

Musical Predispositions in Infancy

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ABSTRACT: Some scholars consider music to exemplify the classic criteria for a complex human adaptation, including universality, orderly development, and special-purpose cortical processes. The present account focuses on processing predispositions for music. The early appearance of receptive musical skills, well before they have obvious utility, is consistent with their proposed status as predispositions. Infants' processing of musical or music-like patterns is much like that of adults. In the early months of life, infants engage in relational processing of pitch and temporal patterns. They recognize a melody when its pitch level is shifted upward or downward, provided the relations between tones are preserved. They also recognize a tone sequence when the tempo is altered so long as the relative durations remain unchanged. Melodic contour seems to be the most salient feature of melodies for infant listeners. However, infants can detect interval changes when the component tones are related by small-integer frequency ratios. They also show enhanced processing for scales with unequal steps and for metric rhythms. Mothers sing regularly to infants, doing so in a distinctive manner marked by high pitch, slow tempo, and emotional expressiveness. The pitch and tempo of mothers' songs are unusually stable over extended periods. Infant listeners prefer the maternal singing style to the usual style of singing, and they are more attentive to maternal singing than to maternal speech. Maternal singing also has a moderating effect on infant arousal. The implications of these findings for the origins of music are discussed.

KEYWORDS: Musical predispositions; Adaptation; Melodic contour; Intervals; Scale structure; Rhythm; Maternal music

MUSICAL PREDISPOSITIONS IN INFANCY

The notion of musical predispositions implies a biological basis for music. For contributors to a forum on the biological foundations of music, consideration of predispositions is hardly surprising. It is worth remembering, however, that the larger scientific community remains skeptical about links between music and biology. Steven Pinker, who popularized the notion of a *language instinct*,¹ dismisses music as “cultural cheesecake”—a confection that tickles our sensitive spots. “As far as biological cause and effect are concerned, music is useless. It shows no signs of design for attaining a goal such as long life, grandchildren, or accurate perception and prediction of the world. Compared with language, vision, social reasoning, and physical

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know-how, music could vanish from our species and the rest of our lifestyle would be virtually unchanged.”²

Amusing words, perhaps, but muddled thinking. For one thing, the *competence–performance* distinction, which is central to theories of language, is accorded no role in music. Pinker emphasizes the capacity of *all* normal children to speak and understand language without explicit instruction, in contrast to the musical incapacity of many adults, particularly those who cannot carry a tune. He notes as well that the majority of adults cannot play an instrument; for the small minority who can, considerable training and practice are required. These apparent deficits in explicit musical knowledge are treated as deficits in implicit knowledge. So how does music still manage to tickle the appropriate spots?

Pinker also contrasts the wide variations in musical sophistication with the presumed uniformity in language ability. Such pronouncements confound language and music in general—the underlying knowledge that makes it possible to produce and understand language or music (i.e., competence)—with language or musical expression (i.e., performance). Instead of comparing musical performance with everyday speaking and listening, why not compare judgments of “grammaticality” for simple musical and speech sequences? Finally, Pinker’s vision of life without music betrays his ethnocentrism—music as material for concerts, dance halls, and movie soundtracks rather than something entwined in the fabric of life. It ignores the historical and cross-cultural importance of music in ritual ceremonies,^{3–6} work,^{7,8} and childcare.⁹

Geoffrey Miller,¹⁰ by contrast, considers music to exemplify many of the classic criteria for a complex human adaptation: (1) no culture in any period of recorded history has been without music—in other words, universality; (2) an orderly developmental schedule;¹¹ (3) high ability, with almost every normal adult capable of carrying a tune and appreciating music (unlike Pinker’s acquaintances); (4) specialized memory that makes it possible to recognize thousands of melodies; (5) involvement of special-purpose cortical areas;^{12,13} (6) analogues in the signals of other species, such as songbirds, gibbons, and whales,¹⁰ raising the possibility of convergent evolution; and (7) the propensity of music to evoke strong emotions, which implies receptive as well as productive adaptations.

If music is a complex biological adaptation rather than a by-product of other evolutionary processes, it must have conferred survival or reproductive benefits through the cumulative effect, over generations, of natural selection or sexual selection.^{10,15,16} The costs of music production—energy expenditure—must be balanced by the benefits. Because no clear survival benefits are evident, Miller argues for the evolution of music on the basis of its reproductive benefits—music as sexual courtship.¹⁰ He contends that, whereas music is typically performed *in* groups, it is not *for* groups. He notes, for example, that group tribal dancing (i.e., vigorous movement to music) would have provided a convenient means for young women to assess the strength, endurance, and motor coordination of potential mates. Ancestral life in relatively stable social groups would have allowed women to scrutinize the contenders over an extended period. Miller acknowledges, however, that perceptual and cognitive preferences would be equally effective for purposes of sexual selection.

The operation of sexual (or natural) selection would result in the replication of genes related to receptive and productive musical ability. Although motor limitations might constrain the expression of productive abilities in early life, they would not

interfere with receptive abilities. In this regard, it is important to emphasize that musical abilities with a biological basis may not be evident at birth. Moreover, such abilities may be influenced by exposure. Learning can be guided by innate preferences, as is the case for many songbird species.¹⁷ Thus, musical skills that are evident in infancy, well before they have obvious utility, can be considered predispositions.

PROPOSED MUSICAL PREDISPOSITIONS

A common means of assessing the music perception skills of 6- to 10-month-old infants is to present them with a repeating melody or tonal pattern from a laterally displaced loudspeaker. In this “game,” infants must turn to the loudspeaker when they hear a change in the repeating pattern. When they respond correctly (i.e., turning within 4 seconds of a change in sound), they are rewarded by a colorful mechanical toy (e.g., dancing bear, acrobatic monkey). Failure to turn to a change or turning at other times has no consequences. The visual rewards are sufficient to motivate attentive listening for 10–15 minutes, or 20–30 test trials. Aside from the bells and whistles (e.g., bears, monkeys) that facilitate communication with nonverbal participants, the task is similar to same–different procedures used with adults. Infants respond (by turning) when they consider the comparison pattern different from the standard pattern (i.e., response of *different*), and they do not respond if they fail to notice any change (i.e., response of *same*). Evidence of detecting the change is provided by significantly more responses (turns) to changed patterns than to unchanged patterns. Infants’ performance also provides information about the features that they encoded from the original (repeating) melody. For example, if infants failed to notice the tempo of the original melody, they would be unable to detect changes in tempo.

Relational Processing of Pitch and Duration

Infants’ resolution of frequency,^{18,19} timing,^{20,21} and timbre^{22,23} is finer than that required for musical purposes. Moreover, perceptual grouping principles that are relevant to music^{24,25} are operative in infancy. For example, infants group isochronous tone sequences on the basis of similarities in pitch, loudness, and timbre.^{26,27}

Infants go well beyond such minimal criteria for music perception. Like adults, they recognize a melody when the pitch level is shifted upward or downward.^{28,29} The critical issue is whether the relations between tones are preserved. An analogous situation prevails with respect to timing. Infants recognize a tone sequence when the tempo is altered, so long as the relative durations remain unchanged.³⁰ In other words, they focus on relational rather than absolute attributes, making an otherwise unmanageable feat—remembering the exact pitches and durations of melodies—potentially manageable.

Infants retain absolute pitch information in some circumstances. When the standard and comparison melodies are presented in the same key, or with the same starting pitch, infants notice some pitch changes that might otherwise go unnoticed.^{31,32} As the task gets more difficult, however, they shift their focus from absolute to relational cues. For example, infants can discriminate a semitone change in the context

of an augmented triad (C-E-G \sharp -E-C to C-E-G-E-C) when the standard and comparison melodies are presented at the same pitch level.³² They are unable to do so when the patterns are presented at different pitch levels.³³ In the latter situation, infants focus on the melodic contour, or overall pitch configuration, of the melody rather than on its component pitches.

Melodic contour is an especially durable feature of melodies. Remarkably, infants can identify changes in contour when the standard and comparison melodies are separated by a full 15 seconds²⁸ or when distractor tones are inserted between standard and comparison sequences.³⁴ In fact, pitch contour seems to be the most salient musical feature for infant listeners.^{35,36} It may also be the most salient feature of mothers' speech to prelinguistic infants.³⁷⁻⁴⁰ Evidence from adult listeners is consistent with contour processing as fundamental and relatively impervious to musical experience. During contour-processing tasks, for example, the amplitude and latency of event-related potentials do not differ for musicians and nonmusicians; during interval-processing tasks, however, experience-dependent differences are apparent.⁴¹

Interval Processing

For adults, the extraction of pitch information is not limited to melodic contour, except in the context of novel melodies.^{42,43} When the melodies are reasonably simple and they conform to familiar musical conventions, adults typically remember more detailed pitch information than would otherwise be the case.⁴⁴⁻⁴⁶ For highly familiar melodies, of course, adults retain the precise pitch distances between tones (i.e., intervals), but not the absolute pitches.^{47,48} When singing their favorite pop song, however, adults deviate by about 2 semitones in pitch⁴⁹ and 8% in tempo from the canonical recording.⁵⁰

In some circumstances, infants also extract rich pitch information. Interestingly, those circumstances are much like the ones that promote enhanced pitch processing for adults. For example, infants detect interval changes in brief melodies that conform to cultural conventions but fail to do so for melodies that violate those conventions.^{33,51,52,53} I am not arguing that six-month-old infants have acquired conventions relating to musical structure. On the contrary, there is evidence that infants lack such implicit knowledge.^{46,54,55} The apparent influence of musical conventions is the consequence of universal or near-universal features.^{35,56}

In studies of infant melodic perception, the presence of a prominent seven-semitone interval, or *perfect fifth*, has been associated with success in interval discrimination, and its absence has been associated with failure.^{33,31,51-53} The perfect fifth is not alone, however, in enhancing infants' perception of pitch relations⁵⁷ (see FIG. 1). Rather, infants, children, and adults more readily detect interval changes in the context of small-integer ratios—the octave (2:1), perfect fifth (3:2), and *perfect fourth* (4:3)—compared to large-integer ratios, such as the *tritone* (45:32 ratio).⁵⁷⁻⁵⁹ In other words, it is likely that inherent differences in ease of processing resulted in consonant intervals assuming a prominent role in most musical systems.^{35,60,61} The historical record is consistent with the inherent inequality of intervals, providing numerous references to the beauty of octaves, perfect fifths, and perfect fourths^{62,63} and the ugliness of the tritone—the *devil in music* in medieval times.⁶⁴

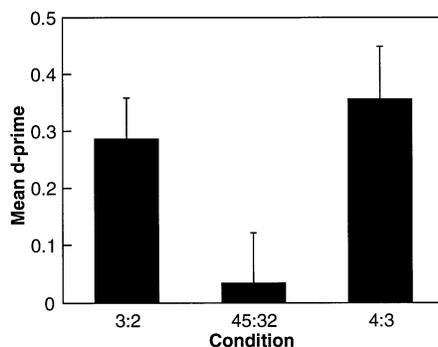


FIGURE 1. Infant discrimination scores as a function of the frequency ratios of tones in melodic (sequential) intervals. (Reproduced with permission from Schellenberg and Trehub.⁵⁷)

Consonant and dissonant intervals not only promote ease of processing; they also influence infant attention and affect. For example, infants are more attentive and exhibit more positive affect while listening to consonant music than to music with many dissonant intervals.^{65–67} In principle, these preferences could arise from the predominance of consonant intervals in the infant’s environment (e.g., speech, music, environmental sounds). Comparable preferences are demonstrable, however, in newborns whose deaf parents communicate by means of sign language.⁶⁸

Processing of Scale Structure

Despite the diversity of scales across cultures, a number of similarities are evident. One of these is the typical division of the octave into five to seven discrete pitches, a design feature that probably arises from cognitive constraints.⁶⁹ Another is the ubiquitous perfect fifth, which is associated with enhanced processing in listeners of all ages.^{57,59,70} Yet another similarity is the presence of unequal scale steps⁷¹—for example, one- and two-semitone steps in diatonic scales—a feature that is thought to confer processing advantages.^{72,73}

In a test of this hypothesis,⁵⁵ nine-month-old infants and adults listened to one of three ascending–descending scales: (1) the major scale, which is highly familiar to adults and potentially familiar to infants; (2) an artificial analogue of the major scale that was created by dividing the octave into 11 equal units, and selecting a seven-tone subset (featuring 1- and 2-unit steps); and (3) an artificial equal-step scale that was created by dividing the octave into 7 equal steps^{74,75} (see FIG. 2). Infants and adults were required to detect a mistuned tone (0.75- and 0.5-semitone change for infants and adults, respectively). Although adults’ performance was highly accurate on the familiar major scale, they performed equally poorly on the two unfamiliar scales. By contrast, infants showed a general facilitation for scales with unequal steps, performing equivalently on the major and artificial unequal-step scales, and significantly more poorly on the equal-step scale (see FIG. 3). These findings provide three important pieces of information. First, unequal-step scales, which are universal or near-universal, facilitate pitch processing in infancy. Second, infants’ performance on the major scale cannot be attributed to familiarity. Thus, other instances of

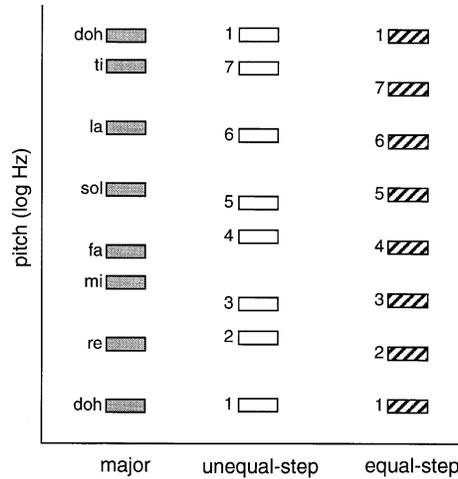


FIGURE 2. Schematic depiction of the major, artificial unequal-step, and equal-step scales. (Reproduced with permission from Trehub, Schellenberg, and Kamenetsky.⁵⁵)

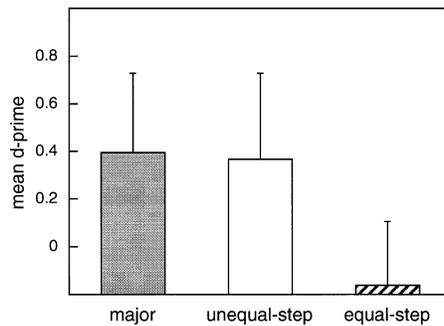


FIGURE 3. Infant discrimination scores on the ascending–descending major scale, artificial, unequal-step scale, and equal-step scale. (Reproduced with permission from Trehub, Schellenberg, and Kamenetsky.⁵⁵)

enhanced processing—small-integer ratios, for example—are likely to be unrelated to exposure. Third, culture-specific experience, such as adults' long-term exposure to the major scale, can override initial processing biases.

There are other examples of culture-specific exposure attenuating or eliminating initial processing biases. For example, pitch processing in infancy is enhanced when the standard and comparison patterns are presented in related keys—specifically, keys standing in a 3:2 ratio—rather than unrelated keys; for adults, such enhancement is limited to conventionally structured melodies.⁵¹ Similarly, the conventionality of a melody is unrelated to infants' ability to profit from melodic redundancy, but it is a major determinant of adults' performance in such circumstances.⁴⁶

Rhythm Processing

Infants can differentiate tone sequences with identical pitches but contrasting rhythmic arrangements.^{30,76,77} As noted, they also impose rhythmic groupings on isochronous tone sequences,^{26,27} raising the possibility that they might be adult-like in other respects. Their detection of pitch and duration changes is best for melodies whose tone durations are related by small-integer ratios, specifically 2:1.⁷⁸ Moreover, there are indications that adults' preferred rhythmic arrangements of melodies generate the best performance on the part of infants.

When adults listen to music, they are presumed to generate an internal clock that reflects the organization of accented notes.⁷⁹ This dynamic mode of attending leads to more accurate reproduction of metric sequences compared to nonmetric sequences.⁸⁰ When nine-month-old infants listen to metric and nonmetric rhythmic patterns, their ability to detect rhythmic changes in one note is evident only in the context of metric patterns.⁸¹ Thus, the available evidence on rhythm perception in infancy is consistent with processing predispositions for metric rhythmic patterns and for tone durations related by small-integer ratios.

Hemispheric Specialization

Well before infants have any understanding of language, they show a right-ear (i.e., left hemisphere) advantage for speech and a left-ear (i.e., right hemisphere) advantage for music.^{82,83} Moreover, eight-month-old infants exhibit a left-ear superiority for contour processing and a right-ear superiority for intervallic processing.⁸⁴ Such laterality effects parallel those reported for adults.^{85,86}

MATERNAL MUSIC

The relevance of these perceptual processing predispositions to the daily lives of infants is unclear. For one thing, the musical patterns in most laboratory studies (e.g., sequences of pure tones) differ dramatically from infants' usual musical input. Every day, indeed many times each day, infants hear distinctive performances of maternal songs, a situation that is common to all cultures and historical periods.^{87–89}

Until very recently, research on maternal vocal behavior focused exclusively on speech to infants—*motherese*, or infant-directed speech—and its effects on infant listeners.^{90,91} When mothers sing to their infants, they typically use a special-purpose repertoire consisting of lullabies and play songs.^{9,88} To a naïve observer, unfamiliar lullabies, including those from foreign musical cultures, sound much like familiar lullabies. For example, when adults listen to pairs of unfamiliar lullabies and nonlullabies that are matched on culture of origin and tempo, they readily identify the lullabies.⁹² Structural simplicity or repetitiveness seems to be the principal cue that guides identification.⁹³

Mothers' style of singing to infants differs from their usual style by virtue of a higher pitch level, slower tempo, and more emotive voice quality.^{94–96} Mothers also vary their performance in subtle ways for infant or preschool listeners.⁹⁷ Specifically, their pitch level is approximately one-semitone higher and their articulation of words more slurred for infant than for preschool audiences. Features of this caregiv-

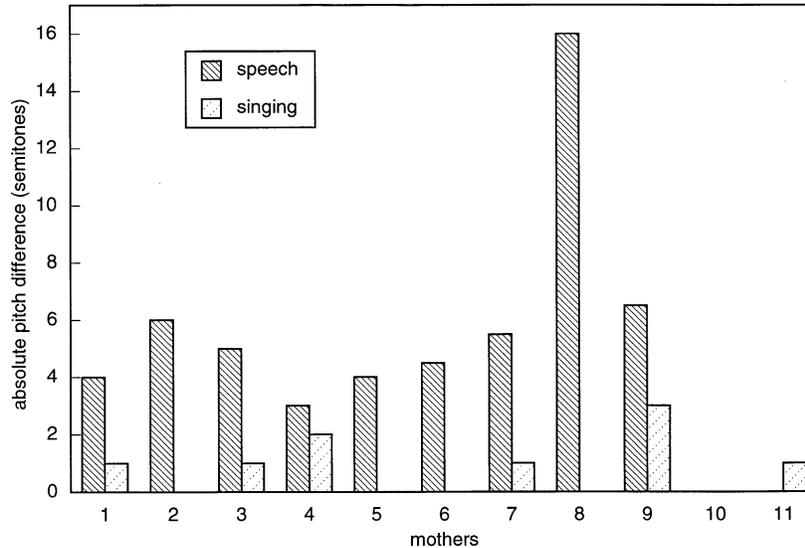


FIGURE 4. Pitch differences, in semitones, of repetitions of songs and verbal phrases by 11 mothers. Note that mothers' repetitions were separated by one week or more. (From Bergeson and Trehub. In press.¹⁰⁰)

ing style are evident in fathers' singing to infants^{96,98} and in preschoolers' singing to their infant siblings.⁹⁹

Although researchers have commented on parallels between speech and song for infants,^{9,36,88} they have been slow to delineate differences. In general, women's singing tends to be higher-pitched than their speech, but speech to infants is higher pitched than singing to infants.¹⁰⁰ This situation results from the large increase in pitch level (three to four semitones) for infant-directed speech¹⁰¹ coupled with the small increase (one semitone) for infant-directed singing.^{94,96}

There is considerable interindividual variation in maternal singing, but surprising intraindividual stability. When mothers sing the same song to their infant on two occasions separated by a week or more, their pitch level differs by less than a semitone (see FIG. 4), and their tempo (in beats per minute) differs by only 3% (see FIG. 5).^{100,102} Such pitch and tempo variations are smaller than those reported for adults' repeated renditions of pop or folk songs.^{49,50,103} Mothers' repetition of identical verbal phrases across the same period shows considerably greater variability in pitch and tempo (see FIGS. 4 and 5). If the act of singing affects mothers' mood or state, that might account, in part, for the stability of pitch and tempo over extended periods—a possible consequence of state-dependent memory. Frequent singing to infants may also implicate motor memory. In any event, mothers' performances of songs seem to become ritualized, which may facilitate their use as communicative signals to prelinguistic infants.

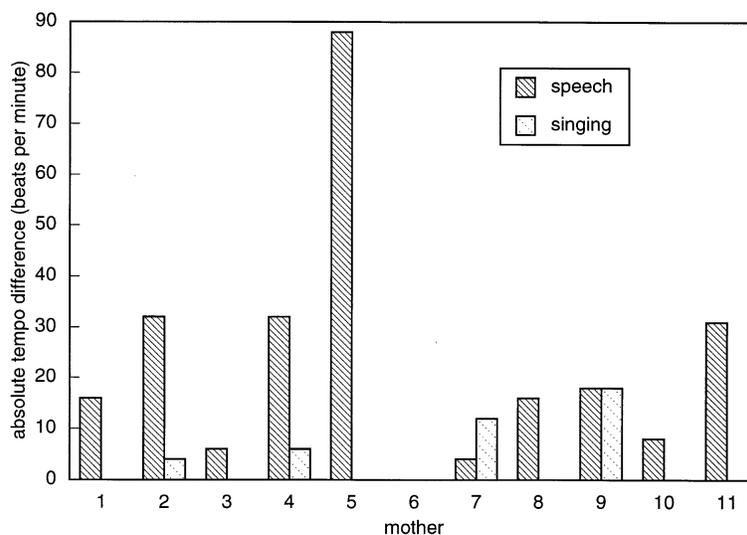


FIGURE 5. Tempo differences, in beats per minute, of repetitions of songs and verbal phrases by 11 mothers. Note that mothers' repetitions were separated by one week or more. (Reproduced with permission from Bergeson and Trehub. In press.¹⁰⁰)

Responsiveness to Maternal Music

How do infants respond to these maternal singing rituals? In the newborn period and beyond, infants listen significantly longer to women's singing (audio recordings) in the maternal style than to these singers' usual informal style.^{104,105} They also exhibit greater attention to higher- over lower-pitched versions of the same song.¹⁰⁶ These preferences indicate the potency of singing, especially in view of the unfamiliar singers and the absence of expressive gestures and movements that typically accompany maternal singing.

When six-month-old infants view videotaped performances of their own mothers (recorded while singing to their infant), which provide access to visual as well as acoustic features, they show more sustained attention to mothers' singing episodes than to their speaking episodes (see FIG. 6).^{107,108} Infants tend to be mesmerized by these sung performances, remaining glued to the monitor for extended periods. Mothers' speaking is also engaging, but not nearly as engaging as her singing.

Although there has been much conjecture about maternal speech and singing as modulators of infant arousal,^{9,90,109} the measurement focus has been on attention rather than arousal. In a recent investigation, six-month-old infants furnished saliva samples before and after mothers sang to them for 10 minutes.¹¹⁰ Changes in salivary cortisol from pre- to posttest levels were highly but inversely correlated with pretest levels (see FIG. 7). Specifically, infants with initially lower levels of salivary cortisol showed cortisol increases, but those with initially higher levels showed decreases. The arousal-modulating effect of maternal singing was also reflected in reduced variance from pre- to posttest levels. These findings are impressive, given the narrow range of initial cortisol levels and the absence of stressful circumstances.

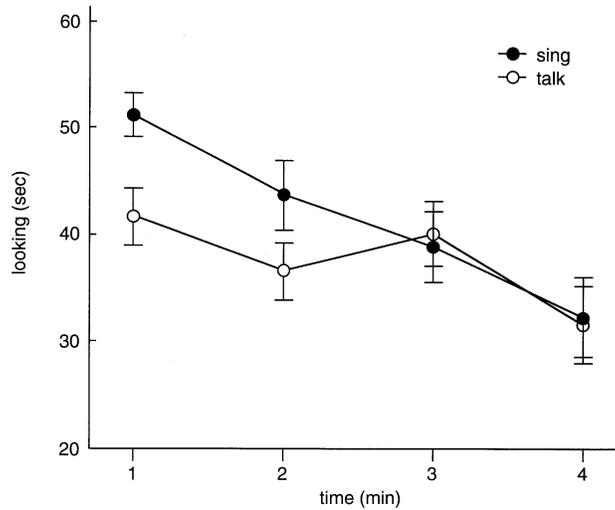


FIGURE 6. Infant looking time, minute by minute, during episodes of mothers' speech and singing. (Reproduced with permission from Bergeson and Trehub.¹⁰⁸)

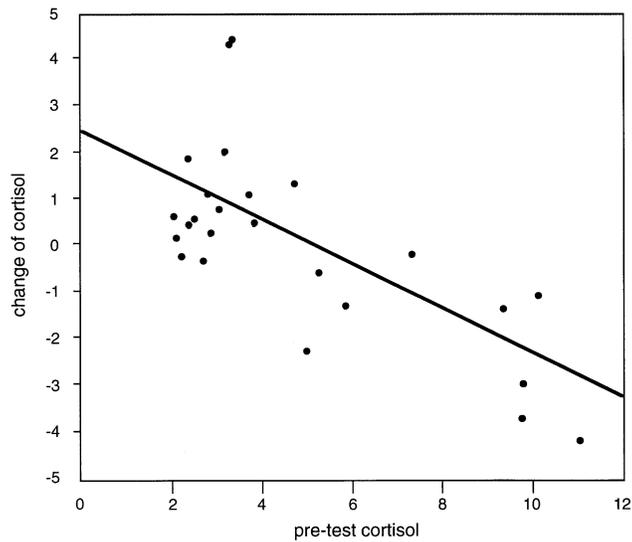


FIGURE 7. Changes in infant salivary cortisol following maternal singing. Data are plotted as a function of pretest levels. (Reproduced with permission from Shenfield and Trehub.¹¹⁰)

Biological Significance of Singing to Infants

Mothers' propensity to sing to infants and the impact of their singing on infant attention and arousal raise the possibility that maternal singing could have enhanced infant survival in difficult ancestral conditions. Children's extended period of help-

lessness would have created intense selection pressures for parental commitment,¹¹¹ including pressures for infant displays to sustain such commitment. It is likely that singing to infants promotes reciprocal emotional ties,⁹⁸ just as singing in other circumstances reduces the psychological distance between singer and listener.^{112,113} Presumably, mother's growing attachment to infants would lead them to generate increasingly expressive performances. To balance the enormous physical and psychological costs of parenting, infant recipients of such largesse would have to advertise their worth. Falling asleep to lullabies or entering trance-like states to performances of other songs might qualify in this respect. In general, favorable consequences of maternal singing on infant arousal, whether through cry reduction, sleep induction, or positive affect, would contribute to infant well-being while promoting the continuation of such maternal behavior. The healthy and contented offspring of singing mothers would be more likely to pass on their genes than would the offspring of non-singing mothers.

MUSICAL COURTSHIP

An alternative, or supplementary, means of gene transmission could operate on mate selection through female musical courtship. According to this scenario, young adult males succumb to the expressive singing of young adult females, a situation for which there are nonhuman parallels. In some avian species, for example, females sing to attract mates and lead duets with their male partner.^{114,115} There is speculation, moreover, that such duetting fosters long-term pair bonding.¹¹⁶

What about Miller's proposal of music as male sexual courtship?¹⁰ In an unusual test of this hypothesis, Miller compared the recorded output of prominent jazz, rock, and classical musicians. The data confirmed Miller's predictions. Males produced ten times as much music as females, their output reaching its zenith near the age of peak mating effort. From this unconventional data set, Miller concluded that music continues to function as a male courtship display to attract females. I could offer more parsimonious interpretations, but they are beyond the scope of the present paper. In the spirit of Miller's real-world analysis, however, I propose an alternative test—assessing the musical skills of ordinary males and females (i.e., nonmusicians), perhaps those without musical training. My prediction is that more females than males will be capable of tuneful, expressive singing.

CODA

It is clear that infants do not begin life with a blank musical slate. Instead, they are predisposed to attend to the melodic contour and rhythmic patterning of sound sequences, whether music or speech. They are tuned to consonant patterns, melodic as well as harmonic, and to metric rhythms. Mothers cater to infants' musical inclinations by singing regularly in the course of caregiving. They also adapt their usual singing style in ways that are congenial to infant listeners. Such maternal singing has the features of a unique vocal signature.

Perhaps it is not surprising that infants are predisposed to attend to and appreciate the species-typical vocalizations of their primary caregiver. Infants' predisposition

to attend to particular aspects of musical structure is surprising only if music is viewed in a narrow sense, as fully developed musical systems of particular cultures. Viewed broadly, however, music embraces what all musical systems have in common. In that sense, infants begin life as musical beings, being responsive to the musical primitives or universals that are the foundation of all styles of music.

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