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PRENATAL DEVELOPMENT AND THE PHYLOGENY AND ONTOGENY OF MUSICAL BEHAVIOR

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INTRODUCTION

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PRENATAL development involves the acquisition of perceptual, cognitive, motor, and emotional abilities that may influence later musical development. "There is evidence that suggests that enriched environment in the form of auditory stimulation can play a substantial role in modulating plasticity during the prenatal period" (Chaudhury, Nag, Jain and Wadhwa, 2013, p. 605). This statement may apply to all prenatally hearing animals, including birds (Kauser et al., 2011; Roy, Nag, Upadhyay, Mathur and Jain, 2014), mammals (Kim et al., 2006) and humans (James, 2010; Hepper, 1992). Moreover, "prenatal auditory experience may set the trajectory for the development of the musical mind" (Ullal-Gupta, der Nederlanden, Tichko, Lahav, and Hannon, 2013, abstract). I argue in this chapter that research in this area can shed light on the origins of musical behaviors, not only in human prehistory (*phylogeny*) but also within the lifespan of an individual (*ontogeny*).

Regarding the ontogeny of music, the infant is surprisingly sensitive to patterns of sound and movement that adults perceive as musical (Trehub, Chapter 24, this volume). The origin and evolutionary function (if any) of this sensitivity is unclear. One possibility is that musical patterns are similar to perceptual patterns to which the fetus is regularly exposed before birth: the fundamental frequency trajectory of the mother's voice, its relationship to breathing, and the rhythm of her heartbeat and footsteps, and its relationship to movement; and the emotional connotations of all such patterns (Parncutt, 1989, 1993).

Music may have emerged phylogenetically for its role in group cohesion, mate selection, or skill acquisition; it may be an elaboration of motherese or primate behaviors; or it may merely involve non-adaptive pleasure seeking (for a summary see Mithen, 2005). An additional possibility, related to the motherese hypothesis, involves classical conditioning of the

fetus during the third trimester by exposure to correlated sounds, movements and hormonal changes within the mother's body (Parncutt, 2009). Since (changes in) maternal emotional states regularly trigger (changes in) the patterns of sound and movement to which the fetus is exposed and involve (changes in) blood hormone levels, the fetus may associate patterns of sound and movement with emotion.

The importance of the prenatal phase for general psychological development was emphasized by Smotherman and Robinson (1990) and Hopkins and Johnson (2005). The fetus responds actively to changes in its intrauterine environment in ways that influence its later behavioral and biological development. The prenatal phase may be regarded as a *developmental niche* (cf. Super and Harkness, 1986) with its own unique characteristics but also lying on the same developmental continuum as postnatal niches. Although no one would question that sensation, emotion, cognition, and motor abilities have prenatal origins (Hall and Oppenheim, 1987), most empirical research about these abilities in the late twentieth century ignored the prenatal period, while at the same time repeatedly asking nature–nurture questions that can only be answered by studying the prenatal epigenesis[1] of behavior.

It is problematic to use the term "music" in conjunction with fetal development. Probably neither the fetus nor the infant discriminates between music (including singing) and speech; *motherese*[2] (Papousek, 1996), the playful vocal-gestural interaction between infants and carers, is a mixture of both—a form of musilanguage (Brown, 2000). Because motherese is not music but may represent music's origin, the term *protomusic* is appropriate (cf. Fitsch, 2006)—by analogy to *protolanguage,* the common ancestor of a group of related languages. For similar reasons, it is misleading to speak of "womb music"[3] or of "playing music to cows" (Uetake, Hurnik and Johnson, 1997), since the sound patterns presented in such studies are not perceived as music (i.e., not as culturally situated) by the experimental participants. Those patterns may nonetheless have musically interesting physiological, behavioral, or cognitive affects.

This chapter focuses on musically relevant psychological aspects of prenatal development: the development of perception, cognition, and emotion, the relationships between them, and the musical and musicological implications of those relationships. I begin by surveying relevant fetal sensory abilities: hearing, the vestibular sense of balance and acceleration, and the proprioceptive sense of body orientation and movement. All those senses may be relevant for musical development, since in all known cultures, music is inseparable from bodily movement and gesture, whether real (Blacking, 1995) or implied (Tolbert, 2001). I go on to consider what sounds and other stimuli are available to the fetus—what patterns are the earliest to be perceptually learned?—and consider psychological and philosophical issues of fetal attention, "consciousness," learning and memory. I close with speculations about the possible role of prenatal development in the phylogeny of musical behaviors.

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[1] The word "epigenesis" (rather than genesis) refers to the role of both nature (genetics) and nurture (environment), and the interaction between them, in the prenatal emergence of behavior.

[2] I use the term *motherese* rather than *infant-directed speech* to emphasize the two-way nature of this form of communication (including the active role of the infant) and the central role of women in the phylogeny of motherese.

[3] E.g., "Babies remember womb music," http://news.bbc.co.uk/2/hi/health/1432495.stm, viewed on August 11, 2007.

The Ontogeny of Music

Fetal Auditory, Vestibular, and Proprioceptive Abilities

All human sensory systems begin to function before birth (Hepper, 1992). The acoustical stimulation to which the fetus is exposed is more diverse and carries more information relative to corresponding discriminatory abilities than visual, tactile, olfactory, or gustatory (biochemical) stimulation. In that sense, hearing may be regarded as the dominant sensory modality in the prenatal phase, and infancy as a transition from auditory to visual dominance.

The fetus can hear throughout the second half of gestation. Because the fetal inner ear is filled with fluid, much of the sound heard by the fetus is transmitted to the inner ear through the skull by bone conduction (Gerhardt et al., 1996; Sohmer, Perez, Sichel, Priner and Freeman, 2001). The cochlea begins to process sounds at about 20 weeks gestation; the cochlea reaches adult size at 25 weeks, but continues to develop until birth (Bibas et al., 2008). Motor responses to sound begin during the same period (Joseph, 2000). At 20 weeks, the fetus is sensitive to a narrow band of spectral frequencies around 300 Hz (Hepper and Shahidullah, 1994). As the fetus develops, its auditory abilities—including the perceptible range of spectral frequencies, the discrimination of frequencies and rapid sequences of events, and the storage and recognition of pitch-time patterns—gradually improve and may approach adult levels at birth (Joseph, 2000). Myelination of auditory pathways occurs during gestational weeks 26–28. Myelination is critical for the onset of auditory function; its density increases for the next year (Moore, Perazzo and Braun, 1995).

It is physically impossible for the fetus to localize sound sources (Parncutt, 2006). First, the fetal head does not cast an acoustic shadow at the relatively low frequencies that are transmitted by the amniotic fluid. Second, inter-aural time differences are smaller for a fetus than for an adult due to the smaller head size and the faster speed of sound in liquid. The fetus therefore has no access to information about the direction from which sounds emanate. Prenatal sound is monophonic and omnidirectional.

The vestibular system (or organ of balance) begins to function at about the same time as the cochlea. The cochlea and vestibular system lie at opposite ends of the (bony/osseous) labyrinth in the temporal bone or inner ear. The vestibular system consists of three semicircular canals that are sensitive to angular accelerations (rotation), and the saccule and utricle which each contain otoliths (dense structures) that are sensitive to gravity and linear accelerations (horizontal movement in the utricle, vertical in the saccule). The membranous labyrinth attains adult size remarkably early, by the middle of the gestation period; the otic capsule ossifies between 18 and 24 weeks (Nemzek et al., 2000).

Fetal Motility and Proprioception

An overview of fetal motor development was given by de Vries and Hopkins (2005). Fetal motility begins at about 8 weeks' gestation, when the fetus begins to move through the amniotic fluid and to extend and flex its limbs. From then on, the movement repertoire of the fetus gradually expands. Some movements may be adaptations to the prenatal environment,

while others prepare the fetus for postnatal life. In the third trimester, different sleep-wake states are associated with different movement repertoires and different sizes and frequencies of movement. Movements are not confined to the limbs, but also include startles, breathing movements, jaw openings, sucking, swallowing, and facial, tongue, and laryngeal movements.

As movements develop, so too does *motor control.* Motor control generally involves an interaction between the neural signals that control muscle activity and sensory feedback about the limb location and muscle tension. The spinal reflex arc begins to function during the first trimester, enabling motor signals to bypass the brain, speeding up motor reflexes.

Development of motor control occurs in parallel with development of *proprioception*—the sense of the relative position and motion of parts of the body. Since musical meaning involves the perception of gesture (Tolbert, 2001), which in turn depends on proprioception, the prenatal development of proprioception may be relevant for the later emergence of musical abilities.

The Fetal Auditory Environment

The fetal auditory environment provides many opportunities for prenatal perceptual learning (James, 2010). The fetus is exposed to sounds from both inside and outside the mother's body. Internal sounds include her voice, breathing, heartbeat, digestion, body movements, and footsteps (Lecanuet, 1996). Of these, the voice may be the most salient (Fifer and Moon, 1994). Internal sounds tend to be louder than the external sounds (Richards et al., 1992). The fetus is also exposed to patterns of movement that are coupled to sound patterns, such as when the mother walks, which can explain diverse findings on infant rhythm perception (summarized by Phillips-Silver, 2009).

Both internal and external sounds are muffled (low-pass filtered) as they pass through the mother's body and amniotic fluid. Spectral components in the approximate range 100-1000 Hz are attenuated relatively little and may even be slightly amplified, even if their origin is external (Richards et al., 1992). When the fetus is exposed to speech, either internally from the mother or from an external source, muffling makes vowels more salient (audible) than consonants and the fundamental frequency contour more salient than spectral information (timbre, phonemes) (cf. Smith, Gerhardt, Griffiths, Huang and Abrams, 2003)—consistent with the important role of pitch contour in music perception (Dowling and Fujitani, 1971).

Fetal "Consciousness"

The fetus is not conscious in the everyday sense of *reflective* consciousness, that is, the ability to reflect upon perceptual experience. It does, however, have primitive abilities that may be considered part of a broad definition of consciousness, including perception, cognition, and emotion; wake-sleep cycles (Nijhuis, Prechtl, Martin and Bots, 1982); preferences; and attention. Newborns are capable of demonstrating preferences by the rate of sucking on a pacifier (DeCasper and Fifer, 1980), suggesting that the fetus could also demonstrate preferences if a suitable, non-invasive empirical method could be developed. Kisilevsky, Hains, Jacquet,

Granier-Deferre, and Lecanuet (2004) investigated the heartrate and movement of fetuses in response to a musical stimulus and observed a change at about 33 weeks, suggesting an ontogeny of attention.

According to the *levels of consciousness* approach (Zelazo, 2003), adult reflective consciousness comprises separable components that are acquired at specific ages. The ability to label objects (including people) is acquired at the age of about 1 year, to distinguish self from others at 2, to reflect about ideas or theories and apply rules at 3, and to reflect about self and others at 4. Since neither the newborn nor the fetus has any of these abilities, the fetus is not conscious in the everyday sense. Attempts to ascribe consciousness to the fetus may be projections of adult reflective consciousness, also called animistic projection or anthropomorphism (Parncutt, 2006).

Prenatal Learning

Learning may be defined as acquisition of information that affects later behavior. Fetal learning has been repeatedly demonstrated by the empirical paradigms of *habituation* and *classical conditioning*.

In habituation, an organism is exposed several times to the same stimulus and gradually stops reacting to it; either the organism gets used to the stimulus or the stimulus becomes uninteresting for the organism. Leader, Baillie, Martin and Vermeulen (1982) observed fetal habituation to a repeated vibrotactile stimulus at 22–30 weeks' gestation. In a different habituation paradigm, Shahidullah and Hepper (1994) found that the fetus can discriminate between sounds at 35 weeks better than at 27 weeks.

Other empirical studies have demonstrated that the fetus is capable of associating stimuli with each other by classical conditioning. In a typical experiment, stimuli are paired with each other in a temporal sequence; after several such pairings, the organism begins to expect the second stimulus when the first is presented. Any stimulus can be associated with any other by classical conditioning, and all animals are capable of classical conditioning; the human fetus is no exception (Smotherman and Robinson, 1990).

Classical conditioning may be regarded as the basic mechanism underlying *statistical learning*. All higher organisms are sensitive to statistical properties of their environment: given many occurrences of event A in different contexts, they learn the probability that it will be accompanied by (or *co-occur with*) event B, that is, the conditional probability that event A predicts event B (Fiser and Aslin, 2002). Saffran, Aslin and Newport (1996) demonstrated that 8-month-old infants can learn statistical properties of nonsense speech during only 2 minutes' exposure. Since statistical learning is such a fundamental means of picking up information about the environment for all organisms (Gibson, 1969), we may safely assume that humans begin to learn statistically before birth.

Transnatal Memory

Transnatal memory is postnatal retention of prenatally acquired information. If the above arguments concerning fetal (lack of) consciousness are correct, transnatal memory is always *implicit*, that is, not under any form of conscious control—unlike an adult's

memory for a telephone number, which normally requires conscious effort. Transnatal memory for stimulus patterns presented repeatedly to different fetal sensory modalites can last for weeks or months and may therefore be considered to be a form of long-term memory (Granier-Deferre, Bassereau, Ribeiro, Jacquet and DeCasper, 2011; Hepper, 1991, 1992; Hopkins and Johnson, 2005; Mastropieri and Turkewitz, 2001; Partanen, Tervaniemi and Huotilainen, 2013).

In experiments to measure the duration of transnatal memory, a given stimulus pattern is presented repeatedly before birth (e.g., a specific piece of music), or a pattern to which the fetus is naturally exposed (e.g., the mother's voice) is used as an experimental stimulus. When the same pattern is presented for the first time after birth, or in a specific new way, the reaction of the infant is observed and compared with its reaction to unfamiliar control stimuli.

Transnatal memory is not *episodic*; it is not memory for single events. The "memories" of therapeutic patients in trance, who report prenatal events or even their own birth, cannot be confirmed (Hartogh, 2003). Such memories can easily be constructed from knowledge of the cultural/social context (Harris, Sardapoor-Bascom and Meyer, 1989). Episodic memory in humans normally depends on language; since prenatal episodic memory has no known evolutionary function, it is unlikely to exist.

Prenatal Association of Sound/Movement Patterns with Emotion

The internal sounds and movements of our bodies depend on our physical and emotional state. The fetus perceives the internal sounds and movements of its mother's body; at the same time, it is continuously exposed to hormonal information about the mother's physical and emotional states, which it partially shares. If the fetus associated sound/movement patterns with physical/emotional states by classical conditioning (Parncutt, 2009), that could explain our propensity to associate emotion with patterns of sound and movement in music—like the associationist "They're playing our song" effect in adults (Schulkind, Hennis and Rubin, 1999), but statistical rather than episodic. The theory of classical conditioning would predict that after several repetitions of such a stimulus pair, the fetus would begin to respond emotionally to the first stimulus (here, behavioral)—before the arrival of the second (emotional, biochemical). The time interval between behavioral and biochemical information in this scenario is presumably of the order of minutes; classical conditioning may also occur for longer interstimulus intervals of the order of hours (Garcia, Hankins and Rusiniak, 1974).

An important consequence of prenatal statistical learning may be the prenatal development of a *mother schema* that improves a newborn's survival chances by facilitating interaction with the mother (Parncutt, 2009). The mother schema is analogous to the infant schema of Lorenz (1943) and has the same function, namely promoting infant survival in ancient hunter-gatherer societies. Both schema are highly emotional and motivational in character. The infant schema combines static and dynamic aspects of the "cuteness" of babies: small body compared to head, round face and skull, large eyes compared to face, typical movements and changes in facial expression, playfulness, appearing fragile or

helpless, innocent affection (Glocker et al., 2009). The mother schema allows the infant to recognize and engage with the mother (or other carers) by combining input from hearing, seeing, touch, smell, taste, balance, and proprioception. Some of these elements are learned before birth and involve transnatal memory. The mother schema is activated when preterm infants are exposed to recordings of their mother's voice and heartbeat (Doheny, Hurwitz, Insoft, Ringer and Lahav, 2012), and when infants prefer natural human speech over similar sound patterns (Vouloumanos and Werker, 2004), people who speak their mother's language (Moon, Cooper and Fifer, 1993), their mother's voice over the voice of a stranger (Mehler, Bertoncini and Barriere, 1978), motherese over natural speech (Fernald and Kuhl, 1987; Schachner and Hannon, 2011; Werker, Pegg and McLeod, 1994), happy over sad speech or music (Corbeil, Trehub and Peretz, 2013; Singh, Morgan and Best, 2002), and motionese (Brand and Shallcross, 2008).

These two theories—prenatal association of sound/movement patterns by classical conditioning and prenatal development of mother schema—can together account for music's strong emotionality and spirituality. The universal association of music with religion or spirituality may be a simple throwback to the mother schema, with which omniscient, omnipotent, omnipresent, omnibenevolent, or eternal supernatural beings are subliminally associated (Parncutt, 2009). Other theories of the origin of music, such as social cohesion or sexual partner selection, may be able to account for strong musical emotions, but they cannot account directly for its inherent spirituality, or for the striking musical abilities of infants.

The Phylogeny of Musical Behavior

Emotion

Strong emotions are generally associated with reflexes, instincts, or drives that promote survival and reproduction (Tinbergen, 1989), such as hunger, lust, fear, pain, disgust, jealousy, surprise, and anger. Music is mysterious, communicating strong emotions although it has no clear adaptive value. Musical emotions are even associated with changed states of consciousness and spiritual experiences (Gabrielsson and Lindström Wik, 2003). A plausible theory of the origins of music should be consistent with these phenomena.

It is often supposed that music is emotional because it is associated with social behavior and group survival (e.g., Dean and Bailes, 2006). Music mainly occurs in groups (many people share the experience) whereas speech mainly occurs between pairs of individuals (it communicates confidential information efficiently). Evolutionary theory primarily explains the behavior of isolated pairs of individuals (e.g., reciprocal altruism)—not groups considered as a whole (Boyd and Richerson, 1988; Trivers, 1971). That is one reason why language is more likely than music to be an adaptation. Group survival cannot easily explain music's *strong* emotionality and spirituality.

Musical emotions are associated with learned patterns of sound and movement. A possible source of those associations is motherese (Dissanayake, 2008), whose vocabulary of gestural meanings evidently includes a universal component (Kuhl et al., 1997; Papousek, 1996). These universal gestural meanings may in turn have a prenatal origin.

Infant Musical Skills: Innate or Learned?

All humans, including infants and with the exception of amusics, possess basic musical abilities or potential (Howe, Davidson and Sloboda, 1998). A plausible theory of the origins of music should be consistent with the quasi-universal musical abilities of infants. Trehub and Hannon (2006) proposed that "infants' music perception skills are a product of general perceptual mechanisms that are neither music- nor species-specific. Along with general-purpose mechanisms for the perceptual foundations of music, we suggest unique motivational mechanisms that can account for the perpetuation of musical behavior in all human societies" (abstract). Prenatal associations between patterns of sound, movement, and emotion could underlie such "general perceptual mechanisms" and "unique motivational mechanisms."

Several sources of evidence suggest that the musical abilities of infants are at least partially "inborn," "innate," or "congenital," all three terms allowing for the possibility of prenatal learning. Amusia is inborn in a small proportion of the population. Infants of deaf parents prefer infant-directed singing over adult-directed singing, suggesting an innate component—or an inborn preference for prosodic exaggeration (Masataka, 1999). The development of musical ability is affected by prenatal testosterone levels (Sluming and Manning, 2000).

Models of the interplay between genes and environments (Garcia Coll, Bearer and Lerner, 2004) additionally suggest that behaviors and skills such as musicality are the result of such interaction. Several empirical studies cited in this chapter are consistent with the prenatal learning of protomusical skills. For example, newborns respond to the emotional content of speech, but only in their maternal language, suggesting that their ability to recognize that emotion was acquired before birth (Mastropieri and Turkewitz, 2001). The claim that musical skills are *largely* learned may be valid throughout the lifespan, including the last prenatal trimester. The gestural vocabulary of motherese may be largely learned from prenatal exposure to the internal sounds of the mother's body. Later, musical expertise depends primarily on the total accumulated duration of practice (Howe et al., 1998).

Fetal–Maternal Communication

Bonding (secure attachment) between primary caregiver and infant plays an important psychological and physiological role in early development (Schore, 2001). The idea that maternal–infant bonding is an evolutionary adaptation is consistent with high rates of infant mortality among both non-human primate and human hunter-gatherer populations (>50%: Denham, 1974). Maternal–infant bonding increases the chance of infant survival, especially under threat of infanticide (Opie et al., 2013; Hausfater, 1984). In primate evolution, bonding strategies changed with larger neocortex, relying more on multimodal sensory cues, associations, and social behavior, and less on olfaction and hormones (Broad, Curley and Keverne, 2006). Prenatally acquired knowledge about maternal emotional states may adaptively promote postnatal bonding and survival by helping the infant to communicate its needs appropriately. Other factors being equal, the chance that an infant will survive to reproductive age will increase if infant demands on the mother or other carers do not radically exceed their capabilities or resources.

Infant–mother bonding is two-way and reciprocal (Lee, 2006): each party is at some level sensitive to the physical and emotional state of the other. Empirical research is beginning to document the infant's active perception of the mother: compare Stern's (2002) and Kenny's (2013) cognitive, psychoanalytic approaches, Trevarthen's (1980) concept of intersubjective communication, and the positive physiological effects of maternal speech, singing, and heartbeat sounds on preterm infants (Doheny et al., 2012; Filippa, Devouce, Arioni, Imberty and Gratier, 2013; Krueger, Parker, Chiu and Theriaque, 2010). To successfully monitor the mother's physical and emotional state, the infant must have prior knowledge about the relationship between maternal state and behavior. The fetus has constant access to two sources of information about the physical and emotional state of its mother: *behavioral* (sound and movement) and *biochemical* (blood hormone concentrations).

Regarding behavioral information, all patterns of sound and movement that are audible within the body in everyday situations, including vocalization, respiration, blood circulation, movement, footsteps, and digestion, depend on physical and emotional state (Mastropieri and Turkewitz, 2001). The human fetus has access to three behavioral sources of information about maternal state: sound patterns, linear, and rotational acceleration of the fetal body, and relative movement of the fetal limbs. These are perceived by the fetal auditory, vestibular, and proprioceptive systems respectively.

Regarding biochemical information, the hormones involved in the maternal–fetal interaction arise from three different sources: placenta, maternal organs, and fetal organs (Power and Schulkin, 2005). The placenta and fetal membranes produce a large number of steroids that regulate and balance both maternal and fetal physiology. They include progesterone, estrogen, and corticotropin-releasing hormone (CRH), which play a role in maintenance and duration of pregnancy (Albrecht, Aberdeen and Pepe, 2000; Hillhouse and Grammatopoulos, 2002); testosterone, which affects fetal development (Matt and MacDonald, 1984); placental lactogen (somatomammotropin), which influences nutrient (carbohydrate, lipid) levels in the maternal blood (Walker, Fitzpatrick, Barrera-Saldana, Resendez-Perez and Saunders, 1991); estrogen, related to female secondary sex characteristics (Nelson and Bulun, 2001); and relaxin, which facilitates birth (Klonisch et al., 1999). In an evolutionary approach, hormonal manipulation of maternal nutrient supply by the fetus represents an early stage of parent–offspring conflict (Wells, 2003).

Hormone production in the mother involves a mixture of regular adult hormonal processes and processes specific to pregnancy; each could be perceived or shared by the fetus and associated with sound and movement patterns. Regarding regular hormonal processes, externally caused stressors (flight–fight reaction) lead to stimulation of the adrenal gland, which secretes adrenaline (epinephrine) and noradrenaline (norepinephrine) into the blood, which in turn increases blood sugar, muscle tension, and blood pressure. Stress also causes the release of CRH and the production of glucocorticoids that affect immune responses (Elenkov, Webster, Torpy and Chrousos, 1999). CRH is also associated with anxiety and depression (Steckler and Holsboer, 1999), and cortisol is associated with fear and stress (Kalin, Larson, Shelton and Davidson, 1998). Oxytocin is more specific to reproduction and is associated with orgasm, birth, and breastfeeding (Newton, 1978).

That the fetus is sensitive to hormone concentrations in the maternal blood is consistent with studies that demonstrate the effect of those concentrations during pregnancy on postnatal development. For example, postpartum concentrations of testosterone, estradiol, androstenedione, and cortisol correlate with children's later levels of physical aggression

(Susman, Schmeelk, Ponirakis and Gariepy, 2001). The placenta is permeable to nutrients, oxygen, alcohol, antibodies, and steroid hormones with different temporal delays of seconds, minutes, or hours (Bajoria, Peek and Fisk, 1998; Bajoria and Fisk, 1998). Molecules that pass the blood–brain barrier include oxygen, carbon dioxide, alcohol, and steroid hormones, of which there are five main groups: progestagens, glucocorticoids, mineralocorticoids, androgens, and estrogens (Pardridge and Mietus, 1979). The permeability of the blood–brain barrier to steroid hormones depends on the molecule and involves different temporal delays (Zloković, Lipovac, Begley, Davson and Rakić, 1988).

Thus, both evolutionary-biological and developmental-psychological approaches predict that the fetus perceives changes in patterns of sound and movement within the mother's body (behavioral information) as well as responding to changes in maternal hormone levels, which are delayed by passage through the placental and fetal blood–brain barriers (biochemical information). The behavioral change thus predicts the biochemical change, allowing classical conditioning to occur—just as in Pavlov's famous experiment, the footsteps of a master bringing food to a dog predicted the appearance of the food.

Prenatal Influences on Postnatal Behavior

Prenatally established associations could influence postnatal behaviors and the development of musical culture in the context of *motherese, play*, and *ritual*. In all three cases, *operant conditioning* (Skinner, 1938) may be the underlying mechanism. Patterns of sound and movement that occur by accident in these behaviors may be similar to patterns of sound and movement that were prenatally linked to emotion. The triggering of associated emotions or altered states may reinforce the actions or behaviors that produced the patterns of sound, increasing their frequency of occurrence. Since motherese, play, and ritual are social activities whose participants were subject to similiar prenatal conditioning processes, the theory predicts that such behaviors and associated emotions will generally be socially shared, enabling the development of music as a form of social behavior.

On this basis, we might expect to find associations between sound, movement, and emotion in all prenatally hearing animals. The reason why non-human animals are not musical in the human sense is presumably that only humans have developed reflective consciousness, which emerged at least 60,000 years ago and enabled a *cultural explosion* (Mithen, 2005). Reflective consciousness may be regarded as a co-requisite for the ability to conceptualize the past and future in relation to the present, which enables deliberate/intentional planning and action (Noble and Davidson, 1996). According to this view, prenatal associations between sound, movement, and emotion became "music" when humans acquired the ability to deliberately manipulate and socially share the emotions—that is, to perform.

Conclusion

Research in music psychology has tended to avoid questions of prenatal development due to the practical and ethical difficulties associated with empirical investigations and the dubious quality of much of the available research literature. The dominance of approaches to

the origin of music based on partner selection and animal behavior could reflect a physicalist empiricist bias in modern science or even latent sexist reactions against explanations involving qualitative arguments or human corporality (cf. Campbell and Wasco, 2000). But the prenatal period could be a rich source of answers to central questions in music psychology. Developing empirical technologies make it increasingly possible to observe the fetus non-invasively, including its fetal facial gestures and expressions (Kurjak, Stanojevic, Azumendi and Carrera, 2005).

The relevant empirical literature is expanding rapidly, but it is spread over many different disciplines, and central issues remain to be critically addressed by independent research groups. The present theory may be internally consistent and logical, but further empirical work will be necessary to examine the details of the hypothesized prenatal associations and their effect on postnatal behavior.

Since our knowledge of music's emergence in the context of ritual will always be limited, any theory of music's phylogeny will always be speculative. The ontological question of how prenatal learning affects postnatal musical development will become increasingly accessible to empirical investigation, as non-invasive observational techniques improve. An improved understanding of the interaction between genes and environment in psychological development (e.g., Bakshi and Kalin, 2000), combined with new approaches to fetal behavior (such as preferences) and prenatal influences on postnatal behavior (including transnatal memory), will lead to new insights that will confirm, complement, challenge, or overthrow the ideas presented in this chapter.

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