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Music Cognition: A Developmental Perspective

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Abstract

Although music is universal, there is a great deal of cultural variability in music structures. Nevertheless, some aspects of music processing generalize across cultures, whereas others rely heavily on the listening environment. Here, we discuss the development of musical knowledge, focusing on four themes: (a) capabilities that are present early in development; (b) culture-general and culture-specific aspects of pitch and rhythm processing; (c) age-related changes in pitch perception; and (d) developmental changes in how listeners perceive emotion in music.

Keywords: Music development; Musical enculturation; Music cognition; Pitch perception; Music and emotion

Although music is evident across cultures, its structure differs in terms of the pitch (i.e., scales, chords) and temporal (i.e., meters, rhythms) patterns formed by sequences of tones and tone combinations. Through simple exposure, listeners eventually become knowledgeable about the music of their native culture. Does this mean that infants are born as musical *blank slates*? If not, what aspects of music are universal and reflective of human processing predispositions? How does experience with a particular genre shape our understanding and appreciation of music? And how do musical cues come to be associated with particular emotions? We explore these questions by reviewing research on culture-general and culture-specific influences on pitch and rhythm perception, and on developmental changes in music cognition and emotional responding to music. Our focus throughout is on basic, behavioral research conducted with typically developing populations.

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1. The starting state

Music is often a complex stimulus, with tones that vary over time in pitch, duration, amplitude, and timbre. Nonetheless, young listeners perceive and remember many of the auditory patterns we call music. They also find some music easier than others to perceive and remember. Indeed, despite the variety that is evident across cultures, there are a number of music universals or near-universals that appear to stem from human processing predispositions.

For cultures that use scales with discrete pitches (i.e., virtually all cultures; Burns, 1999), the ability to detect differences in pitch is obviously important. Across cultures, the smallest difference in pitch between tones that is structurally important tends be at least one semitone in size. Pitch changes this size are well within the discrimination abilities of young infants, who detect changes as small as 1/3 of a semitone (Olsho, Schoon, Sakai, Turpin, & Sperduto, 1982). Such fine-grained pitch-discrimination abilities imply that scales could have more than 30 tones per *octave* (i.e., 12 semitones, from low *do* to high *do*). This number would greatly exceed the capacity to form discrete categories from a continuous variable (Miller, 1956; Pollack, 1952), however, which is thought to be the reason why scales across cultures tend to have between five and seven tones per octave (Dowling & Harwood, 1986).

Indeed, music composed from scales with a greater number of tones, such as the 12-tone scale (e.g., music composed by Berg or Schönberg), remains notoriously unpopular among the general population. Although unfamiliarity undoubtedly plays a role, another possible contributing factor is that 12-tone scales have no *tonic* (the tone called *do*), because all tones are equally spaced, each separated by a semitone. Virtually all scales (except for 12-tone and whole-tone scales) have tones with *unequal* spacings, which allow different tones to have different functions and for one tone to emerge as the tonic (or focal point). Nine-month-olds form more stable mental representations of unfamiliar scales with unequal steps than similarly unfamiliar scales with equal steps (Trehub, Schellenberg, & Kamenetsky, 1999), which suggests that scales with unequal steps confer natural processing advantages.

Other constraints on scale structure involve the particular *intervals*, or distances in pitch between pairs of tones. *Consonant* or pleasant-sounding intervals have small-integer frequency ratios, with more overtones common across tones. These include the *octave* (12 semitones, frequency ratio of 2:1), *perfect fifth* (seven semitones, 3:2), and *perfect fourth* (five semitones, 4:3). By contrast, *dissonant* or unpleasant-sounding intervals, such as the *tritone* (six semitones, 45:32) and *major seventh* (11 semitones, 15:8), have larger-integer frequency ratios and fewer common overtones. A preference for consonant intervals is evident in 2-month-olds (Trainor, Tsang, & Cheung, 2002), newborns with deaf or hearing parents (Masataka, 2006), and newly hatched chicks (Chiandetti & Vallortigara, 2011). By 7 months of age, human infants categorize intervals on the basis of consonance, finding two consonant intervals (five and seven semitones) to be more similar than a consonant and a dissonant interval (seven and six semitones), even though the two consonant intervals differ more in size (Schellenberg & Trainor, 1996). Moreover, 6-year-olds as well as 6-month-olds process and remember consonant intervals better than dissonant intervals, even when the intervals comprise pure tones presented sequentially (i.e., no overtones, no audible roughness; Schellenberg & Trehub, 1996a,b). It is no wonder, then, that consonant intervals are structurally important in many musical scales.

Consecutive tones in melodies are typically separated by small intervals of one or two scale steps. In fact, large melodic intervals, such as the upward octave at the beginning of *Over the Rainbow,* are relatively rare in music regardless of culture or genre (Dowling & Harwood, 1986; Vos & Troost, 1989). Tones separated by large differences in pitch are likely to be heard as coming from different sources (Bregman, 1990), which make it difficult to perceive a melody as a coherent whole. Indeed, some theorists propose that innate perceptual grouping principles cause listeners to expect the next tone in a melody to be proximate in pitch to the tones they heard most recently (Narmour, 1990; Schellenberg, 1997). In line with this view, adults and children from Asia and North America exhibit expectancies for proximate tones in melodies composed with familiar and unfamiliar scales (Schellenberg, 1996; Schellenberg, Adachi, Purdy, & McKinnon, 2002).

The ability to perceive and remember temporal information is also evident early in development. For example, heart-rate decelerations reveal that 5-month-olds notice when a pause in a sequence of six different tones has been moved from one position (before the third tone) to another (before the fifth tone; Chang & Trehub, 1977). At 2 months of age, visual fixations indicate that infants can distinguish an isochronous sequence of tones from a non-isochronous sequence, as well as two different non-isochronous sequences even when the temporal gaps between tones are identical but simply re-ordered (Demany, McKenzie, & Vurpillot, 1977). Even newborns exhibit neurological signs of detecting when a relatively important metrical event (e.g., with two percussion instruments played simultaneously rather than one) is removed from a repeating drum pattern (Winkler, Haden, Ladinig, Sziller, & Honing, 2009). These findings imply that some aspects of temporal processing relevant to music are innate.

The *meter* in music refers to the underlying pattern of strong and weak beats (i.e., the pulse), which must be inferred from the surface structure because musical events do not necessarily coincide with beats. Western music tends to be composed in (a) *duple* meters, with emphasis on every other beat or the first of every four beats, or (b) *triple* meters, with emphasis on the first of every three beats. Western meters are typically isochronous whether one considers every beat or just the strong beats. By contrast, *rhythm* refers to the actual pattern of musical events and accents that listeners hear. Different rhythms (e.g., tango, disco) can have the same meter, whereas different patterns of accents can make the same tone sequence have different meters.

Infants discriminate a duple from a triple meter at 7 months of age even when the standard and comparison patterns have different rhythms (Hannon & Johnson, 2005). When infants the same age listen to a temporally ambiguous rhythm while being bounced either on every second or every third beat, they subsequently exhibit a preference for the same piece of music with accents on every second or every third beat, respectively (Phillips-Silver & Trainor, 2005), presumably because the bouncing was enjoyable and influenced their perception of the meter. Similar influences of movement on meter perception are evident among adults (Phillips-Silver & Trainor, 2007) and can be attributed to head movements (Phillips-Silver & Trainor, 2008) and activation of the vestibular system (Trainor, Gao, Lei, Lehtovaara, & Harris, 2009). In fact, infants move more regularly when they hear music compared to speech, and their movements are better coordinated with music they enjoy (i.e., as measured by smiling; Zentner & Eerola, 2010). In short, there is a strong connection between movement and meter perception throughout the lifespan.

Studies of rhythm perception reveal equally precocious abilities. Infants 7–9 months of age distinguish rhythmic sequences that are identical but presented at different tempi, even in the context of pitch variations (Trehub & Thorpe, 1989). They can also discriminate one rhythmic sequence from another (e.g., X_XX vs. XX_X), even in the context of pitch *and* tempo variations (Trehub & Thorpe, 1989). Simple as opposed to complex rhythms enhance 6-month-old infants' ability to remember the pitch *and* temporal patterning of a melody, whereas for adults the benefits of the simple rhythm are evident for only the temporal aspects (Trehub & Hannon, 2009). At 9 months of age, infants more readily notice a temporal disruption to a rhythm if it strongly rather than weakly implies a meter, and if the meter is duple rather than triple (Bergeson & Trehub, 2006).

2. From culture-general to culture-specific music listening

The enculturation process involves learning to attend selectively to the pitch and temporal structures that are relevant in one's native music environment. This learning process is often accompanied by a decreased ability to perceive and remember non-native structures. For example, when Western infants and adults are required to detect a mistuning to melodies formed from native or non-native musical scales, 6-month-olds perform equally well with either melody but adults perform better with native melodies (Lynch, Eilers, Oller, & Urbano, 1990). Adults' difficulties at detecting mistunings extend more generally to melodies composed from unfamiliar scales, even those with unequal steps (Lynch & Eilers, 1992; Lynch, Eilers, Oller, Urbano, & Wilson, 1991; Trehub et al., 1999). Similar difficulties with melodies composed from unfamiliar scales are evident among 10- to 13-year-olds (Lynch & Eilers, 1991), and in some instances, even among 12-month-olds (Lynch & Eilers, 1992; Lynch, Short, & Chua, 1995). These findings point to a rapid process of musical enculturation that parallels language acquisition. It is well known that by 12 months of age, infants have difficulty detecting speech contrasts that are not phonemic in their native language (e.g., Werker & Tees, 1984).

Other evidence points to a more protracted music-enculturation process. For example, infants are better at detecting mistunings to melodies that have more redundancy (repeated tones), regardless of whether the melodies are composed from a familiar or an unfamiliar scale (Schellenberg & Trehub, 1999). By 5 years of age, such redundancy effects are stronger when the melodies are composed with the familiar compared to the unfamiliar scale; by adulthood, the effect is evident only in the familiar context. These results suggest that a listener becomes fully enculturated sometime *after* 5 years of age.

Converging evidence of protracted enculturation comes from studies that examine listeners' knowledge of *tonality* and *harmony* in Western music. Tonality refers to the levels of stability that vary among tones in the context of a Western musical key. *Do* is the most stable tone, followed by *sol* and *mi*, and then by the rest of the tones in the scale. Tones from outside the scale are the least stable. In the typical paradigm, a key-defining context is presented followed by a variety of probe tones that listeners rate in terms of goodness-of-fit with the context (Krumhansl, 1990). In some instances, children in elementary school provide ratings that are similar to those of adults (Cuddy & Badertscher, 1987). In others, there is a steady progression from 6 to 12 years of age, but even 12-year-olds do not exhibit adult-like knowledge of tonality (Krumhansl & Keil, 1982).

Harmony refers to chords (simultaneous combinations of tones) and chord progressions (sequences of chords). In Western music, pieces often end with a *perfect cadence*—a chord based on *sol* (the dominant) followed by a chord based on *do* (the tonic). When adults are asked to make a judgment about the final chord in a sequence, performance tends to be faster and more accurate when the chord is the tonic compared to another chord even though the task is unrelated to its function (e.g., *is the final chord sung with the vowel/i/or/u/?*; Bigand, Tillmann, Poulin, D'Adamo, & Madurell, 2001). Interestingly, children as young as 6 years of age respond similarly (Schellenberg, Bigand, Poulin-Charronnat, Garnier, & Stevens, 2005). In very simple contexts that require listeners to make explicit good/bad judgments about correct or incorrect harmonies, some signs of harmonic knowledge are evident as early as 4 years of age (Corrigall & Trainor, 2010), particularly among children with formal music training, which accelerates the enculturation process (Corrigall & Trainor, 2009). When the task is altered to test listeners' understanding of the harmonies *implied* by consecutive tones in a melody, adults and 5- to 7-year-olds have difficulty noticing when a tone in a melody is changed but remains consistent with the implied harmony, but infants do not (Trainor & Trehub, 1992, 1994). For 5-year-olds but not the older listeners, poor performance is also evident for tones that go outside the harmony but stay within the key, which points to an under-developed knowledge of implied harmony for this age group (Trainor & Trehub, 1994).

Culture-specific exposure also influences temporal perception in music. In contrast to the typical isochronous meters of Western music, meters from other cultures (e.g., Balkan or Turkish) can be based on isochronous or non-isochronous (e.g., a group of 3 beats followed by a group of 4 beats) temporal groups. Balkan adults detect temporal disruptions to either isochronous or non-isochronous meters, whereas North American adults notice the disruption only in the isochronous context (Hannon & Trehub, 2005a). North American 6-month-old infants perform similarly in the isochronous and non-isochronous contexts because they are not yet fully enculturated with Western meters. By 12 months of age, infants fail to detect disruptions in the non-isochronous meters, which once again implicates relatively early enculturation (Hannon & Trehub, 2005b). The bias at this young age is still formative, however, and can be eliminated after 2 weeks of exposure to non-isochronous meters. North American adults do not show the same plasticity because a similar amount of exposure does not eliminate their performance advantage with isochronous meters. Infants' facility with non-isochronous meters does not extend to artificial, highly complex meters that are not used in any musical culture (Hannon, Soley, & Levine, 2011), just as their facility with foreign speech sounds does not extend to arbitrary non-phonetic contrasts in speech (Werker & Lalonde, 1988).

Infants show some signs of cultural specificity before 12 months by demonstrating preferences for the meters of their native musical environment, a process that may be accelerated by formal exposure to music (e.g., through Kindermusik classes; Gerry, Faux, & Trainor, 2010). For example, North American but not Turkish 4- to 8-month-olds prefer isochronous to non-isochronous meters (Soley & Hannon, 2010). Interestingly, both groups of infants also demonstrate some cultural generality, preferring either meter to an artificial meter that is not used in music from any culture.

3. Absolute-to-relative shifts in pitch perception

Pitch information can be processed in two different ways: absolutely and relatively. Absolute pitch processing focuses on the particular pitches that are heard, whereas relative pitch processing focuses on relations (intervals) between pairs of consecutive tones. To illustrate, the tune *Happy Birthday* can be played in a variety of musical keys (i.e., with a variety of starting notes). In each key, the actual tones differ but the melody retains its identity because the intervals between consecutive tones remain the same.

One view holds that an initial predisposition to process pitch absolutely is lost over development as listening experience increases and relative processing takes precedence (e.g., Takeuchi & Hulse, 1993). Research on nonhumans reveals that monkeys (e.g., D'Amato, 1988) and birds (e.g., Friedrich, Zentall, & Weisman, 2007) perceive pitch absolutely rather than relatively, suggesting a possible evolutionary ''default'' for absolute pitch processing. Additional evidence for this view comes from individuals with Absolute (or ''perfect'') Pitch proper, which refers to the rare ability to produce or identify a musical tone without reference to an external pitch. Absolute pitch is seen primarily among those who begin their music training by age 7 (Takeuchi & Hulse, 1993) and among individuals who speak tone languages (e.g., Deutsch, Henthorn, Marvin, & Xu, 2006), which implicates the importance of early and intensive focus on pitch information (i.e., a critical period) to maintain an absolute processing style (Trainor, 2005).

Evidence of a developmental shift from absolute to relative pitch processing (Saffran, 2003; Saffran & Griepentrog, 2001) appears to be contradicted, however, by evidence that (a) infants and children process pitch relatively, and (b) children and adults without music training process pitch absolutely. For example, infants are sensitive to pitch *contour*, the most basic dimension of relative pitch. A melody's contour refers to directional changes in the pitch between consecutive tones (upward, downward, or lateral). Contour is highly salient for listeners of all ages and cultures (for a review see Thompson & Schellenberg, 2006). Indeed, infants who fail to notice a change in the key of a melody sometimes notice a change in pitch contour (Trehub, Bull, & Thorpe, 1984). Infants can also detect a change in interval size between consecutive tones, even when the change does not alter the contour and the melodic stimuli are presented in transposition (i.e., at different pitch levels; Trainor & Trehub, 1993). Moreover, when infants are exposed to a melody for a week, they show a preference for a new melody (i.e., a change in relative pitch) but not for a change in pitch level (i.e., a change in absolute pitch; Plantinga & Trainor, 2005). Finally, at 5 years of age, children can explicitly identify the direction of a pitch change (i.e., *up* or *down*) even when the change is smaller than half a semitone (Stalinski, Schellenberg, & Trehub, 2008). Like adults, then, young listeners encode and store pitch relations in short- and long-term memory.

Moreover, when musically untrained adults are tested with ecologically valid auditory stimuli, they exhibit evidence of memory for specific pitches even though they cannot name particular tones or keys. For example, they sing well-known songs at close to the recorded pitch level (Levitin, 1994), they remember the pitch of the dial tone (Smith & Schmuckler, 2008), and they identify the original pitch of familiar recordings even when comparison recordings are shifted in pitch by only one or two semitones (Schellenberg & Trehub, 2003). Similar findings are evident among children, who remember the pitch of the theme songs from TV shows (Schellenberg & Trehub, 2008; Trehub, Schellenberg, & Nakata, 2008), and 6-month-olds, who remember the pitch of familiar lullabies (Volkova, Trehub, & Schellenberg, 2006). Thus, despite the proposed absolute-to-relative developmental trajectory, there is much evidence of absolute *and* relative pitch processing across the lifespan.

Recent findings help to reconcile this apparent discrepancy by providing evidence of both developmental change *and* developmental consistency in how pitch information is processed (Stalinski & Schellenberg, 2010). On each trial, adults and children between the ages of 5 and 12 heard two melodies and rated how similar they sounded. The second melody was identical to the first, a transposed version of the same melody (i.e., a change in absolute pitch), a different melody (i.e., a change in relative pitch), or a transposition of a different melody (i.e., a change in absolute *and* relative pitch). Listeners of all ages were able to identify changes in both pitch level and melody, providing evidence that children as well as adults are able to make use of both absolute and relative pitch information. As age increased, however, the importance of relative pitch information increased monotonically, while the importance of absolute pitch information decreased. It would be interesting to see if a similar absolute-to-relative trajectory is evident with temporal information. For example, tempo differences may be particularly salient for younger listeners, with differences in rhythms more salient among older listeners.

4. Emotional responding to music

People listen to music for a variety of emotional reasons, including catharsis, stress relief, and attempts to change their emotional state. Effects of music on emotion are apparent from an early age, with mothers across cultures singing to their infants in order to regulate mood and communicate emotion (e.g., Trehub & Trainor, 1998). Nevertheless, emotional responding to music differs between children and adults. Because actual emotional responding to music is mediated by listeners' perception of the emotions expressed by the music (Hunter, Schellenberg, & Schimmack, 2010), our discussion focuses on developmental differences in emotion perception.

Whereas infants as young as 5–7 months are just beginning to discriminate happy- from sad-sounding music (Flom, Gentile, & Pick, 2008), 3- to 4-year-olds can readily make this distinction (Kastner & Crowder, 1990), and 4-year-olds recognize happy-sounding music outright (Cunningham & Sterling, 1988). Recognition of other emotions, such as anger and fear, follows a more protracted developmental course (Dolgin & Adelson, 1990). Even adults are not perfectly accurate at identifying emotions in music that are easily confused (e.g., sadness and tenderness; Gabrielsson & Juslin, 1996).

One model (Russell, 1980) posits that emotions vary along two independent dimensions: arousal (level of activation) and valence (positive or negative). Two dimensions of music are closely related to these emotional dimensions, with tempo (fast or slow) being associated with arousal, and mode (major or minor) associated with valence (Husain, Thompson, & Schellenberg, 2002). Happy-sounding music tends to be composed with a fast tempo and in major mode, whereas sad-sounding music is typically slow and minor (Hunter & Schellenberg, 2010). Because happiness (high arousal, positive valence) and sadness (low arousal, negative valence) differ on both dimensions, they may be relatively easy to discriminate compared to other pairs of emotions, such as fear and anger, which are the same on both dimensions (high arousal, negative valence), or sadness and peacefulness (low arousal, positive valence), which differ on only one dimension.

Vieillard et al. (2008) developed a set of music excerpts in which arousal and valence vary in a factorial manner (happiness: high arousal, positive valence; fear: high arousal, negative valence; peacefulness: low arousal, positive valence; sadness: low arousal, negative valence). Although adults in their standardization sample were quite good at identifying the emotions expressed by these stimuli, happy-sounding excerpts were identified better than sad- or scary-sounding excerpts, and peaceful-sounding excerpts were the least successfully identified. Interestingly, when emotions were considered as a function of arousal and valence ratings, there was a clearer distinction between high- and low-arousal emotions than between positively and negatively valenced emotions, which implies that the arousal/tempo dimension may typically assume priority.

In line with this view, 4- and 5-year-olds tend use tempo cues when making judgments of emotionality in music, with mode cues becoming important later in development (Dalla Bella, Peretz, Rousseau, & Gosselin, 2001; Gregory, Worrall, & Sarge, 1996; Mote, 2011). Tempo cues also appear to be more universal because the distinction between major and minor modes is specific to Western music. Indeed, when asked to judge the emotion conveyed in foreign music (such that mode is irrelevant), adults use tempo as the basis for their judgments (Balkwill & Thompson, 1999).

Hunter, Schellenberg, and Stalinski (2011) examined emotion identification in music using a subset of the stimuli from Vieillard et al. (2008), specifically those that were the most easily identified by adults in a pilot study. Participants in the actual experiment included adults as well as 5-, 8-, and 11-year-old children. All listeners were better at identifying high- compared to low-arousal excerpts, but this bias was particularly pronounced for younger children. By 11 years of age, children were as accurate as adults. There was also a developmental change in liking for the different excerpts. Children from all three age groups preferred the high-arousal excerpts, whereas adults preferred the excerpts with positive valence. In other words, liking for music mirrors the tendency to focus on different musical characteristics at different points in development. Whereas emotional identification may be adult-like at age 11, liking for music that conveys emotions is not adult-like until later in development. More generally, developmental changes are evident not only in the basic perceptual and foundational characteristics of music but also in more complex factors, such as emotion perception and identification, and in music preferences.

5. Conclusions

Young infants have relatively sophisticated abilities to discriminate the subtle differences in pitch and time that characterize music. At the same time, cognitive and perceptual predispositions appear to influence the structure of music across cultures, including the number of tones per octave in musical scales, the use of unequal scale steps, the structural importance of consonant intervals, and the predominance of small intervals in melodies. Moving to music appears to be closely related to infants' precocious abilities with musical meter and rhythm.

Infants are born culture-free with respect to music. Over time, they learn the pitch and temporal structures in their native music environment, exhibiting enhanced processing and preferences for native over non-native musical patterns. Whereas some signs of enculturation are evident during the first year of life, other signs indicate that the enculturation process is not complete until sometime in the teenage years. The most protracted processes are those that are the most culture specific. In Western music, these include knowledge of tonality, harmony, and associating major and minor modes with emotions. The available data also indicate that musical pitch is processed both absolutely and relatively across the lifespan, with relative and absolute cues becoming more and less important, respectively, as the listener ages.

In sum, although there are a number of predispositions that aid in our initial attempts to process and understand music, the influence of our early listening experience, dictated by our cultural upbringing, becomes apparent very early in development. Developmental changes are evident not only at basic levels of processing, such as pitch and temporal perception, but also at more complex levels, such as the ability to identify emotion in music.

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