Music and Babies' Brains

by Benjamin Bolden

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I have recently become an uncle; my niece is six weeks old. A few days ago my younger sister and I dropped in to see the baby and her parents. In the course of a very pleasant visit I picked up a guitar and strummed a few chords, improvising a few brand new Emma songs.

Emma, she wears a pink hat.
Emma, her cheeks are so fat…

My brother joined in, playing a mandolin, while my sister held the baby and danced gently to the music. Emma appeared to be enjoying herself (in that she didn't cry or squirm—it is very rare indeed that she will grace us with a smile). But what *was* she actually taking in? Do her ears pick up all that I hear? Does she assemble the pitches I sing into the contour of a melody? Will she sing along? Does she notice when I sing flat? Or when I fumble my finger-picking and play a wildly non-diatonic pitch? Does she recognize and become familiar with our repeated rhythmic patterns? Can she tell if my sister's dancing is in time with our music? Or is it all just wild and glorious sound?

Children all over the world, regardless of the music culture in which they are raised, develop the basic musical abilities necessary to participate in their own musical culture before the age of ten, a process of enculturation which takes place "automatically and subconsciously" (Gembris, 2002, p.491), and with or without formal music education. Mary Louise Serafine conducted extensive research with children between the ages of 5 and 8 with the aim of determining their cognitive ability to understand various aspects of music. She found that musical temporal processes (succession and simultaneity) and nontemporal processes (closure, transformation, abstraction and hierarchic levels) "are generally well in place in human cognition by the age of 10 or 11 years; are *not* strongly in evidence earlier at around 5 years of age; and are not dependent on intensive formal tuition in the interim" (1988, p.153).

Infants, however, are still works in progress, musically speaking. Understandably, many aspects of musical cognition are not yet in place. Nevertheless, there is much within the musical domain that babies *do* perceive and understand. Some of the musical abilities that children develop in the first year of life are described below.

A note of warning! Children demonstrate significant developmental differences in music abilities (or, indeed, *any* abilities) from a very early age. Children develop at different rates as a result of many factors. Just one such factor is the musical culture in which the child lives, as musical development is inextricably linked to the musical culture in which she is raised (Gembris, 2002). Our children, accordingly, will probably experience a

music culture very different than that of our own childhood (however much we subject them to Bach, Beethoven, or The Beatles), and their musical development will reflect that difference (Buller, 2004). So, while examining the following research findings, it is essential to keep in mind that considerable variation can occur in musical (and general) development; such differences are not necessarily an indication of giftedness or disability.

Fetal Listening

In the fifth month of gestation nerve cells of the inner ear, or cochlea, begin functioning. They respond best to mid-range frequencies. Structural maturity of the ear is reached at 24 weeks. By the third trimester, the fetus responds to auditory stimuli:

> The neonate processes pure tones within the same intensity range as the adult, discriminates location of sounds, and is sensitive to differences in frequency, intensity, stimulus rate, the phonetic components of speech, and voices (Woodward, 1992, p.787).

Sheila Woodward's (1992) research involved the recording of sounds from a microphone placed within the uterus, next to the fetus. The mother's voice, white noise, and pure tones were all audible. External male and female voices, presented at the regular volume of 60 decibels, also made it through to the fetus. Although vocal consonants were indistinguishable, vowels, melody, rhythm, and the timbre and character of voices could all be picked up. Bach's Brandenburg concerto #1, played at 80 decibels, was also found to be audible above the intrauterine sounds.

The extent of the fetus's cognitive or psychological perception of such sounds, however, is still rather uncertain. Some research has indicated that long-term memory of sounds heard before birth is possible. Feijoo (1981) regularly presented short melodies to mothers during the 6^{th} to 8^{th} month of pregnancy, for a period of four weeks. Tested shortly after they were born, the babies stopped crying when they heard the same melodies. In a similar experiment Satt (1984) played a lullaby to mothers every day for the last two months of pregnancy, and determined that a significant proportion of the newborns could recognize the same lullaby. Hepper (1991) found that infants just a few days old could distinguish the main tune of a TV program that they had heard regularly before birth.

Phyllis Wilken (1991) conducted research by playing a series of recordings to a sample of 8-month fetuses (while the mothers wore earplugs). Wilken used: 1) a Beethoven piano sonata, 2) white noise, 3) Palestrina's Kyrie, and 4) instrumental rock by Emmerson, Lake and Palmer. The unborn babies responded (with fetal movement) most to the piano, to a lesser extent to the choral music, and still less to the rock selection (in fact, the response was the same for the rock music as it was for white noise). Tested again at the age of 4-6 weeks, the infants had more movement for the three music items than white noise, and also demonstrated more 'eyes open' and 'still and listening' behaviour than when the music was absent. Anecdotally, based on responses from the mothers in the sample, rock music made both fetuses *and* newborns anxious, piano music made them relaxed but pleasantly alert, and choral music (Palestrina) made them soothed and relaxed.

The evidence suggests, then, that the human fetus has the ability to not only hear but also remember music.

Newborn Listening

A newborn baby is physically equipped to hear sounds vibrating at a speed of up to 20,000 cycles a second—very high indeed in the musical audio spectrum (the predominant frequency of the top note of a piano is a sound vibration of a mere 4000 cycles per second). This is the peak moment of a human's hearing ability; the apparatus begins its inevitable decline immediately. By the age of 50, we can generally only hear sounds that vibrate at a speed less than 13 000 cycles per second (Jourdain, 2002).

Although it is very difficult to know what a baby sonically perceives at the moment of birth, an infant will turn its head to seek a voice only seconds after it is born. Infants as young as 1 to 5-days-old have demonstrated the ability to discriminate differences in frequency, while at the age of one week, babies can differentiate their mother's voice from the voices of other females (Hodges, 2000).

Infant Listening -- Melodies

An important aspect of melodic recognition is the cognitive ability to group similar things (pitches) into a whole, or Gestalt. Because infants can determine the distinction between equal and different stimuli—meaning they can group like with like—they know to treat a series of notes as an identifiable or rememberable group or stimulus (a construct they will later learn to call a melody) (Fassbender, 1996). By the age of about six months babies have developed the ability to recognize short melodies. It is the melodic contour that they latch on to; memory and recognition of the rising and falling line enable the infants to identify familiar tunes, rather than the perception of absolute pitches or intervals (Dowling, 1988, 1999). The case for the contour being the recognized aspect of the tune is further supported by the ability of infants to recognize melodies shifted in terms of tempo and pitch level (transpositions) (Trehub, 2000).

Sandra Trehub has conducted extensive research with infants. When the babies respond to a change in the music by turning towards the loudspeaker, she rewards the infants by showing them a glimpse of a toy or dancing puppets for a short time. This ploy has enabled Trehub to determine that infants actually can distinguish various musical changes. She continues to learn more about the specific changes in music which infants can and cannot perceive. For example, infants are better at recognizing diatonic melodies—those that stick to the pitches of major or minor scales—than melodies that contain non-tonal (chromatic) pitches (Trehub et al, 1990). Infants are also able to detect 'wrong notes' in diatonic melodies; experiments have shown they are able to identify a change when a melody has a pitch varied by a semi-tone or less, even when the contour of the melody remains the same (Trainor & Trehub, 1993 and Trehub, Schellenberg, & Kamenetsky, 1999).

Other research shows that infants (like adults) have difficulty comparing melodies in distantly related keys (D major vs. Db major, for example), and are more likely to notice similarities and differences between tunes when the keys are closely related (such as D major and G major) (Trainor & Trehub, 1993). In other words, the very same melodic pattern moved by a semitone is more difficult for the babies to recognize than the pattern

moved by an interval of a fifth. This suggests the infants are not attending to the contour only, but have some concept of the relationship of keys. In the case of adults, this aspect of music perception may be explained by a prolonged exposure to the norms of western tonality. In the case of the infants, however, it suggests there might be a universal tendency towards an understanding of relationships based on consonant intervals (such as perfect fourths and fifths) rather than dissonant intervals (such as the semitone). This possibility of a musical universal gains credibility when one takes into account infants' preference for consonant melodic intervals (Trehub, 2003).

Infant Listening -- Intervals

Infants prefer consonant melodic intervals. When 2- and 6-month-old infants were tested, they were observed to listen longer to sequences of consonant intervals as opposed to sequences of dissonant intervals (Trainor& Heinmiller, 1998). Similarly, a study by Zentner & Kagan (1996) found that 4-month-old infants were content to listen to folk melodies they had not heard before, but showed signs of distress (fussing, squirming, and looking elsewhere) when they were played similar folk songs which had been modified by replacing some of the consonant intervals with dissonant intervals.

Babies are also better at identifying intervals that are consonant. They are more precise in perceiving perfect fourths and perfect fifths than tritones (Schellenberg & Trehub, 1996).

Infant Listening -- Recognizing out-of-tune notes

The first issue in recognizing out-of-tune notes is the ability to perceive very small pitch differences. An average healthy ear can recognize about 12 gradations between A 440 and the A# above it (Jourdain, 2002). Trehub (2003), referencing Werner's (1992) work in developmental psychoacoustics, assures us that 'infants' resolution of pitch and timing enables them to detect the smallest differences that are musically meaningful in any culture'. This allows us to move to the second issue: whether the infant has the ability to remember what an *in-tune* scale sounds like. This is necessary, of course, as a point of reference with which to compare the questionable pitch, and determine if it is out-of-tune.

Lynch, Eilers, Oller, & Urbano, found that American six-month-old babies could recognize out-of-tune notes in scales from their own (Western) culture *and* (after a brief period of familiarization) from non-western (Javanese *pelog*) scales (1990). Adults tested simultaneously were not able to recognize changes in the Javanese scale. Interestingly, when this research was replicated with a western major scale and an *invented* scale with equal steps (a scale not used by any musical culture, being a precise mathematical division of an octave), the infants still did well identifying the out-of-tune notes in the major scale, but could not detect changes in the invented scale. However, when presented with out-of-tune notes in a *different* invented scale, which had unequal steps (as do the scales in all world musical cultures), the babies were able to identify the changed notes *while adults similarly tested could not* (Trehub, Schellenberg, & Kamenetsky, 1999). Apparently the adults in these experiments had been trained by exposure to western music to the point that they found unusual scales incomprehensible, as was demonstrated in their response to the Javanese *pelog* and both invented scales. The infants, however, were quickly able to learn the *pelog* and invented *unequal*-step scale, and recognize small pitch variations, or 'out-of-tune' notes. The infants, however, were also unable to make

sense of the equal-step scale, a finding that has fascinating implications in suggesting musical universals—these researchers seem to have identified a musical scale which humans are simply not equipped to aurally comprehend.

Infant Listening -- sensitivity to Western tonal structure

When a melody was varied by changing a pitch to imply dominant harmony (diatonic change), 8-month-old infants noticed the change to the same degree that they noticed the change when the pitch was moved by a semitone (nondiatonic change). Adults were much better at detecting the nondiatonic change, and performed sometimes worse than the infants in detecting the diatonic change. These findings suggest that infants have not absorbed the common western music practice of moving to the dominant, and adults have. To the infants, it is just as strange to move to the dominant as it is to move any way out of the diatonic context (Trehub, 1992).

Infant Listening -- mothers

Infants like to listen to their mothers speak, but they prefer to listen to them sing. Researchers measured the amount of time infants voluntarily watched videos of their mothers speaking and videos of their mothers singing—the infants remained engaged for significantly longer periods while watching the singing (Trehub, & Nakata, 2001–2002). Not surprisingly, by measuring cortisol levels in infants' saliva before and after a maternal singing session, researchers were able to establish that maternal singing can both arouse a sleepy baby and calm one who is stressed (Shenfield, Trehub & Nakata, 2003).

Infant Listening -- rhythm

Infants can generally differentiate very early on between regular and irregular heartbeat or click sounds (Spiegler, 1967). By five months, infants can distinguish simple rhythmic patterns, such as long-short from short-long (Shuter-Dyson & Gabriel, 1981). In a recent study Sandra Trehub and Erin E. Hannon (2005) familiarized a group of 6-month-olds with both Balkan and Western music examples, then played them versions that were rhythmically altered (extra beats were inserted in some bars). By comparing the babies' responses, Trehub and Hannon were able to ascertain that the infants were generally able to recognize when the rhythms were altered, with equal facility, in both the Western and Balkan music examples. A sample of 12-month-olds, tested in the same manner, were not as good at recognizing the rhythmic changes to the Balkan music as they were the rhythmic changes to the western music. However, the 12-month-olds were tested again after being sent home to listen to Balkan music every day for two weeks. In this set of tests the 12-monthers showed a significantly stronger ability to recognize rhythmic changes in the Balkan music. Adults, given a similar opportunity to become more familiar with the Balkan music, scored just as poorly the second time round. Trehub and Hannon have concluded:

> 12-month-old infants show an adult-like, culture-specific pattern of responding to musical rhythms, in contrast to the culture-general responding that is evident at 6 months of age. Nevertheless, brief exposure to foreign music enables 12-month-olds, but not adults, to perceive rhythmic distinctions in foreign musical contexts. These findings may indicate a sensitive period early in life for acquiring rhythm in particular or socially and biologically important structures more generally (p.12639).

The ability to *reproduce* rhythms, for example by singing in metred phrases, generally does not occur until after an infant's first birthday (Gembris, 2002).

Infant Singing

Babies begin cooing and making purposeful vocalizations at 15-16 weeks (Hodges, 2000) and start singing descending glissandi figures at 3 or 4 months (Fox, 1990). Some six-month old babies have been successful in matching specific pitches (Hodges, 2000). Various kinds of vocal play happen from 12 to 18 months (Stadler, 2000). It is usually about the age of 12 months that infants differentiate between singing and speaking. A typical song of an 18-month-old toddler:

> consists of an often-repeated phrase with a steady melodic contour at a continuously changing level of pitch. The song is quite often interrupted by breathing; however, the rhythmical contour remains within the phrase and sometimes even stretches over several phrases. These songs are often derived from the rhythm of language (Gembris, 2002, p.495).

As remarked earlier, singing in regular metre generally does not occur until the second year of life.

Infant Dancing

Although babies have been consistently observed to move their limbs in time with the speech of caregivers, the first synchronization of music and movement generally occurs between 18 months and 2 years of age (Moog, 1976). But this does not mean babies do not make connections between auditory rhythm and movement. Jessica Phillips-Silver and Laurel J. Trainor conducted research to determine if movement influences the way human infants hear and encode rhythm patterns. A sample of 7-month-olds listened to two minutes of a looped rhythm pattern devoid of accented beats. Half of the babies were bounced on every second beat, and the rest were bounced on every third beat. Then the infants listened to two more versions of the looped rhythm pattern, one with intensity accents on every second beat (the duple form), and the other with accents on every third beat (the triple form). The infants chose to listen longer to the version with accented beats that matched the beats on which they were bounced. In other words, their pattern of bouncing determined which version they would prefer.

Debunking the myth of the first 3 years

It seems almost impossible to have any conversation about music and babies without reference to the communal folk wisdom that places a huge emphasis on the developmental implications of a child's early sensory experiences. Much media-reported brain development research over the past twenty years has focused on the fact that the number of synapses in the cortex grows enormously over human infancy. Parents, policy-makers and educators have been valiantly trying to maximize the experiences of infants for maximum learning. The first three years of life have been viewed as a time of considerable brain plasticity, when young children had opportunities for learning and development that were finite—use the synapses, or lose them. The belief was that infants and toddlers raised in an impoverished sensory environment would create fewer neuronal connections, and would never be able to make up for that lost learning, while those raised in a fertile sensory environment would manufacture many more and have better-connected brains for the rest of their lives. In *It Takes a Village*, Hillary Clinton wrote:

"with proper stimulation brain synapses will form at a rapid pace, reaching adult levels by the age of two and far surpassing them in the next several years." *Inside the Brain*, by Ron Kotulak suggests: "Growing evidence indicates that early mental stimulation promotes the growth of synaptic connections between brain cells." And, with a more sinister tone: "For a growing number of children, the period from birth to age 3 has become a mental wasteland that can sustain only the gnarled roots of violent behaviour."

In *The Myth of the First Three Years: A New Understanding of Early Brain Development and Lifelong Learning*, John T. Bruer (1999) takes issue with these and other widespread and influential assumptions about the early years of brain development, arguing that there is no evidence in neurobiology suggesting that infancy is a better time for learning than any other. He examines the research in three areas: 1) synapse formation and loss in the cerebral cortex of humans and other primates; 2) studies of critical periods in the development of patterns of cortical connectivity in cats and monkeys; and 3) studies of the effects of environmental complexity on the brain. He finds no research indicating that the potential to learn declines after the first years of human life.

In fact, no evidence relates the growth of synapses in the cortex to variations in learning capacity. Learning capacity actually increases through childhood, as synapse numbers decline. And although some cognitive systems, such as those concerning visual function and language, show particularly vital periods of development, not all such periods occur between the age of zero and three.

So what of the argument espousing the benefits of early synapse building, and encouraging parents, teachers and policy-makers to find as many opportunities as possible for early sensory stimulation? Bruer explains that laboratory rats in more interesting environments *do* have more synapses in some parts of their brains than rats that live in uninteresting environments. However, the effects of environmental complexity are observed not just early on in life, but *throughout* development and into adulthood. So perhaps it is OK to save some of the sensory stimulation for later in life after all. Human brains grow a huge number of synapses in the first three years of life, but they continue to learn for many years.

In a more recent analysis of the research in the area of critical periods for musical development, Laurel Trainor reached similar conclusions to Bruer: "While there is a general belief that early musical experience and training is necessary for reaching high levels of musical expertise, there is actually little direct evidence on this question" (Trainor, 2005a, 262). Her thorough review of the research concerning this topic closes as follows:

> What can we conclude about critical periods for musical expertise? Deprivation studies certainly have indicated that it is necessary to experience spectrally and temporally patterned rich sound to wire brain circuits for pitch processing (Chang & Merzenich, 2003). And enrichment studies also have indicated that early intensive musical experience has an effect on brain development (Shahin et al., 2004). However, the adult brain also retains some plasticity (Bosnyak et al., 2004), and it appears to be at least possible, if uncommon, to acquire musical expertise later in life. Therefore, critical periods for higher levels of musical expertise are probably quite fluid, and it is clear that there are multiple pathways to achieving musical expertise (Trainor, 2005a, 274).

I feel the need to include this perspective on children's first three years in response to those for whom the knowledge of what young children *can* do governs the mandate for what they *should* do. As Bruer points out:

> The parents at the poolside, and other parents who have been bewitched by the Myth, can relax. Those parents were doing exactly what they should have been doing. They were interacting with their child as she played…Brain science, even if we add in behavioural science, cannot tell us how to raise a scientifically correct child. Parents should realize that children thrive in a wide variety of physical and cultural environments and learn and benefit from experiences throughout their lives (p. 243).

Where young children are concerned, it is vital to critically consider the benefits of any activity while mindfully taking into account the detrimental stress of overwhelming expectations or a punishing schedule. Music is a fantastic vehicle for entertaining, stimulating and communicating with young children. But there is no reason to push music past the threshold of enjoyment. I suppose I am doing my best to articulate the heartfelt response I received from psychologist Sandra Trehub, who has done extensive work in the area of infants and their response to music, and whose research greatly informs the content of this article. At a recent lecture presentation of her work, I asked: "Having learned so much about the way humans and especially young people respond to and perceive music, what would you most like to share with music educators?" Trehub replied that she would most like to impress upon parents and educators the importance and value, while learning music, of having fun.

Conclusion

Caregivers all over the world instinctively make use of music to soothe, teach, communicate and play with infants. Not surprisingly, research has indicated that the music is not falling on deaf ears; babies are competent in perceiving and cognitively processing a variety of musical components. So in response to my earlier pondering:

But what was she actually taking in? Do her ears pick up all that I hear? Emma is certainly physically equipped to hear all the musical events that I can—in fact, not having had the chance to deteriorate, her hearing is a good deal more acute than my own.

Does she assemble the pitches I sing into the contour of a melody? She can recognize the contour of a melody, and will probably remember and recognize it even if I shift keys or change tempo. In fact, she may even recognize the melody as one she has heard (slightly muffled) up to three months before she was born. She will most likely *prefer* the melody if it contains consonant rather than dissonant intervals.

Will she sing along? Emma might possibly sing along (although will probably wait until her first birthday), and there is a possibility she could even match some of the pitches I produce.

Does she notice when I sing flat? Or when I fumble my finger-picking and play a wildly non-diatonic pitch? As far as noticing my occasional 'out-of-tune' notes, a six-month-old is fully capable of hearing even slight pitch alterations, and, as infants quickly learn the patterns of scales, Emma is most likely *very* aware of my sour notes! (Of course,

she has not been encultured to think of them as sour, and will only recognize them as 'different'…if only all critics were so open-minded!) She is also equipped to distinguish (diatonic) pitches that fit within the key and those that do not… sloppy fingers beware!

Does she recognize and become familiar with our repeated rhythmic patterns? Can she tell if my sister's dancing is in time with our music? Emma is able to distinguish simple rhythmic patterns—and accordingly is able to recognize and become familiar with them—but she cannot reproduce them. As far as dancing, she may be inspired by the music to move her limbs around, but will not do so *in time* with the rhythm until well after her first birthday. However, the accented movements that my sister makes in time to the music will influence the way Emma encodes what she hears.

…Or is it all just wild and glorious sound? No! It's *music*; babies are able to perceive many fascinating aspects of music. It may be wild and glorious, but the sounds are encoded and analysed with many of the same cognitive processes as those found in adult music listening.

Most importantly, the wisdom of countless cultures and generations is not misplaced in showering babies with musical offerings; infants are highly capable of receiving and making sense of music. And, better yet, if the response of my own six-month-old niece is anything to go by, music is something they enjoy very much.

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