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CHAPTER 1

PRENATAL DEVELOPMENT

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Introduction

Infants have a wide range of skills that can be described as musical (see Chapter 2). What is the origin of those skills? This chapter considers the possibility that they are—at least in part—learned before birth, as the fetus becomes familiar with the internal sound patterns of its mother's body and associates these patterns with her physical and emotional state. The chapter begins by presenting background information about the fetal sound environment and musically relevant fetal abilities and behaviours that may be related to musical abilities as they emerge after birth. It goes on to consider the question of how to evaluate and reconcile conflicting research findings on prenatal musicality, and concludes with specific, tentative recommendations for expectant mothers or parents interested in the musical development of their fetus. The chapter aims to give readers background material in the controversial area of prenatal musical psychology, so that they can make informed decisions about the validity of published claims for themselves.

The fetal sound environment

The most important sounds to which the human fetus is regularly exposed are its mother's voice, her heartbeat, her movements (including footsteps), her breathing, and her digestion (stomach growling or borborygmi—the rumbling sounds caused by gas moving through the intestines) (Lecanuet, 1996). Less important, but often still audible, are sounds produced by the fetus itself (heartbeat, movement) and sounds from outside the mother's body. In the following, I will use the word 'audible' in the sense of 'audible for a human adult with normal hearing', and will return later to the question of whether the fetus can hear these sounds.

The internal sounds of the mother's body may reach the fetal ears by different paths. For example, maternal heartbeat sounds may be transmitted directly from the heart, the umbilical artery, the uterine artery, or uteroplacental blood flow. For this and other reasons, the loudness or audibility of each kind of sound may be different in different parts of the amniotic cavity so fetal perception depends on the fetus's physical orientation.

All the sounds to which the fetus is exposed, regardless of whether they originate inside or outside the mother's body, are *muffled*. The high frequencies are attenuated by the amniotic fluid and body of the mother, which act as a *low-pass filter* (Armitage *et al.*, 1980; Richards *et al.*, 1992). Sounds below about 300 Hz may not be attenuated at all, while higher frequencies are increasingly attenuated; frequencies beyond about 2 kHz are generally inaudible (Abrams *et al.*, 1998).

Audible sounds from outside the mother's body include the voices of other people, sounds in the environment, and music. The intensity of these sounds is attenuated considerably (typical estimate: 30 dB) by comparison with internal sounds, as they pass through the mother's body. This makes them more susceptible to drowning out (complete masking) by internal sounds (Querleu *et al.*, 1988; Peters *et al.*, 1993). This presumably explains why newborns can recognize their mother's but not their father's voice, even if they were regularly exposed to both before birth, and even though the father's voice is less affected by low-pass filtering (DeCasper & Prescott, 1984).

The speech of an expectant mother would be largely intelligible to her fetus, if it could understand speech. Uterine muffling does not affect the ups and downs in pitch (prosody or intonation), the timing of phonemes (rhythm), variations in loudness (accentuation), or variations in pitch register (including the difference between male and female voices) (Smith *et al.*, 2003). As all but a few lower partials are rendered inaudible, the timbre of the mother's speech, which includes the identity of individual vowels and consonants, is strongly affected. It is nevertheless still possible for both adult listeners and the fetus itself to distinguish between different phonemes (vowels and consonants) in uterine recordings of the mother's voice (Querleu *et al.*, 1988, Decasper *et al.*, 1994). The relative salience of pitch (as opposed to timbre) in prenatally audible speech may explain in part why infants are more interested in maternal singing than maternal speech (cf. Trehub & Nakata, 2001–02). A further possibility is that learning is facilitated when expression is exaggerated in any modality (Masataka, 1998).

Musically relevant fetal abilities and behaviours

Postnatal musicality involves not only hearing but also movement, balance (essential for dance), and emotion. All of these depend on neurocognition, and all have roots in the prenatal period (Hepper, 1992).

The brain

Before birth, different brain regions develop at different rates, and sensory organs initially develop independently of the brain regions to which they will later be connected. Connections between periphery sense organs and the central nervous system start to mature in about the 25th week,[1] after which sensory learning can begin in earnest (Oerter & Montada, 1995; Chapter 3, this volume). From this point, brain development is influenced by external sensory stimulation (Panicker *et al.*, 2002).

[1] The age of the fetus is referred to throughout this chapter in the conventional way as gestational age, or age since last menstruation. This is 2 weeks greater than conceptual age. For example, normal birth at 40 weeks gestation age corresponds to 38 weeks since conception. The term *embryo* applies during the first 8–12 weeks of gestation, while gross body structures and internal organs are developing; the term *fetus* applies from the third month (Oerter & Montada, 1995).

Hearing

The most important organ for hearing is the cochlea of the inner ear.[2] Here, vibrations are converted to neural impulses, and different frequencies are separated. A range of studies, both behavioural (Hepper & Shahidullah, 1994) and physiological (Rubel & Ryals, 1983; Pujol *et al.*, 1991), have demonstrated that the fetal auditory system begins to process sounds between about 16 and 20 weeks, before it is anatomically mature.[3] The range of frequencies to which the cochlea responds is initially small and lies somewhere between 200 and 1000 Hz (Rubel & Ryals, 1983; Hepper & Shahidullah, 1994). As the frequency response of the cochlea gradually broadens, so too does its ability to separate simultaneous frequencies (frequency discrimination), to separate rapid sequences of sounds as in ordinary speech (temporal discrimination), and to perceive very quiet sounds (auditory threshold). At birth, all these abilities approach adult levels (cf. Ptok & Ptok, 1996). Numerous empirical studies are consistent with this general picture (for reviews see Busnel & Granier-Deferre, 1983; Lecanuet, 1996).

An important, survival-promoting function of postnatal hearing is the *localization* of sound sources (Blauert, 1997). Different cues indicate the direction from which a sound arrives in the left–right dimension (interaural time and intensity differences), the up–down dimension (spectral envelope variations due to reflections from the irregular shape of the pinna), and the front–back dimension (acoustic shadow cast by the pinna). The distance of the sound source is estimated on the basis of known relationships between loudness and distance for specific sound sources in specific situations. All these cues depend on frequency. Although babies can localize in the left–right dimension at birth (Morrongiello *et al.*, 1994; Furst *et al.*, 2004), they could hardly have had prenatal practice at this task. First, the fetal head does not cast an acoustic shadow at the relatively low frequencies that are available in the uterus. Second, interaural time differences, which are important for sound localization by adults at low frequencies (Wightman & Kistler, 1992), are an order of magnitude smaller for the fetus than for an adult due to the smaller size of the fetal head and the faster speed of sound in fluid. Thus, anecdotal reports of the fetus turning its head towards a sound (e.g., Bitnour, 2000) are implausible.

Balance and orientation

A discussion of the prenatal development of musicality would be incomplete without a consideration of the prenatal development of balance and orientation. First, music is associated with dance in all known musical cultures (Blacking, 1979). Second, the cochlea (organ

[2] Vibration can also be perceived through the skin or by bone conduction to the inner ear (Gerhardt *et al.*, 1996); but experimental attempts to demonstrate this in animal fetuses (e.g., Parkes *et al.*, 1991) have been unsuccessful. The mucus that fills the fetal middle ear throughout the prenatal period does not prevent it from functioning (Keith, 1975), but it may cause some attenuation (Abrams *et al.*, 1995).

[3] Anatomical maturity involves several developmental stages. At about 10 weeks, hair cells begin to appear on the basilar membrane; at about 20 weeks, the efferent innervation of the outer hair cells begins; and at about 24–28 weeks, the cochlear receptors and auditory synapses mature (Pujol *et al.*, 1991). The organ and tunnel of Corti are present in all turns of the cochlea at about 26 weeks (Altmann, 1950). The auditory pathway (from cochlear nerve to inferior colliculus) undergoes myelination between weeks 26 and 28, which improves the speed and synchronization of auditory impulses (Morre *et al.*, 1995).

of hearing) and vestibule (organ of balance) are anatomically and physiologically united (Todd & Cody, 2000) and develop prenatally in parallel (Lai & Chan, 2002).

The vestibular system enables adults to perceive and monitor orientation (up versus down) and acceleration. The vestibular sense or *proprioception* begins to function before the fetus first shows a *righting reflex* at 25 weeks (Hooker, 1952) and may plays a part in bringing the fetus into a head-down (cephalic) position before birth (Hepper, 1992).

Like all other senses, the vestibular sense needs stimulation to develop normally. Animal experiments (e.g., Ronca & Alberts, 2000) have demonstrated that prenatal proprioceptive abilities are not only present, but also trained before birth, consistent with the existence of fetal cognitive representations of orientation and acceleration.

Movement and heart rate responses to sounds

Fetal hearing can be investigated by checking whether fetal heart rate and movements consistently change after repeated exposure to a sound. Fetal movements are especially interesting for musical development because of the connection between music and dance.

Heart rate accelerations or decelerations in response to sound begin at about 20 weeks (Lecanuet, 1996) and occur in most human fetuses from about 26 weeks (Abrams, 1995). Spontaneous fetal movements begin at 6–9 weeks, but are not felt by the mother until about 20 weeks (Hooker, 1952; Oerter & Montada, 1995). Motor responses to loud, broad-band noises begin at about 24 weeks (Lecanuet, 1996); responses to pure tones begin a few weeks later. Motor responses to sound become consistent at 28–32 weeks (Birnholz & Benacerraf, 1983; Kisilevsky *et al.*, 1992). Motor and heart rate responses to music are more frequent at 38 than at 32 weeks (Wilkin, 1995/96). Responses have greater amplitude (e.g., greater heartbeat acceleration or deceleration) and are more likely when the fetus is awake, and depend on levels of alertness within sleep/wake states.

A problem with such behavioural measures is that the fetus may perceive something and not react to it (Hepper, 1992). However, no consistent auditory brainstem responses (auditory evoked potentials) have been observed before 25–30 weeks (Lecanuet, 1996).

Emotional communication

The relevance of emotional communication between mother and fetus for musical development lies in its potential to help explain an important—and still somewhat mysterious—property of music: the emotional implications of sound and movement patterns (cf. Juslin & Persson, 2002). The sophisticated emotional communicative abilities and sensitivities of infants suggest that they had prenatal practice; and the importance of emotional communication for infant survival suggests that there is evolutionary pressure for prenatal development of emotional communication.

Young infants communicate emotion through crying, babbling, facial expressions, and bodily gestures (Trevarthen, 1985; Zeifman, 2001). These messages inform the mother or other carer about the infant's physical and emotional state (which are largely inseparable) and hence about its current needs. The nature and origins of these processes can be explained by speculating on their contribution to infant survival in prehistoric human and prehuman societies (evolutionary psychology). The primary evolutionary purpose of infant–adult communication is presumably to motivate carers to help infants survive into childhood, when language gradually takes over the function of communicating needs.

Psychologists study the behavioural, physiological, and experiential aspects of emotion, and the relationships among them (Strongman, 2003). As experiential aspects of fetal emotion are absent or inaccessible, fetal emotion can only be investigated by tracking changes in physiological and behavioural states (Van den Bergh, 1992).

Physiological emotional communication

This may be said to occur when emotionally implicated biochemicals pass from the mother to the fetus (or from the fetus to the mother) via the placenta and umbilical cord, and reach the fetal brain. Specific biochemicals are associated with specific behaviours and emotions; for example, hormones are associated with anger, fear, sex, love, stress, or exertion, and endorphines are for example associated with pain, stress, hunger, digestion. As all biochemicals have multiple functions, and as all such mappings depend strongly on operational definitions of terms such as 'anger', they should be approached with caution.

As the fetus is anatomically connected to the mother, but physiologically to some extent independent of her, it shares some, but not all, of its mother's physiological states. For example, the maternal and fetal heartbeat correlate from about 32 weeks (DiPietro *et al.*, 2004); the coupling mechanism is presumably biochemical. The placenta is a filter that primarily passes nutrients and oxygen in one direction and wastes and carbon dioxide in the other. It partly filters out bacteria, viruses, toxins, drugs, and chemicals including alcohol, nicotine, and cocaine. For example, fetal steroids are highly lipophilic and so easily cross the placenta (Welberg & Seckl, 2001).

Recent years have seen considerable progress in the area of biochemistry of stress. Stress is associated with activation of the hypothalamic–pituitary–adrenal (HPA) axis and the sympathetic nervous (or sympatho-adrenomedullar) system (SA) (Van den Bergh, 1992). Stressors produce responses in a variety of endocrine systems and involve hormones such as cortisol, adrenaline (epinephrine), noradrenaline (norepinephrine), prolactin, thyroxine, insulin, and testosterone (Mason, 1975) as well as corticotrophin-releasing hormone (CRH) and adrenocorticotrophic hormone (ACTH) (Mulder *et al.*, 2002). Levels of neuropeptides such as CRH in the amygdala, hypothalamus, and pituitary gland are associated with emotionality, anxiety, and stress (cf. Brown & Gray, 1988; Davis, 1992). Corticosteroids, a class of steroid hormones, are involved in stress and immune responses and associated with fear and anxiety (Korte, 2001). Stress and fear affect levels of glucocorticoids, of which cortisol is the most important (Welberg & Seckl, 2001). Hormone release in response to stressors depends not only on the stressor itself, but also on a range of genetic, personality, and environmental factors.

Such research can shed light on the question of prenatal emotional communication. Changes in maternal physical and emotional state (such as stress or relaxation) affect fetal behaviours such as heart rate, heart rate variability, body movements, and breathing movements (Van den Bergh, 1992 cites numerous studies). These effects are presumably biochemically mediated. These effects are presumably biochemically mediated. For example, maternal anger can be communicated to the fetus via high cortisol and adrenaline and low dopamine and serotonin levels (Field *et al.*, 2002).

In both humans and other mammals, maternal emotion and stress affect the offspring's *physiology* (neurochemistry, endocrine function) and *psychology* (emotion, cognition) (Maret, 1997; Weinstock, 1997; Buitelaar *et al.*, 2003). Against a background of steadily increasing blood concentrations of CRH, ACTH, and cortisol throughout the pregnancy, information about maternal stress can reach the fetus as a temporary reduction in blood flow, transfer of maternal hormones across the placenta, or release of placental CRH; CRH enters fetal circulation via the umbilical vein, whereas cortisol enters via the umbilical arteries (Mulder *et al.*, 2002). Prenatal exposure to glucocorticoids such as cortisol affects fetal development (Coe *et al.*, 2003), produces hypertension and other medical and behavioural problems in later life (Seckl, 2001), affects the development of internal organs including the ear (Canlon *et al.*, 2003), and plays a part in the aetiology of schizophrenia (Koenig *et al.*, 2002). The intrauterine hormonal environment affects development of the fetal hippocampus and amygdala, and hence programming of the HPA axis (Matthews, 2002). The neuroendocrine system acts as a link between prenatal biochemical, neurodevelopmental variables such as plasma levels of ACTH and cortisol, and elements of the maternal psychosocial environment such as stress, social support, and personality (Wadhwa *et al.*, 1996). Maternal prenatal stress and associated placental levels of adrenocorticotrophin, endorphins, and CRH can lead to premature (preterm) delivery, adverse neurodevelopment, and chronic degenerative diseases and psychopathologies in adulthood (Wadhwa *et al.*, 2002; Huizink *et al.*, 2004).

Elevated prenatal cortisol levels caused by excessive maternal stress can cause temperamental, behavioural, emotional, motor, and cognitive problems in infants (De Weerth *et al.*, 2003). Infants of 'emotionally disturbed women' are 'typically described as restless, irritable, poor sleepers, and prone to gastrointestinal difficulties'; and 'mothers under severe emotional stress tend to have hyperactive fetuses' (Van den Bergh, 1992, pp. 159 and 160, citing various studies). Children of women treated with the glucocorticoid receptor agonist dexamethasone (DEX), which readily passes the placenta (Welberg & Seckl, 2001), are shyer, more avoidant, and more emotional (Trautman *et al.*, 1995). The effect of prenatal stress on cognitive development and temperament of infants is stronger when it occurs later in the pregnancy (Buitelaar *et al.*, 2003).

Biochemical-emotional communication between mother and fetus is not always associated with stress. Oestrogen and testosterone levels can influence the probability of hyperactivity and social and emotional problems (Williams *et al.*, 2003). Oxytocin is not only used to induce labour (Loghis *et al.*, 1999)—it is also associated with singing (Grape *et al.*, 2003), social contact, and sexuality (Keverne & Curley, 2004), and has therefore been implicated in aspects of mother–infant bonding such as breastfeeding and lullabies. Melatonin helps the circadian rhythms of fetus and mother to synchronize (Reppert & Weaver, 1988).

The word 'communication' implies that information travels in both directions. An example of two-way biochemical communication between mother and fetus is the process leading to the onset of labour. An increase in fetal plasma androgen concentration leads to increases in maternal plasma oestrogen, oxytocin, and amnion fibronectin concentrations (Mecenas *et al.*, 1996). Fetal cortisol levels trigger subsequent maternal endocrine changes leading to labour (Wu *et al.*, 2001). These levels are sensitive not only to onset of labour, but also to mode of delivery—whether normal/spontaneous, instrumental, or Caesarean (Mears *et al.*, 2004).

The claims I have made in this section should be treated with caution. All emotionally implicated biochemicals have other, non-emotional functions, and the link between biochemicals and emotion tends to be quite indirect (Korte, 2001). Changes in biochemical levels may be due to circadian variations rather than emotion (Walsh *et al.*, 1984). Emotionally implicated biochemicals may be associated only with arousal and not with emotional valence. Ongoing research in this area will doubtless generate important new insights and surprises in the coming years.

Behavioural emotional communication

Behavioural emotional communication between mother and fetus may be said to occur when the fetus picks up emotionally informative patterns of sound and movement from within the mother's body. As already pointed out, the most clearly audible sound sources are the voice, breathing, heartbeat, digestion, and walking. In each case, the sound or movement pattern depends strongly on the mother's physical and emotional state (e.g., heart rate: Ekman *et al.*, 1983; respiratory changes: Averill, 1969; uterine contractions, Moawad, 1973). Mastropieri and Turkewitz (1999) explain:

> For example, changes in voice intonation associated with an emotional state such as anger may be accompanied by increased respiration, causing a different pattern of diaphragmatic movements, as well as increased muscular tension and an increase in heart rate. Additionally, those physiological changes involved in the production of speech and which contribute to vocal intonation may also be detectable to the fetus, particularly because autonomic changes immediately precede and influence changes in voice intonation (Scherer, 1986). Temporal relationships between distinctive prosodic acoustic stimulation and distinctive responses associated with maternal physiological changes would provide an opportunity for associative learning (via classical conditioning) in utero. This form of learning would serve as a basis for the perception of and a differential response to different vocal expressions of emotion after birth. (p. 205)

What might motivate the fetus to become sensitive to patterns of sound and movement and their emotional connotations? Again, evolutionary psychology can provide tentative answers.

- Fetal survival is threatened by premature delivery, regardless of whether the mother survives the birth. The fetus is therefore under evolutionary pressure to prepare appropriately for premature delivery.
- After birth, the baby is under evolutionary pressure to be sensitive and adapt to the changing physical and emotional states of its mother (or other caretaker), so that the demands it makes on the mother can generally be met. To begin to acquire this ability before birth, it must monitor its mother's physical and emotional state by attending to biochemical correlates of emotion and emotionally informative sound and movement patterns.

Prenatally available sources of information about the mother's state can be associated with each other by *classical conditioning* (Parncutt, 1993, 1997). The existence of fetal classical conditioning was demonstrated by Spelt (1948) and discussed by Hepper (1992). As changes in maternal sound and movement patterns in response to an external event are faster than associated biochemical changes, they are also predictive of those biochemical changes. Once the different responses have been linked by association, the faster sound and movement responses can act as an early warning system.

This theory is consistent with recent empirical findings. Fetal physiology is plastic in the sense that it responds to environmental factors, preparing the fetus to respond optimally to environmental conditions outside of the uterus (Welberg & Seckl. 2001). The fetuses of anxious women tend to be more active (Van den Bergh *et al.*, 1989). Prenatal stress increases the likelihood of premature delivery, low birth weight, and small head circumference (Dunkel-Schetter *et al.*, 1998). All these phenomena either increase the chance of surviving premature birth or may be a result of preparing for premature birth due to maternal accident, illness, or emotional turmoil. The fetus can evidently go into a state akin to shock, shutting down all developmental processes to maximize chances of survival in a potentially hostile external environment. Mothers who survive fetal death are also usually in shock (Rogers *et al.*, 1999).

Fetal sensitivity to the emotional state of the mother plays a part in postnatal bonding. Infant behaviour is influenced by facial and vocal expression (Campos *et al.*, 2003) and infants as young as 3 months can detect depression in their mothers (Weinberg & Tronick, 1998). A baby that responds to the emotional state of the mother can better co-ordinate with her, again enhancing its chances of survival. This may explain why infants are sensitive to emotional implications of pitch contours in both speech (Mastropieri & Turkewitz, 1999) and music (Trehub & Nakata, 2001–02). Such sensitivities could be prenatally learned (Parncutt, 1993, 1997), genetically predetermined (Trehub, 2003), or both.

Auditory learning and memory

Without auditory learning and memory, there could be no prenatal psychological or musical development. It is therefore interesting in this context to investigate the prenatal emergence of learning and memory. Learning may be defined as storage of information, and in the absence of language, its existence can be investigated by observing behaviour. Prenatal memory is not memory in the everyday sense of remembering a phone number or what happened yesterday, which presupposes adult, linguistically mediated consciousness; it may therefore be more accurate to speak of 'transnatal retention of auditory experience' (Arabin, 2002, p. 428).

The only studies convincingly demonstrating fetal memory have involved many stimulus repetitions (details follow). For that reason, I assume that fetal memories are *procedural* (or *implicit*)—and no more than that. In adults, for example, procedural memory underlies technical skills on a musical instrument, or the ability to drive a car—things that we do mainly automatically, without thinking. In the fetus, procedural memory enables associations to be formed between stimuli that frequently occur in close temporal proximity (classical conditioning). Fetal memories clearly cannot be *declarative* (*explicit*) or *semantic conceptual*) in the everyday adult sense, as the fetus has no language. I know of no direct, convincing evidence of fetal *episodic* (*autobiographical*) memory, or fetal memory for individual events; and the arguments in this chapter do not require that assumption.

Experiments on prenatal auditory learning can be divided into two categories: those where both exposure and behavioural demonstration of learning are prenatal, and those in which exposure is prenatal and behavioural demonstration is postnatal.

Prenatal–prenatal memory

The fetus can habituate (get used and stop responding) to a repeated stimulus (Peiper, 1925), even if it is as complex as music (Cassidy & Standley, 1995; Wilkin, 1995/96). Experiments on habituation do not *necessarily* demonstrate learning, because the subject may also stop responding for reasons of perceptual or motor fatigue; but as prenatal learning occurs in many animals, it is not surprising that it occurs in humans (Hepper, 1992).

Prenatal–postnatal memory

Newborns' sensitivity to heartbeat sounds may be due to prenatal conditioning by the sound of the mother's cardiovascular system (Salk, 1962; Dettermann, 1978). Hepper (1991) demonstrated that babies who had heard a specific piece of music regularly before birth (the theme from the TV soap opera *Neighbours*) but not after birth (before the experimental session) responded with heightened alertness, lower heart rate and fewer movements; but 3 weeks after birth, the infants seemed to have forgotten the music (or were no longer interested in it). Conflicting data were obtained by British music psychologist Alexandra Lamont, who found that memories for prenatally heard music can last as long as a year (Jones, 2001). In a comparable postnatal–postnatal study, 7-month infants presented with the same music daily for 2 weeks remembered it for a further 2 weeks (Saffran *et al.*, 2000). Further research is needed on the postnatal duration of prenatally established auditory memories under different conditions. Presumably, postnatal memory for prenatal sounds lasts longer when those sounds are heard very often, such as the mother's voice and sounds associated with her movements and digestion, and lasts longest when those sounds occur almost constantly, such as the mother's heartbeat and breathing sounds.

Survival value of prenatal hearing

Why can the fetus hear? If prenatal hearing and musical development are related, an answer to this question may contribute to an understanding of musical development and perhaps of music itself. Mammals that hear before birth include humans, sheep, goats, and guinea pigs; those that do not include ferrets, gerbils, rats, and cats (cf. Hepper, 1992; Sohmer & Freeman, 1995). This raises the question of the survival value of prenatal hearing. Consider the following three possibilities.

Preparation for perception

Prenatal perception (including prenatal hearing) may 'serve as a 'running-in' period for the sensory systems' (Hepper, 1992, p. 145). The physiological development of the sensory systems depends on sensory input, and the sensory systems need practice with a restricted range of stimuli in order to be able to cope with the greater diversity of stimuli to which they will be exposed after birth. Prenatal sensory learning may provide a foundation for future sensory learning ability.

Preparation for language

A child typically learns to *understand* language long before s/he can *produce* language at the same level (Karmiloff & Karmiloff-Smith, 2001). This suggests that prenatal (passive) language exposure speeds up postnatal (active) language acquisition and increases the baby's chance of survival (Seebach *et al.*, 1994).

Preparation for bonding

Prenatal hearing indirectly promotes postnatal bonding (or attachment) between baby and mother (Hepper, 1992, 1996), which in turn promotes infant survival. Thanks to prenatal hearing, newborns can distinguish their mother's voice from the voice of other new mothers (DeCasper & Fifer, 1980), and may recognize (Kolata, 1984) or even prefer (DeCasper & Spence, 1986) a story they heard repeatedly before birth, or people speaking their mother's language to another language (Moon *et al.*, 1993). Such studies are evidence for a sophisticated prenatal ability to memorize complex sound patterns. They suggest that the ability to process gestural aspects of language (prosody, intonation, contour), which inform the listener about the intentions and emotions of the speaker, begins before birth (Childs, 1998; Karmiloff & Karmiloff-Smith, 2001).

Evaluating research on prenatal musicality

Research relevant to prenatal musicality is a minefield of poorly defined terms, inappropriately motivated research, poor communication between research groups with different backgrounds and underlying assumptions, and tenuous connections between research results and practical applications (including applications in music education). Popular sources (such as Tsiaras, 2003) are not always reliable. The value and applicability of literature can depend strongly on researchers' motives. Searching the internet can be a problem, because much of the easily accessible literature is politically motivated (e.g., the pro-life, anti-abortion movement).

Consider the following example. Several sources (Karmiloff & Karmiloff-Smith, undated; Whitwell, undated; Wilkin, 1995/96) report that the fetus moves in time to music ('dances'). I could find no plausible empirical evidence for this claim, which seems to be a misinterpretation or exaggeration of the fetus's tendency to change its pattern of movements depending on the kind of stimulation it receives—regardless of whether adults hear that stimulation as music. Any repeated movement can be regarded as rhythmic, but synchronization to music is another matter. Children do not learn to synchronize their movements to a beat, at least temporarily, until their second postnatal year (Moog, 1963). Moreover, there is no evolutionary reason why the fetus should possess this ability.

The following discussion aims to help readers develop a feel for the contradictions in the literature and their origins, and in this way to obtain plausible answers to their questions.

Scientific-conservative versus romantic-progressive research

Gooch (1972, cited in Boyce-Tillman, 2004) classified human cultures into two types, according to the way in which they construct knowledge. 'Type A' systems focus on products, objectivity, impersonal logic, detachment, and discrete categories of knowledge based on proof and scientific evidence. 'Type B' systems favour being, subjectivity, emotion, magic, involvement, association, belief, spirituality, and non-causal knowledge, and are suppressed in modern Western culture. The literature on prenatal psychology may be similarly divided into two categories, which I call *scientific-conservative* and *romantic-progressive.*

Scientific-conservative literature relies on carefully controlled experiments, and is represented by respected medical journals such as the *Journal of Obstetrics and Gynecology* and the numerous journals associated with the American Psychological Association. While these traditions exemplify high academic standards and successful quality control mechanisms, they are not perfect. Scientific-conservative medical research still downplays apparently successful paramedical approaches that are difficult to investigate empirically or reconcile with a Western, materialist approach. And this tradition has not entirely eliminated its patriarchal and sexist traditions and tendencies (e.g., Bickel *et al.*, 1996; Woodward, 1999; Yedidia & Bickel, 2001). The association between fetal psychology and women's bodies and issues may explain why, until a few decades ago, the scientific and medical mainstream showed remarkably little interest in fetal psychology. Scientific-conservative and patriarchal (or stereotypically masculine) thinking is also strong within the field of cognitive psychology, which traditionally treats the brain as a computer separate from the human body and the physical/social environment, and regards quantitative research methods (statistical analysis of numerical data) as superior to qualitative methods (content analysis of linguistic data).

Romantic-progressive researchers tend to the other extreme—united in their opposition to groups as diverse as conservative scientists, the political right wing, and feminists (Verny, 1999). They address scientifically problematic topics such as the interaction between emotional and physical health, paramedical healing, and spirituality. Their flagship journal is the *Journal of Prenatal and Perinatal Psychology and Health.*

Romantic-progressive claims are often undeniably valid and important. Regarding 'prenatal and birth themes and symbols in dance, movement, art, dreams, language, myth, ritual, play, and psychotherapy', Menzam (2002, abstract) wrote: 'Although we cannot prove that specific movement patterns re-enact prenatal and birth events, we can conclude that prenatal and birth themes appear to present everywhere in our lives'. Nor is there always a clear distinction between romantic-progressive and scientific-conservative research. For example, the scientific-conservative Hepper (1992) adopted a progressive stance when he pointed out the danger of underestimating fetal abilities: 'a fetus may sense a stimulus, but exhibit no response' (p. 133).

Some romantic-progressive researchers wildly exaggerate fetal abilities. For example, Cheek (1986) found evidence for out-of-body prenatal memories in memories accessed through hypnotic regression. The call for papers of the 16th International Congress of the International Society for Prenatal and Perinatal Psychology and Medicine (ISPPM Heidelberg 2005) begins as follows: 'Research in the field of prenatal psychology has extended our life-history back to conception and beyond—right back to our parents' thoughts and plans for a child of their own.' The theme of the 12th International ISPPM (London, 1998) was *Conscious Birth: The Experience of a Lifetime*, and the website explained:

> The dawning awareness that the human baby is normally conscious at birth lays the foundation for a paradigm shift with immense consequences. The Congress will review the

> now irrefutable tide of evidence for prenatal and perinatal consciousness, examine its impact on the dynamics of the human condition, survey the history of the emergence of the new paradigm and the reaction it has met and explore the implications for a range of fields.

Chamberlain (1993) drew on anecdotal evidence from psychotherapy to support claims of 'fetal intelligence' and 'thinking before birth'. Sallenbach (1993) even wondered when the 'intelligent' prenate has 'the capacity to formulate hypotheses' (p. 77). These authors failed to distinguish between intelligence and the more elementary abilities to learn and react. Intelligence is normally understood to involve both the possession of knowledge and the ability to use it efficiently and adaptively in real and unexpected situations (Sternberg, 1985). It is misleading to apply this term to the fetus.

Every field of research has its radicals and conservatives, but seldom is the gap between them as large as in prenatal psychology. We can only guess the reason. Perhaps it stems from the strong emotions that babies evoke in adults—combined with the mystery and fascination of a largely inaccessible experimental subject (the fetus). Adults are strongly motivated to meet babies' needs by caring for and playing with them, which has clear survival value (Bjorklund *et al.*, 2002). To what extent should researchers in pre- and perinatal psychology be objective about these feelings? Parenting behaviours are incompatible with the airs of self-importance traditionally cultivated by university professors to maintain the respect of their students and of the general public, who may not be in a position to evaluate their research and intellectual competence by less superficial means. This is an important issue for music educators, whose parental instincts can motivate them to devote their lives to the good cause of child musicality, but at the same time cloud their judgement when confronted with scientific questions related to their research. It is a classic example of the tension between objectivity and subjectivity, or between facts and values, in scientific research (Lassman & Speirs, 1994).

This chapter aims to steer a middle course between 'Type A' scientific-conservative and 'Type B' romantic-progressive extremes. I acknowledge not only the explanatory power of 'Type A' systems but also the descriptive relevance of 'Type B' systems for musical experience and meaning. Like a scientific-conservative, I avoid claims that contradict the best empirical literature. Like a romantic-progressive, I consider promising theories and scenarios for which little or no empirical evidence yet exists. I support my claims with available empirical literature, abstract logic, evolutionary arguments, and everyday experience. I acknowledge, and attempt to combine, the different (tacit) philosophies and criteria of 'truth' that characterize the sciences and the humanities: empiricism, rationalism, intersubjectivity, pragmatism. This radically (and perhaps dangerously) interdisciplinary approach is my attempt to creatively resolve the profound fragmentation of the field of prenatal psychology and, in that way, to contribute to its coming of age.

Definition of talent, music, and consciousness

Terminology in prenatal development can be misleading and inconsistent. Scientific conservatives may overuse scientific jargon, while romantic progressives may project adult or postnatal concepts onto the fetus.

Talent

Musical performance skills (Chapter 5 and 12) are clearly unavailable and irrelevant to the fetus. Fetuses may nevertheless vary in their musical *potential* (giftedness, talent, propensity, musicality, aptitude). If musical potential is genetically determined, it exists before birth and presumably influences the prenatal perceptual-cognitive abilities of hearing, processing, memorizing, recalling, recognizing pitch-time patterns, and associating these with emotion.

Like any other ability, musical ability emerges from an interaction between genes and environment (Plomin & Bergeman, 1991). Presumably, this process begins as soon as the fetus begins to hear. Behaviourally, babies vary in many ways, for example in their irritability (e.g. the frequency of occurrence, duration, and intensity of their crying), which can be regarded as an aspect of personality (Kohnstamm *et al.*, 1989). The extent to which a baby's irritability might be genetically determined is unclear, because it is strongly influenced by the prenatal environment (see 'Emotional communication'). The same presumably applies to a baby's musical ability.

The relative significance of the prenatal stage for long-term musical development is unknown—but unlikely to be comparable with the childhood stage, in which a range of factors influence long-term musical success, including the presence of musical instruments, parents who love music, meaningful (family) musical activities, understanding teachers, parental tolerance of informal practice, and so on. Empirical studies (e.g., Howe *et al.*, 1998) have demonstrated that musical skill depends almost entirely on the amount and quality of practice; but this depends in turn on the motivation to practice long and hard, which may have a considerable genetic–biological component.

Music

What does a fetus perceive, when it perceives *music*? Clearly, not what an adult perceives. First, the fetus has no language or reflective awareness with which to process the music. Second, music perception always depends strongly on previous musical experience (as ethnomusicological research makes clear). Thus, it is important to define what is meant by music. If music is an integral feature of human culture, then it can hardly be relevant to the fetus, which—romantic-progressive objections to the contrary—has not yet been initiated into that culture. For that initiation runs parallel to the acquisition of language (Noble & Davidson, 1996) and does not begin until about one year after birth.

To understand fetal responses to music, it is instructive to consider music perception by non-human animals, which—like the fetus—do not contribute actively or directly to human culture and therefore, presumably, do not experience music (or anything else) in the way human children or adults do. Cows, for example, may produce more milk when exposed to slow music and less when exposed to fast music, because a slow beat reduces stress and a faster beat increases it (North & MacKenzie, 2001). Similarly, the human fetus may prefer musical tempos close to the resting heart rate of the mother (Whitwell, undated). Such work can shed light on inborn responses to specific musical parameters (here, beat and tempo), but not on music in the sense of human musical culture.

Consciousness

Progressive-romantic researchers who are also psychotherapists, psychoanalysts, or hypnotists such as Cheek (1986) often suggest that the fetus has a kind of consciousness (or awareness). Whereas a term such as 'sentient prenate' (Chamberlain, 1994) may be appropriate, as the word sentient refers merely to perception, the parallel claim that 'unborn children are sensitive and aware' (abstract) is unfounded and misleading, and the claim that 'consciousness may not be dependent on the central nervous system, or even on the body' (Wade, 1998, abstract), does not distinguish the fetus from other living or non-living things. A scientific-conservative approach regards the anecdotal experience of therapists and clients in psychoanalysis, psychotherapy, and hypnosis as unreliable, because the various factors that may influence it cannot be separated and controlled.

The confusion about consciousness in the literature on prenatal psychology is unsurprising considering the continuing confusion in the general philosophical, psychological, and neuroscientific literature on consciousness (e.g. Baier, 1999). This confusion appears to stem from variations in both the (operational) definition of consciousness and underlying philosophical assumptions. Often, neither of these is clearly explained. Some possible definitions or components of consciousness are listed below; the most interesting and mysterious of these may be termed *reflective consciousness*, or simply *reflection*.

Regarding philosophical beliefs, scientific-conservatives often seem to be philosophical materialists who believe that only the physical world exists, whereas other researchers may be mind–body dualists. Popper and Eccles (1977) acknowledged the existence of 'three worlds': the physical world, including the brain and all its anatomical and physiological contents (World 1); the world of private experiences—sensations and emotions (2); and the world of information, knowledge, and culture (3). According to their approach, mind–body dualism is about Worlds 1 and 2. But reflection involves (linguistic) description of one's private world of experience, and is therefore an interaction between Worlds 2 and 3. This is consistent with the thesis that reflection and language emerged in parallel, both phylogenetically (in human evolution) and ontogenetically (in child development) (Noble & Davidson, 1996).

By definition, reflection can only be directly observed from within, that is, by introspection. We guess and assume that other people can reflect, but have no direct evidence. The term consciousness is often used in a more general sense that includes observable behaviours such as wakefulness, attention, and preference, as well as unobservable cognitive phenomena such as working memory and cognitive representations. I will consider each of these in turn with regard to the fetus.

The concept of *fetal wakefulness* is unproblematic. It is also directly relevant to prenatal musicality, as fetuses—like newborns—are more likely to react to and process sound when they are awake, and are much more often asleep than awake. An infant's eye, body and respiratory movements allow five behavioural states to be identified—two sleep states (non-REM, REM) and three states of wakefulness (Prechtl, 1974). At 36 weeks gestational age, four of these five neonate states can be identified from fetal heart rate and its variability: quiet sleep, active or REM sleep, quiet wakefulness, and active wakefulness; and the amount of time the fetus spends per day in each state gradually changes as it develops (Nijhuis *et al.*, 1982). It is also possible to determine sleep/wake states from prenatal body movements using ultrasound (Arabin & Riedewald 1992). Sleep-state differentiation begins somewhere between 14 weeks (Oerter & Montada, 1995) and 28 weeks (Awoust & Levi, 1983; Selton *et al.*, 2000). The circadian rhythms of the fetus are synchronized to those of the mother: the fetus tends to be most awake and active when the mother sleeps (Reppert & Weaver, 1988). Incidentally, the fact that the fetus 'dreams' (as babies do in REM sleep: Roffwarg *et al.*, 1966) is no evidence of reflection, since REM sleep also occurs in other animals.

As already noted, the fetus is capable of learning. According to Baddeley's (1986) concept of working memory, stimuli must be processed in working memory before they can be memorized, implying that the fetus also has working memory. If working memory is 'an essential contributor to the neural basis of consciousness' (Osaka, 2003), the fetus may be conscious in this sense. But a scientific approach should preferably distinguish concepts such consciousness, attention, perception, and working memory (Baars, 1997).

The concept of fetal *attention* is less straightforward. The word 'listening' (as opposed to merely hearing) implies attention, which may be psychologically defined as a state of heightened wakefulness or vigilance in response to a stimulus, coupled with selective perception of that stimulus. The fetus cannot turn towards an external sound source, because it has no means of determining its direction (see *sound localization* above). A change in fetal behavioural state in response to a stimulus does not necessary imply attention, either. However, many studies have shown that the fetus *habituates* to a repeated stimulus (Lecanuet, 1996). If habituation is defined as a discontinuation of attention, then it is also evidence for the existence of attention. Attention is not the same as consciousness, but is involved in the selection and maintenance of conscious contents (Baars, 1997). Musical *preferences* begin early. Babies can show preferences for different sounds by sucking in different ways on a pacifier (DeCasper & Fifer, 1980). Newborns prefer the sound of their mother's voice when the high frequencies had been filtered out so that it more closely resembled the muffled sound of the mother's voice *in utero* (Querleu *et al.*, 1984; Fifer & Moon, 1988). Presumably, the fetus could also show preferences if an experimental paradigm could be designed to demonstrate it (perhaps some kind of brain scan, cf. Weiskopf, 2003) or if fetal behavioural reactions (movements, heart rate) characteristic of preference could be identified. All this is unsurprising, as it is normal for non-human animals to show preferences, such as for different foods. The existence of preferences is therefore no evidence for reflection.

Psychologists distinguish between *sensation*, the initial message from the senses, and *perception*, the extraction of information and meaning from sensations (Hepper, 1992), but also use the blanket term perception to cover both. In a cognitive approach, perception involves the construction of *cognitive representations* of environmental objects, usually by comparing sensory inputs in different sense modalities. The concept of prenatal bonding (e.g. Sallenbach, 1993) implies that the fetus forms a cognitive representation of the mother: it combines auditory, movement, biochemical, and other signals that it picks up from the mother so as to construct her as a unified object. Oberhoff (2005) has suggested that this cognitive representation has two essential qualities that might enable a later connection to music: it is *big* and *moving*, just as music is often considered to have virtual spatial properties that are associated with bodily motion and independent of the physical spatial locations of musical instruments (Eitan & Granot, 2004). Again, this is no evidence for fetal reflection, as it is normal for non-human animals to form cognitive representations of environmental objects.

Reflection distinguishes humans from non-humans. Associated with reflection are uniquely human behaviours such as *realizing* that one is attending to or doing something, doing things deliberately (*intentionality*), knowing that one knows something (*metacognition*), and knowing that others have separate reflective consciousness (*theory of mind*) (Noble & Davidson, 1996; Szendre, 1996; Garfield *et al.*, 2001). We cannot conclusively disprove that fetal reflection exists, because if the fetus had a private world of reflection, adults would have no access to it. The only known way to access the reflection of another being or group is through language. However, current knowledge about the role of language in the ontogenesis of reflection makes the existence of fetal reflection seem very unlikely. Phylogenetically, the gradual prehistoric emergence of human speech and language presumably ran parallel to the gradual emergence of reflection and associated characteristically human behaviours (Corballis, 2004). Ontogenetically, babies acquire language, reflection, and a concept of self gradually as they interact imitatively and socially with caretakers; the process begins actively around the age of 1 and continues for at least 10 years (Slobodchikov & Tsukerman, 1992; Papoušek & Papoušek, 1995; Flavell *et al.*, 1999; Asendorpf, 2002; Decety & Chaminade, 2003).

It seems to be human nature to attribute mental processes, including one's inner life and reflective consciousness of sensations and emotions, to other beings or objects such as pets (Archer, 1997). This process, sometimes called *animistic projection*, plays a part in theories of the origin of art (Wulf, 1947) and religion (Roheim, 1932), and in the psychological concept of theory of mind. As animistic projection involves the assumption or attribution of human characteristics, it may be regarded as a form of *anthropomorphism* (also called *anthropomorphization* or *personification*), which is an important issue in fields as diverse as veterinary science, ethology (animal behaviour), animal welfare, evolutionary biology, anthropology, primatology, psychology, history, philosophy, and literary criticism (Mitchell *et al.*, 1997). In the sciences, human qualities may be projected on to animals such as dolphins (Hafemann, 1987), while in areas addressed by the humanities (religion, myths, fairy tales, children's literature), reflection and intentionality may be projected on to living and non-living objects, non-human animals, and gods. The more specific Freudian concept of *projection*—a defence mechanism by which feelings or impulses are attributed to another person (Baumeister *et al.*, 1998)—also plays a part in religion (Beit-Hallahmi & Argyle, 1975). The psychological function of animistic projection may be to overcome the loneliness that accompanies the discovery of self, which in turn accompanies the onset of reflection (cf. Davis & Franzoi, 1986).

Animistic projection on to (and hence anthropomorphism of) the fetus begins when a mother starts to feel her fetus move at about 20 weeks, and gets the impression that it is kicking on purpose, or trying to communicate (Gloger-Tippelt, 1988). Later, adults project reflection on to a baby or child during infant–adult vocal play (otherwise known as *motherese*: Papoušek & Papoušek, 1995; also Chapter 2, this volume); that is, they speak and behave as if the baby or child can reflect.

Children appear to learn both reflection and animistic projection by imitating the behaviour of their carers. Animistic projection is also taught directly when adults project reflection on to animals or other objects during infant–child interactions. Such behaviours help the baby or child to gradually discover that adults (as well as other animals and objects) have different minds, and to conclude that they have their own (Garfield *et al.*, 2001). The child also projects its own reflective consciousness on to objects and animals, when such assignment is plausible and meaningful (Szendre, 1996).

The concepts of animistic projection and anthropomorphism can explain why so many romantic-progressive researchers accept and promote the idea of prenatal reflection. It can also explain the prevalence of the belief that the womb is a safe and happy place, in which the fetus experiences well-being and perfection (Montagu, 1962; Whitwell, undated; I committed the same logical error in Parncutt, 1993, 1997). But even if the fetus could reflect, it could only be 'happy' if it could compare its present state with a previous, less ideal, 'sadder' state. Sounds associated with prenatal 'experience' are not, therefore, necessarily associated with positive emotions. To imagine things from the perspective of the fetus, it is necessary to leave all aspects of the adult world behind, including associations between happiness and abundance, and between sadness and work or responsibility.

Summarizing this section, fetal 'consciousness' is limited to *wakefulness*, *attention*, *perception*, and *preference*. These capabilities are shared by non-human animals (as well as non-human fetuses), suggesting the prenatal human development is not essentially different (and therefore no more wonderful) than prenatal development in other animals. Neither the fetus nor the baby is capable of *reflection*. As the expression 'prenatal experience' (as used for example by Hepper, 1992 and Lecanuet, 1996) implies reflection (consider, in everyday language, the 'experience' of a holiday on a Greek island), it is misleading and should be avoided.

Prenatal music education

Can and should music education begin before birth? The following two arguments suggest that it should:

- *Fetal abilities.* During the third trimester, the fetus is mature enough to survive birth. It can hear, process, and remember musical patterns of sound, and associate them with emotions. Moreover, sound is the most complex (and therefore interesting) prenatally available stimulus: as soon as the baby is born, the amount of competing information that it can potentially extract from the other senses (primarily vision) increases dramatically, while the simultaneous increase in available acoustic information is relatively small. This point can explain the contrast between newborn's striking perceptual musical abilities and the relatively slow rate at which infants learn specific musical structures such as tonality (Krumhansl & Keil, 1982, cited in Trehub, 2003).
- *Parental motivation.* The parents' desire for a child increases steadily during pregnancy and reaches a peak just before the birth (Gloger-Tippelt, 1988). During the last 10 weeks, expectant mothers actively imagine the appearance and behaviour of their baby and what it will be like to care for it. During that time, the parents (and especially the mother) are

highly motivated to participate in activities that will promote the health and well-being of their child.

Is this not a perfect window of opportunity to get the child started on musical development? Should parents take advantage of this period to give their child a head start on musical education? The answer would be 'yes' if it could be demonstrated that prenatally stimulated babies or children had superior musical abilities. And a number of studies seem to have shown that prenatal sensory-motor stimulation—beyond the wealth of sounds and other stimulation normally available in the mother's body—can contribute not only to musical development but also to general sensory-motor, language, emotional, social, and even physical development (Manrique *et al.*, 1993; Panthuraamphorn, 1993; Chen *et al.*, 1994).

Unfortunately, all such studies are methodologically problematic. No researcher has yet succeeded in clearly separating effects of prenatal stimulation from postnatal effects on musical development. For example, Lafuente *et al.* (1997) attempted to 'advance the intellectual and physical development of the fetus by means of musical stimuli' (abstract). Fetuses between 28 and 40 weeks were regularly exposed to violin sounds, and their postnatal development was monitored. The authors claimed that the babies in the experimental group were 'superior in gross and fine motor activities, linguistic development, some aspects of body-sensory co-ordination and certain cognitive behaviours'. If that were true, it would be a sensation. Why might violin sounds have such specific effects, while the sound of the mother's voice and the multitude of other sounds to which the fetus is exposed do not? The fetus has no way of distinguishing between speech and music. More plausibly, Tafuri and Villa (2002) suggested that prenatally musically educated babies produce musical vocalizations (babbling) earlier, more frequently and with musically higher quality than controls. But again it was not possible to control or eliminate postnatal effects on musical development. We thus have no convincing evidence that prenatal fetal acoustic, tactile, or movement stimulation influences intelligence, creativity, or later development. Hepper (1992) wrote: 'My own studies indicate that there may be some benefits resulting from prenatal stimulation, but this appears to be not the result of stimulation *per se*, but rather the results of increasing the interest of the mother in her pregnancy, which has 'knock-on' effects for development after birth' (p. 149).

If prenatal exposure to music indeed gives the fetus a headstart in the development of musical abilities, which is certainly possible, what kind of music should the mother listen to? Should the mother *like* the music, encouraging the fetus to associate it with positive emotions that might later motivate it to become actively involved in music? Or should the mother choose music whose emotion she feels strongly, regardless of whether those feelings are positive or negative, given that memories associated with strong emotions are more salient and last longer (Kulas *et al.*, 2003; Phelps, 2004)? Again, confounds make this question hard to verify empirically; and it is not (yet) possible to investigate fetal preferences.

A further problem is the holistic, amodal nature of fetal and infant perception (Sallenbach, 1993). Neither the fetus nor the infant distinguishes between music and speech; infant–adult vocal play is a combination of speech and music, suggesting that children do not begin to separate the two until their second year. Similarly, the idea of talking to the fetus to encourage prenatal bonding (e.g. Sallenbach, 1993) can only work in one direction: the mother may get the impression of bonding (Bitnour, 2000), but the fetus has no 'idea' that speech is normally directed toward people, and has no possible way of 'knowing' whether speech is directed toward it or someone else.

In summary, empirical studies have not yet demonstrated the success of prenatal music education. The best musicians tend to be those who work the hardest, and the ones who work the hardest are the ones who are most motivated to work and most persistent when the going gets tough (O'Neill & McPherson, 2002). There is no known way of promoting the prenatal development of these attributes.

Contraindications

The problem is not only that benefits of prenatal music education cannot be verified. Attempts to educate the fetus by regularly playing music or other sounds through a loudspeaker strapped to the mother's abdomen could be also dangerous—or at least negatively affect development—in the following ways.

- *Hearing damage.* The fetus is not evolutionarily prepared to hear sound more loudly than the mother does, as it may do when a loudspeaker is strapped to its mother's abdomen. In this situation, the mother may not be in a position to adjust the loudness to an appropriate level. Children of mothers who were working in noisy environments such as factories while pregnant, which is now illegal in some countries (Brezinka *et al.*, 1997), may be more likely to develop high-frequency hearing loss; evidence has been presented both for this claim (Lalande *et al.*, 1986; Pierson, 1996) and against it (Ohel *et al.*, 1987; Arulkumaran *et al.*, 1991).
- *Stress.* Prenatal noise can have other long-term effects. For example, aeroplane noise can lead to a reduction in newborn body weight and height at age 3 years (Kawada, 2004). Noise-induced stress may impair the development of the fetal immune system (Sobrian *et al.*, 1997). Again, these findings are controversial; some investigators (e.g., Hartikainen-Sorri *et al.*, 1991) found no effects of noise.
- *Sleep.* An abdominal loudspeaker could disturb the wake/sleep cycle of the fetus (Nijhuis *et al.*,1982) and disrupt the timing of brain development (Fifer, reported in Bitnour, 2000). The same applies to fetal massage or games. The fetus is much more often asleep than awake, and sleep is important for physiological development. Interrupted sleep may be regarded as a kind of prenatal stress. No one would place a blaring loudspeaker next to a sleeping baby (DiPietro, reported in Bitnour, 2000). It is presumably important at least to ensure that the fetus is awake (moving) before applying such techniques.
- *Bonding.* Prenatal music education via an abdominal loudspeaker could inhibit prenatal bonding. From the viewpoint of the fetus, bonding with the mother involves perceiving her in all sense modalities. A loudspeaker could disrupt and confuse the development of a cognitive representation of the mother.
- *Uncertainty.* Researchers do not yet know enough about the developing fetal brain and auditory system to be sure about the possible positive or negative effects of deliberate prenatal auditory stimulation. Its consequences (like, for example, the consequences of

eating genetically modified foods) are hard to predict. Until things become clearer, it may be better to avoid such procedures altogether.

Ethics

Is it *ethical* to try to educate the fetus? Clearly, it cannot hurt if the fetus gets a headstart on musical skill acquisition that will later help it to compete with musical peers. But:

- *Parentification.* Parents who feel inadequate about themselves may try to compensate by encouraging their children to make up for their own failures—such as their (perceived) lack of musical talent. This is an example of *co-dependence*, which involves shame-proneness, low self-esteem, and *parentification* (Wells *et al.*, 1999). Children are 'parentified' when they are expected to take on the role of caretaker to their siblings or even to their own parents (Chase, 1999). Parents should avoid projecting their wishes on to their child, who has (or will develop) its own wishes, and instead focus on creating a loving environment in which the child can develop in its own, individual way.
- *Pressure.* If too much emphasis is placed on achievement and 'hothousing' in early childhood, the child may achieve less rather than more, miss out on valuable childhood experiences, and develop psychological problems (Hyson *et al.*, 1991). Placing unreasonable expectations on the fetus may set up a negative and lasting dynamic between parents and children. Modern children are under enough pressure (Elkind, 1981) without it starting before birth (DiPietro, reported in Bitnour, 2000).
- *Priorities.* We cannot foresee the contribution a fetus will later make to society. Music is one of countless positive alternatives, but surely not the most important. The world is threatened by poverty, war, and environmental change. Because tomorrow's adults will have to solve these problems, they are a challenge to education in general. Peer and teacher–student interactions are important for social development (Kim & Stevens, 1987). Parents can contribute by nurturing their children's natural altruism (Hurlbut, 2002), promoting situations that encourage them to think clearly, independently, and critically, and nurturing their natural abilities and tendencies. 'Our ultimate objective, of course, is to help create not a musical genius but a person well integrated in his [sic.] physical, emotional, intellectual and spiritual self' (Whitwell, undated).

Recommendations

In conclusion, the following recommendations can be made to expectant mothers wishing to support their unborn child's musical development. Because the empirical evidence is incomplete, the recommendations are necessarily tentative and intuitive.

- *General health.* Promote general fetal development by eating and exercising wisely. A chronic lack of important nutrients can restrict fetal growth and permanently affect cardiovascular, endocrine, and metabolic systems (Bertram & Hanson, 2002).

- *Stress.* Restrict stress to reasonable limits. Recent research (cited above) has clearly and repeatedly demonstrated that *excessive* maternal stress is bad for the fetus. Conversely, *mild* stress is normal and may even promote development (DiPietro, 2004).
- *Auditory health.* Minimize the chance of hearing problems by avoiding infections. The most common cause of prenatal hearing loss is viral infection by cytomegalovirus or rubella. In Western countries, rubella has become rare due to vaccination (Lagasse *et al.*, 2000). As it is unclear whether prenatal noise affects postnatal hearing, avoid long-term exposure to high sound levels in discos or factories. The fetus may be affected primarily by the stress you feel when exposed to loud sounds; the noise itself may be secondary.
- *Music.* Listen to and play a lot of music—provided you enjoy the music yourself. The more music the fetus hears, the more it will learn about it, at least in the sense of storing pitch-time patterns in memory. Maternal enjoyment may also promote the development of positive emotional associations to music, and is certainly more important than arbitrary aesthetic judgements of musicologists; 'classical' music is not necessarily better (cf. Cook, 1998). However, do not force yourself to play or listen to music, as stress is problematic (see above) and negative connotations may cancel out the positive effect of neutral exposure. Avoid very loud music (see above), but remember that moderately quiet music will be inaudible to the fetus. Some researchers claim that music with a clear beat is preferable and that you should listen to the same music regularly, but the evidence for this is weak.
- *Singing.* If you enjoy singing, sing. The quality of your singing (e.g., in the sense of staying in tune or in key) doesn't matter: your fetus is very accommodating! Nor does it matter whether you sing, speak, or something in between. If it helps you to imagine that your fetus is listening, and this makes music making (and listening) more enjoyable, OK—but be aware that the fetus is unable to reflect on what it hears. Regardless of its prenatal effect, singing to your fetus can give you a headstart on bonding with your baby (Fridman, 2000) and get you into the habit of singing lullabies after the birth, which is musically, cognitively, emotionally, and socially beneficial (cf. Chapter 2, this volume).
- *Living.* Paradoxically, the best way to promote a child's musical ability before its birth may be to do nothing specifically musical at all. Just eat, sleep, walk, talk, and experience emotional ups and downs as usual. All these activities produce sound patterns that stimulate the prenatal development of hearing, auditory pattern recognition, and the emotional connotations of sound patterns that underlie music.

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