics, psychotherapy (including psychoanalysis and psychiatry), zoology (including ethology or animal behaviour), anthropology (physical, cultural), archaeology, theology, sociology, linguistics, and education. The interdisciplinary nature of the theory may be regarded as both a strength and a weakness. On the positive side, the theory’s interdisciplinarity contributes in a practical sense to its falsifiability: experts from contrasting disciplines may critically examine the theory from different points of view and in the context of many different empirical and theoretical traditions. The downside is that no individual researcher can hope in a single lifetime to properly understand the relevant foundations of many contrasting disciplines – let alone keep abreast of current developments.

A strength of the theory is its ability to shed light on the origins and development of music independently of whether music has adaptive value - that is, whether there has ever been any biological or genetic selection for music. The theory argues neither for nor against the idea that music is adaptive and innate to humans, as suggested for example by Cross (1999) and Peretz (2005), but leaves the question open. Instead, the theory suggests that music is an *evolutionary parasite of prenatal auditory, vestibular and proprioceptive development.* The adaptive value of the prenatal development of those three senses presumably lies in the promotion of postnatal infant-mother bonding, motor control, and language. The development of music and religion is regarded as a byproduct of those adaptations.

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