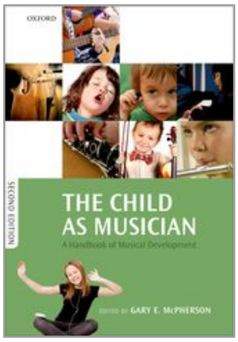

The Child as Musician: A handbook of musical development

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Print publication date: 2015
Print ISBN-13: 9780198744443
Published to Oxford Scholarship Online: November 2015
DOI: 10.1093/acprof:oso/9780198744443.001.0001

Music cognition in childhood

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DOI:10.1093/acprof:oso/9780198744443.003.0005

[–] Abstract and Keywords

This chapter examines the development of music perception and cognition during early and middle childhood. Although infants have fairly sophisticated musical abilities, it takes many years to acquire adult-like musical knowledge. Much of this development occurs early in life, when children accumulate informal listening experience with the music of their culture. With increasing musical experience and general cognitive development, children’s knowledge of culture-general aspects of musical structure improves. Even larger developmental changes are seen in their acquisition of culture-specific knowledge of pitch and temporal structures. In some cases, formal music training accelerates the development of culture-specific knowledge and improves explicit understanding of musical concepts. In other cases—such as perceiving emotion expressed musically—music training has little effect. Future research could include age groups (i.e., toddlers) and musical cultures (e.g., Chinese, Indian) that have been largely neglected to date.

Keywords: children, music perception, music cognition, music acquisition, enculturation, music training

Music cognition in childhood: Introduction

Music is ubiquitous in children’s lives. Caregivers sing lullabies to soothe their upset infants, and sing playsongs to create fun and excitement (Rock, Trainor, & Addison, 1999). Music is also used to teach concepts in daycares and school classrooms, and musical interludes are common in children’s television programming. Although it is clear that infants possess sophisticated musical knowledge (see Trehub & Degé, Chapter 2), such knowledge develops over many years (see Stalinski & Schellenberg, 2012; Trainor & Corrigall, 2010; Trainor & Hannon, 2013 for reviews). In this chapter, we focus on the acquisition of musical knowledge during early and middle childhood, when children become increasingly sophisticated at understanding aspects of musical structure that are common to all musical systems. This time in development is also important for musical *enculturation*: the acquisition of knowledge about structural aspects that are particular to a given musical system. Our focus is primarily on children's developing sensitivity to Western music (e.g., music that is prevalent in western Europe, Australia, and much of North America), because there is little research on musical development in non-Western cultures. As we will see, much of children's developing sensitivity to music is a consequence of informal listening experience and general cognitive development. In some instances, enriched musical experience through formal training accelerates the acquisition of musical knowledge and improves children's ability to demonstrate explicit knowledge of musical structure.

Acquisition of musical pitch structure

Much of the research on children's understanding of structure in music has focused on pitch. Some aspects of pitch perception are culture-general, such as the ability to process pitch in a relative way, sensitivity to melodic contour, and the expectation for subsequent notes in a melody to be proximate in pitch. These aspects are also acquired early in development. By contrast, other aspects of pitch structure are specific to Western music structure—such as sensitivity to key membership and harmony—and take years to develop.

Culture-general aspects of pitch processing: Absolute vs. relative pitch

Pitch information in melodies can be processed in two ways: in absolute pitch processing, the exact pitch level of each note is encoded and stored in memory; by contrast, relative pitch processing involves encoding and storing information about the *relations* between subsequent pitches in a melody. Although adults are likely to process melodic information according to both an absolute and a relative pitch code (e.g., Schellenberg, Stalinski, & Marks, 2014), relative pitch is typically more salient because it allows an individual to recognize the same tune presented at different pitch **(p.82)** levels (i.e., in different keys). Only a small minority of individuals—those with *absolute pitch*—can name an isolated tone without the help of a reference tone, produce the correct pitch of a musical tone (e.g., middle C), and retain an isolated pitch in memory for long durations even when interfering tones are heard in the interim (Ross et al., 2004; Takeuchi & Hulse, 1993). This rare ability appears to result from a genetic predisposition, early music training, and learning to speak a tone language (for reviews see Chin, 2003; Deutsch, 2013; Takeuchi & Hulse, 1993; Trainor, 2005; and Zatorre, 2003).

Some researchers suggest that infants and young children are biased toward processing pitch in absolute terms, whereas older children and adults are biased toward processing pitch in relative terms (Takeuchi & Hulse, 1993). For example, Sergeant and Roche (1973) found that 3- to 4-year-olds were more accurate than 6-year-olds at singing familiar melodies' absolute pitches, but worse at producing relational aspects of the melody, such as the correct intervals between subsequent notes and staying within a key. In another study, Stalinski and Schellenberg (2010) asked 5- to 12-year-olds and adults to rate how similar pairs of melodies sounded. Adults rated melodies that shared a relative pitch code as sounding more similar than melodies that had the exact same pitches but in a different order; 5- to 9-year-olds showed the opposite pattern. A similar focus on absolute pitch cues has also been reported in infants (Saffran, 2003; Saffran & Griepentrog, 2001; Volkova, Trehub, & Schellenberg, 2006). The results from these studies fit nicely with general theories of child development: across domains, with increases in age children focus less on concrete, surface-level features and more on abstract, relational features (e.g., Piaget, 1966; Vygotsky, 1934/86).

Other evidence suggests, however, that this developmental shift from absolute to relative pitch processing is oversimplified. First, adults retain some information about the absolute pitch level of previously unfamiliar melodies even after only two exposures (Schellenberg et al., 2014), and memory for key is especially long-lasting for recordings that are highly familiar and always heard in the same key (e.g., TV theme songs, pop songs; Levitin, 1994; Schellenberg & Trehub, 2003). Second, several studies have shown that 6- to 11-month-old infants exhibit relative pitch because they recognize a melody when it is transposed (Plantinga & Trainor, 2005; Schellenberg & Trehub, 1999; Trainor & Trehub, 1992; Trehub, Bull, & Thorpe, 1984), whereas memory for the absolute pitch of an isolated tone decays after a few seconds and is disrupted by tones heard in the interim, which implies that infants' absolute pitch processing abilities are not particularly precocious (Plantinga & Trainor, 2008). Moreover, 8-month-olds are able to use relative pitch cues when they are more informative than absolute pitch cues (Saffran et al., 2005). It appears, then, that infants are capable of flexibly using absolute or relative pitch cues depending on task demands and the structure of the stimulus.

Finally, evidence that young children preferentially process pitch according to an absolute pitch code is mixed. Although the results of Stalinski and Schellenberg (2010) suggest that 5- to 9-year-olds focus less on relative pitch cues than older children and adults, other evidence suggests that children's memory for the absolute pitch level of familiar songs is no better than that of adults. In some studies, children's memory for the key of familiar songs did not change from 5 to 10 years of age (Trehub, Schellenberg, & Nakata, 2008), or from 9 to 12 years of age (Schellenberg & Trehub, 2008). In a sample from Japan, however, *older* children remembered the pitch level of familiar songs better than their younger counterparts (Trehub, Schellenberg, & Nakata, 2008). Memory for the absolute pitch of familiar songs may be influenced by particular experiences, such as early experience with using consistent labels for specific pitches (as in a "fixed do" system). Although learning to speak a tone language improves the likelihood of developing absolute pitch (Deutsch et al., 2006), it has little effect on memory for the pitch level of recordings **(p.83)** (Schellenberg & Trehub, 2008). In sum, relative pitch processing becomes more salient with age, but listeners of *all* ages process pitch both absolutely and relatively.

Culture-general aspects of pitch processing: Melodic contour

Another culture-general aspect of melodic processing is pitch contour—whether successive notes go up in pitch, down in pitch, or stay the same. Sensitivity to contour requires understanding directional pitch changes without necessarily encoding specific pitch intervals (i.e., exact distances between tones). Knowledge of contour can be implicit or explicit. Studies that examine implicit knowledge of contour typically test whether listeners are better able to perceive a melodic change if it violates the contour than when it alters the melody's intervals but maintains the contour. Even 5- to 11-month-old infants are sensitive to changes in contour (Chang & Trehub, 1977a; Trehub, Bull, & Thorpe, 1984), as are 5- to 6-year-old children

(Morrongiello et al., 1985; Trehub, Morrongiello, & Thorpe, 1985). When asked to sing back a melody, young children between the ages of 3 and 5 are better at reproducing melodic contour than they are at producing exact pitches or intervals (Flowers & Dunne-Sousa, 1990). These kinds of processing biases suggest that contour may be one of the most basic and salient dimensions of melodic processing. Although musically trained children are better than untrained children at detecting contour-violating as well as contour-preserving changes in unfamiliar melodies (Morrongiello, Roes, & Donnelly, 1989), it is unclear whether music training actually improves such abilities. Children with naturally better listening skills may be more likely to take music lessons in the first place.

Explicit knowledge of contour requires listeners to identify pitch direction with verbal labels such as *up, down*, and *same*. Children who are able to demonstrate implicit knowledge of contour (e.g., 5- and 6-year-olds) do not necessarily associate terms such as *high*/*higher*/*up* and *low*/*lower*/*down* with pitches or pitch changes, and may describe pitch changes with terms such as *louder*/*softer* and *faster*/*slower* (e.g., Flowers & Costa-Giomi, 1991; Hair, 1981; Van Zee, 1976). Nevertheless, with extensive training (i.e., over several days), children as young as 5 years show improvements in their ability to describe pitch changes of sine tones (Soderquist & Moore, 1970). In fact, when Stalinski, Schellenberg, and Trehub (2008) used piano tones and only minimal training (a few minutes), 5-year-olds could identify whether the second of three notes went up or down in pitch even when the pitch change was less than a semitone.

Learning to associate pitch changes with *spatial* labels is likely to be a source of difficulty for young children. When French-speaking children are taught to label pitch changes either with spatial terms (*haut* and *bas*, equivalent to *high* and *low*), or with terms that specifically describe pitch (*aigu* and *grave*, no equivalent terms in English), those who are taught the music-specific terms perform better on subsequent pitch-direction tests than children who are taught spatial terms, which have multiple meanings (Costa-Giomi & Descombes, 1996). Thus, development of explicit knowledge of contour may differ across cultures because of language influences.

Culture-general aspects of pitch processing: Melodic expectations

Many years ago, Meyer (1956) proposed that expectations form the basis of emotional responses to music as well as the perception of musical meaning, a theory that was further elaborated by Huron (2006). Meyer argued that musical interest arises from the interplay between unexpected events that produce a feeling of tension and expected events that produce a feeling of relaxation. As such, expectations are fundamental to music appreciation and aesthetics.

Some of these musical expectations stem from culture-general grouping principles that are relevant in vision as well as audition. For example, across cultures and levels of music training, adults' **(p.84)** melodic expectations are influenced by two principles (Schellenberg, 1996, 1997): an expectation that subsequent tones will be close to the last tone heard in terms of pitch (pitch proximity), and an expectation for pitch to change direction, either toward the penultimate tone or after a large interval (pitch reversal). Although both of these principles are culture-general, expectations based on pitch reversal are more complex and take longer to develop because they are based on the interval size and contour of the two previous tones, whereas pitch-proximity expectations are based solely on the previous tone (Schellenberg et al., 2002). When Schellenberg et al. (2002) asked children and adults either to judge how well a test tone continued a melodic fragment, or to sing a continuation of a melody, even 5-year-olds expected the next tone to be proximate in pitch. By contrast, expectations based on pitch reversal became stronger with age. Pitch-reversal expectancies may emerge from accumulating exposure to music, as well as from developmental improvements in general cognitive capabilities (e.g., working memory). Children's ability to predict melodic patterns using culture-general principles may facilitate their later acquisition of culture-specific aspects of pitch processing, and the ability to interpret emotions expressed musically.

Culture-specific aspects of pitch processing: Enculturation to Western pitch structure

Musical systems differ across cultures in their use of different musical scales upon which pieces are based, such as the major and minor scales used in Western music (Huron, 2006; Schellenberg & von Scheve, 2012). Most scales are organized around a central reference tone, such as the *tonic* in Western music (i.e., *do* in moveable *do* systems), which also identifies the key of a piece. Knowledge of key membership involves understanding which notes from the chromatic scale belong in a key and which notes do not. Enculturated listeners also acquire sensitivity to the *tonal hierarchy*: the relative frequency, stability, and importance of each note in a scale. *Harmony* is an added dimension of complexity in pitch structure in Western music, but otherwise rare across cultures. Harmony refers to rules and conventions governing the simultaneous combinations of notes that form chords, and how one chord follows another. For enculturated listeners, harmonies are over-learned, such that they can be implied by a single-line melody (i.e., when they are not actually present). Children learn to form expectations based on tonality and harmony by accumulating listening experience with the music of their culture. One possible mechanism is that they implicitly track the statistical probabilities of certain notes and chords heard sequentially (McMullen Jonaitis & Saffran, 2009). For example, in Western music, a dominant-seventh chord near the end of the piece has a high probability of being followed by a tonic chord.

Implicit knowledge of key membership and harmony has been tested in different ways. Change-detection paradigms are based on the premise that culturally familiar pitch schemas facilitate the processing of musical structure, such that a change will be easier to detect if a pattern is typical rather than atypical of Western music. For example, 10- to 13-year-olds have more difficulty detecting mistunings in a melody when it is based on an unfamiliar Javanese pelog scale compared to when the melody is based on familiar major and minor Western scales (Lynch & Eilers, 1991). The advantage for the Western melodies is greater in musically trained than untrained children, which suggests that increased musical experience—whether from formal music instruction or because musically trained children also have more informal exposure to music—accelerates enculturation to musical pitch structure. Even children as young as 4 or 5 years old are better able to detect a semitone change to a melody based on the familiar major triad than to a melody based on less familiar augmented or diminished triads (Schellenberg & Trehub, 1999; Trehub et al., 1986).

(p.85) By contrast, 6- to 11-month-old infants detect changes to culturally typical and atypical melodies equally well because none is particularly familiar (Lynch et al., 1990; Schellenberg & Trehub, 1999; Trehub et al., 1986; Trehub, Schellenberg, & Kamenetsky, 1999). In general, infants' and young children's performance on change-detection tasks appears to be influenced primarily by culture-general factors, such as how simple the melodies are (e.g., with many repeated tones), rather than by culture-specific factors, although this pattern changes with increasing exposure to music (Schellenberg & Trehub, 1999). In some instances, however, evidence of the onset of enculturation to culture-typical pitch structures can be evident between 6 and 12 months of age (Cohen, Thorpe, & Trehub, 1987; Lynch & Eilers, 1992).

Trainor and Trehub (1994) found that 7-year-olds, like adults, perform equally well at detecting deviant notes in a melody that go outside the key or the implied harmony, but they have difficulty detecting changes that preserve both the key and the harmony. At 5 years of age, children detect only the changes that go outside the key, because unlike 7-year-olds and older listeners, they are not yet sensitive to harmonic relationships within a given key. At 8 months of age, infants detect both in-key and out-of-key changes equally well (Trainor & Trehub, 1992). In other words, enculturation to culture-specific pitch structures influences melody perception sometime between infancy and the preschool years (i.e., before 5 years of age), with additional exposure (from 5 to 7 years) having even greater influence.

Implicit knowledge of Western pitch structure can also be tested using reaction times. The rationale is that enculturated listeners will be slower to make speeded judgments and will make more errors about unexpected chords (those that violate key membership or harmony), even when the task involves unrelated questions such as whether a chord is played in one timbre or another (e.g., piano or trumpet). The method has been used extensively with adults (see Bigand & Poulin-Charronnat, 2006 for a review), but not frequently with children, most likely because of children's difficulty with making speeded judgments and completing many trials. In one instance, however, 6- to 11-year-olds had implicit knowledge of harmony, as evidenced by faster and more accurate judgments of a sung vowel, instrumental timbre, or consonance when the target chord was more stable in the key of the piece (i.e., the tonic rather than the sub-dominant; Schellenberg et al., 2005).

Production tasks can also reveal implicit knowledge of key membership and harmony, although it is difficult to know whether an inability to sing in key reflects a lack of knowledge, a lack of motivation to perform well, difficulty in controlling the motor movements of the vocal apparatus, or cognitive constraints such as memory limitations. Studies on children's singing accuracy also tend to lack controlled and objective measures (see Tsang, Friendly, & Trainor, 2011 for a review), which leads to results that are difficult to interpret. For example, one study found that 3- to 5-year-olds had difficulty maintaining a consistent key while singing (assessed by subjective ratings of tonality), but there was a non-significant trend for 4-year-olds to perform better than 5- and 3-year-olds (Flowers & Dunne-Sousa, 1990). Another study that also used a subjective rating scale found that fourth- and fifth-grade children were better at staying in key compared to third- and sixth-grade children (Mizener, 1993). Future studies could compare singing accuracy in tonal compared to atonal contexts to examine whether tonality influences performance accuracy, ideally using objective measures (e.g., by recording and measuring the exact pitches produced). Measures of motivation and cognitive ability could also be assessed to examine whether they influence performance.

Knowledge of Western pitch structures can also be examined using neurophysiological methods such as EEG, which measures ERPs. When Western adults hear a chord that violates the established key or the most expected harmony in a chord sequence, their brains respond differently **(p.86)** than when an expected chord occurs. Two specific brain responses are elicited in response to these violations (e.g., Koelsch et al., 2000, 2001; see Koelsch, 2009 for a review). One (the early right anterior negativity, or ERAN) is automatic because it is elicited even when listeners focus their attention on something other than the music (e.g., watching a silent film; Koelsch et al., 2001; Koelsch, Schröger, & Gunter, 2002), which makes it particularly useful for studying young children, who often have difficulty focusing on a task for long periods of time. The second brain response (the N5) differs because it is more influenced by attentional focus (e.g., Koelsch et al., 2000). Nevertheless, both brain responses are sensitive to the degree of harmonic violation, with larger responses elicited in response to stronger violations (e.g., Koelsch et al., 2000, 2003). In other words, brain-activation patterns tell us when listeners hear a chord that sounds wrong in a musical context, and even when they hear a chord that sounds particularly bad, but *not* whether "bad chords" are actually perceived as such.

The ERAN can be elicited in children as young as 5 years of age in response to strong violations of key structure (Koelsch et al., 2003) and to harmonic violations (Jentschke et al., 2008). The ERAN also tends to be larger in musically trained 11-year-olds compared to untrained children of the same age (Jentschke & Koelsch, 2009), which implies that it strengthens with additional exposure to Western music. But even an immature ERP response can be elicited in much younger children. Corrigall and Trainor (2014) examined 4-year-olds' and adults' ERP responses to violations of key membership and harmony in chord sequences. Among adults, the typical brain responses were elicited in both violation conditions. Among 4-year-olds, an immature brain response (an early *positivity*, thought to be an immature ERAN) was elicited in response to both kinds of violations. Other ERP responses also exhibit a developmental shift from an immature to a mature response during infancy (e.g., He, Hotson, & Trainor, 2009; Tew et al., 2009; Trainor et al., 2003). One goal for future research could be to examine at what age these components emerge in response to violations of key membership and harmony. Although one study reported that an immature early positivity response was elicited in 3-year-olds (Corrigall & Trainor, 2012), another study found that children as young as 2.5 years of age had brain responses comparable to those of adults (Jentschke, Friederici, & Koelsch, 2014). The apparent maturity of the brain response is likely to be influenced by individual differences in cognitive development and exposure to music, how strongly the stimuli establish harmonic expectations, and how strongly deviant chords violate those expectations.

Considered jointly, the results reviewed suggest that children do not become enculturated listeners until the preschool and school years, with the process beginning at around 3 or 4 years of age. There is some evidence, however, that active participation in music classes for infants between 6 and 12 months of age can accelerate the enculturation process (Gerry, Unrau, & Trainor, 2012; Trainor et al., 2012). Even infants who do not participate in any specialized music classes exhibit processing biases that provide the foundation for later acquisition of key membership and harmonic knowledge. For example, 9-month-olds' better processing of unequal-step scales compared to equal-step scales (Trehub et al., 1999) prepares them to learn the particular unequal-step scales of their culture. Moreover, infants' processing advantages and preferences for consonant intervals (related to harmonic relaxation) compared to dissonant intervals (related to harmonic tension) may form the basis for later harmony perception (Masataka, 2006; Schellenberg & Trehub, 1996a,b; Trainor & Heinmiller, 1998; Trainor, Tsang,

& Cheung, 2002; Zentner & Kagan, 1998; but see Plantinga & Trehub, 2014). Finally, infants' and children's ability to process pitch relatively allows them to understand and attend to pitch patterns rather than absolute frequencies, abilities that are essential for the acquisition of abstract knowledge of key membership.

As with sensitivity to other musical aspects such as contour, explicit knowledge of key membership and harmony takes longer to develop than implicit knowledge. Explicit knowledge is **(p.87)** usually tested by judging how well particular notes and chords continue a particular melody or chord sequence, how good a melody sounds, or whether music is played correctly or incorrectly. Western adults show a reliable pattern of rating in-key notes and chords higher than out-of-key notes and chords, but they also differentiate between notes and chords within a given key by providing the highest rating to the tonic (based on the first note of the scale) and the second highest rating to the dominant (the fifth note; Cuddy & Badertscher, 1987; Krumhansl, 1990; see Krumhansl & Cuddy, 2010 for a review). When rating tasks are simplified to be appropriate for children, similar but cruder patterns emerge by around 6 years of age (Cuddy & Badertscher, 1987; Speer & Meeks, 1985), with continued development between 6 and 11 years of age (Costa-Giomi, 2003; Krumhansl & Keil, 1982; Lamont & Cross, 1994).

Rating scales are difficult for preschoolers because they require them to keep track of several points at once, which taxes young children's memory and attentional capacity. Age-appropriate methods designed to be engaging for young children allowed Corrigall and Trainor (2014) to assess 4- and 5-year-olds' explicit knowledge of Western pitch structure, in the context of both melodies and chord sequences. Four- and 5-year-olds watched videos of pairs of puppets playing the piano. One puppet played an unfamiliar but typical Western melody or chord sequence; the other puppet played an identical sequence with one violation (Corrigall & Trainor, 2014). Children awarded a prize to the puppet that played the best song, and their tendency to award the puppet that played the "correct" song was assessed. Five-year-olds were sensitive to key membership in both melodies and chord sequences, but they were not yet sensitive to harmonic violations (those that remained in key but were not the highly expected tonic). Four-year-olds failed to show sensitivity to either type of violation despite evidence that they understood the task. When tested with a *familiar* song, however, even 4-year-olds could identify when the melody alone, the melody accompanied by chords, or the chords alone were played correctly (Corrigall & Trainor, 2010). As one would expect, formal music training enhances children's explicit knowledge of pitch structures (Corrigall & Trainor, 2009; Lamont, 1998).

Findings from implicit and explicit tests of enculturation to Western pitch structures allow for several conclusions: 1) sensitivity to key membership and harmony takes many years to become adult-like; 2) knowledge of key membership develops before knowledge of harmony; 3) implicit knowledge of pitch structures develops before explicit knowledge; and 4) children demonstrate explicit knowledge of the pitch structure of familiar songs before they do so with unfamiliar songs. Future research could examine in greater detail how listening experience and general cognitive abilities influence the enculturation process. Although Corrigall and Trainor (2014) found that there was no association between children's scores on a short-term memory task and their performance on the test of explicit knowledge of Western pitch structure, other measures of cognitive functioning could be measured, such as attention. The same researchers also found that girls, who were more likely to have taken early informal music or dance classes, performed better than boys on the music task, but the role of listening experience has yet to be tested directly. To our knowledge, moreover, there is no published research on children's understanding of pitch structure in the context of the *minor* mode. This would be a particularly interesting avenue to pursue because the use of minor mode in popular music has increased dramatically since the 1960s (Schellenberg & von Scheve, 2012).

Acquisition of the temporal structure of music

The temporal structure of music includes *rhythm*, which refers to the sequence of sound events and silence, and *meter*, which refers to the underlying alternation of strong and weak beats. Meter **(p.88)** must be abstracted from the rhythmic structure because it is not always present in the physical stimulus (Lerdahl & Jackendoff, 1983). Rhythm and meter may be the most fundamental aspects of music because some musical genres (e.g., drum circles) do not exhibit pitch patterning, and because adults readily entrain—or synchronize their movements—to the musical beat (Iversen & Patel, 2008; Repp & Su, 2013). Despite its importance in the experience of music, very little research has been conducted on children's temporal perception and production abilities. One challenge is to develop tasks that are engaging and age-appropriate, avoiding those that rely on sophisticated motor responses, such as the ability to tap along to music.

Culture-general aspects of temporal processing

Implicit measures reveal that 2- to 5-month-old infants discriminate two simple rhythms (Chang & Trehub, 1977b; Demany, McKenzie, & Vurpillot, 1977), and that 7- to 9-month-olds recognize rhythmic patterns even when the tempo and key are varied (Trehub & Thorpe, 1989). As with pitch processing, there are several aspects of temporal processing that may be universal. Drake and Bertrand (2001) proposed five such aspects, which should be evident early in development.

The first proposed universal involves rhythmic grouping. Similarities based on pitch and timbre or temporal proximity allow listeners to perceive musical phrases as well as the break between phrases (Drake & Bertrand, 2001). For example, the last note of a phrase is typically longer in duration than earlier notes. Even 4- to 9-month-old infants appear to group musical phrases similarly to adults (Krumhansl & Jusczyk, 1990; Thorpe & Trehub, 1989; Trainor & Adams, 2000), at least implicitly. There is little to no research on preschoolers' and school-aged children's knowledge of grouping structure, however, and the acquisition of explicit knowledge is likely to follow a protracted developmental trajectory.

A second proposed temporal universal is that the more regular a rhythmic sequence is, the easier it is to process, and that our perceptual systems tend to regularize irregular temporal intervals if they fall within a given window of tolerance (Drake & Bertrand, 2001). Regularity refers to the duration of each temporal interval in a sequence. A completely regular sequence is entirely isochronous, with all note durations identical, whereas a highly irregular sequence comprises many different durations. Regular sequences may also comprise binary subdivisions and multiples of a regular beat, which correspond to the use of eighth notes, quarter notes, half notes, and so on. Five- to 7-year-olds are more accurate at tapping regular sequences than less regular sequences (Drake & Gérard, 1989); when asked to reproduce irregular sequences, they tend to distort temporal intervals toward a more regular pattern.

The third temporal processing universal concerns metrical rather than rhythmic processing. Drake and Bertrand (2001) proposed that we actively search for a regular pulse (the musical beat), and we use this organization to facilitate processing of other aspects of the sequence. Research using both electrophysiological measures (Winkler et al., 2009) as well as behavioral measures (Bergeson & Trehub, 2006; Patel et al., 2011) suggests that even infants perceive the beat in music from the time they are born. In fact, beat *perception* may be one of the most fundamental musical processing abilities, even though the ability to synchronize to a beat takes much longer to develop. For example, infants and toddlers under the age of 4 years do not usually synchronize their sucking rate or their body movements with an auditory beat (Bobin-Bègue et al., 2006; Eerola, Luck, & Toiviainen, 2006; Zentner & Eerola, 2010), although they move more rhythmically to music (or isochronous drum beats) compared to speech (Zentner & Eerola, 2010), and they adjust their movements if the tempo changes (Bobin-Bègue et al., 2006; Zentner & Eerola, 2010).

(p.89) Preschoolers and toddlers as young as 2 years of age can synchronize to a beat if it matches their *spontaneous motor tempo*—the tempo at which they are most comfortable moving to periodically—but they have difficulty if the beat is slower or faster (Drake, Jones, & Baruch, 2000; Provasi & Bobin-Bègue, 2003). This finding is in line with Drake and Bertrand's (2001) fourth proposed universal, which suggests that processing is best at an intermediate or preferred tempo compared to tempi that are too slow or too fast. Young children have a faster preferred tempo than adults, corresponding to around 140–150 and 100 beats per minute, respectively (e.g., Drake, Jones, & Baruch, 2000; Eerola, Luck, & Toiviainen, 2006; Fitzpatrick, Schmidt, & Lockman, 1996; McAuley et al., 2006; Provasi & Bobin-Bègue, 2003). With age, children's preferred tempo slows down and they become better at synchronizing with a wide range of tempi, due to improvements in cognitive processing (e.g., attention and working memory), motor control, coordination, and planning (Drake, Jones, & Baruch, 2000). Music training improves beat-keeping abilities (Slater, Tierney, & Kraus, 2013), which implicates a role for experience. Finally, 2- to 4-year-old children demonstrate more accurate auditory–motor synchronization abilities when they drum along with a human social partner compared to drumming along with an auditory beat alone or with a robot-like drum machine that provides visual cues (Kirschner & Tomasello, 2009). Two-year-olds can also synchronize with a beat outside their preferred tempo range if they drum along with a social partner (Kirschner & Tomasello, 2009). In other words, the social context plays a role in the motivation and ability to move in synchrony with music.

Drake and Bertrand (2001) proposed a fifth processing bias based on duration ratios, with better processing of binary ratios, in which one temporal interval is twice as long as another, compared to ternary or more complex ratios. For example, 5- and 7-year-olds are quite good at reproducing simple rhythms based on a binary subdivision of the beat (e.g., 2/4 time), but not at rhythms based on a ternary subdivision (e.g., 6/8 time; Drake, 1993). Recent research suggests, however, that this finding may reflect enculturation to Western metrical structures rather than a universal processing bias (Hannon & Trehub, 2005a).

Culture-specific aspects of temporal processing: Enculturation to Western metrical structure

As listeners acquire knowledge of the pitch structure of their culture's music, they also learn about typical metrical structures. In Western cultures, simple isochronous structures dominate, with accented beats occurring every two or (less commonly) three beats and at regular intervals. In other musical systems (e.g., from parts of South Asia, Africa, the Middle East, and parts of southeastern Europe), complex, non-isochronous meters are common, with accented beats occurring periodically but not at regularly spaced intervals. For example, a complex meter might include two accented beats of unequal length per measure, in which the first beat is subdivided into two but the second beat is subdivided into three, such as in 5/4 time. Although complex meters are difficult for Western adults to perceive or reproduce, adults from cultures that frequently use complex meters show equivalent abilities with simple and complex meters (Hannon & Trehub, 2005a; Snyder et al., 2006).

Implicit knowledge of culture-specific meters develops rapidly during infancy. Hannon and Trehub (2005a,b) created different versions of musical pieces composed in either simple or complex meters. Deviants either changed the surface rhythm but preserved the metrical structure, or changed the rhythm *and* the meter. North American 6-month-olds detected meter-disrupting changes just as easily in simple meters as in complex meters (Hannon & Trehub, 2005a), whereas 12-month-olds exhibited a processing advantage for simple metrical structures that typify most **(p.90)** Western music (Hannon & Trehub, 2005b). Moreover, North American 4- to 8-month-olds *prefer* to listen to simple meters compared to complex meters, but Turkish infants—who are exposed to both kinds of metrical structure—exhibit no such preference (Soley & Hannon, 2010). These findings are inconsistent with Drake and Bertrand's (2001) proposal that simple duration ratios are inherently easier to process than complex duration ratios. Rather, they suggest that infants are born equally ready to process either type of meter, and that perceptual specialization for culture-specific meters begins during the first year of life. Nevertheless, there are constraints on how well young infants process very complex meters. For example, 5-month-olds who notice metrical disruptions in simple and complex meters fail to do so with highly complex meters that are not used in music from *any* culture (Hannon, Soley, & Levine, 2011). Moreover, both North American and Turkish infants prefer to listen to simple or complex meters compared to artificial, highly complex meters (Soley & Hannon, 2010). Thus, although there is a processing bias for simple ratios to some degree, young listeners readily learn meters that are actually used in the music they hear.

Measures of enculturation to metrical structure in infancy examine implicit knowledge, such as the type revealed by processing biases. Very little research has been done on preschool- and school-aged children's ability to make explicit perceptual judgments about the musical beat in culturally familiar or unfamiliar contexts. In a notable exception, Einarson and Trainor (2015a,b) adapted Iversen and Patel's (2008) Beat Alignment Task for children, using videos of puppets similar to those developed by Corrigall and Trainor (2014). North American 5-year-olds watched pairs of videos in which one puppet drummed along with the beat, but the other puppet drummed too fast or too slow (i.e., at a different tempo than the musical beat), or too early or too late (i.e., out of phase from the musical beat). Children were asked to award a prize to the puppet that drummed better, and performance was compared between excerpts that were composed in simple or complex meters. The drumming had no intensity accents, being comprised solely of isochronous woodblock taps in both simple and complex meters. Five-year-olds performed at chance at choosing the puppet that drummed better in the context of complex meters, but they were significantly above chance levels in the context of simple meters.

Although implicit measures reveal enculturation to musical meter during the first year of life (Hannon, Soley, & Levine, 2011; Hannon & Trehub, 2005a,b; Soley & Hannon, 2010), it is unknown whether *explicit* judgments of beat perception would show a bias for simple meters in children younger than 5 years. Moreover, beat perception has yet to be examined in children from cultures with musical systems that frequently use complex meters. Both of these questions would help to determine the role of experience in the development of meter perception. Evidence of a sensitive period for the perception of meter implies that experience with different metrical structures plays a greater role during early compared to later stages of development. For example, when Hannon and Trehub (2005b) provided North American 12-month-olds and adults with one to two weeks of exposure to music with complex meters, 12-month-olds regained their ability to notice meter-disrupting changes in complex metrical structures, but adults did not. Similarly, after two weeks of exposure to music composed in complex meters, North American 5-, 7-, and 9-year-olds showed a reduction in their bias for simple meters, but 11-year-olds and adults did not (Hannon, Vanden Bosch der Nederlanden, & Tichko, 2012). In short, experience with music plays a particularly important role during infancy and early childhood.

Development of sensitivity to musical emotion

People choose to listen to music in order to experience and regulate emotions, and because listening to music is enjoyable (Juslin & Laukka, 2004). Meyer (1956), and later Huron (2006), **(p.91)** proposed that expectations are central to the experience of musical emotion. Because enculturation plays a role in the development of musical knowledge and expectations (see Hannon & Trainor, 2007 for a review), it is reasonable to ask whether young children perceive and experience musical emotion in the same way as adults do, even though they may not possess the same degree of culture-specific musical knowledge. To date, research has focused largely on children's *perception* of emotions expressed through music rather than on their actual emotional responses.

Nevertheless, the experience *and* perception of emotion begin in infancy. For example, infant- and child-directed speech—with exaggerated pitch contours, a higher overall pitch, and a slower rate—is essentially *musical* speech (e.g., Trainor et al., 1997), which communicates emotion and promotes infant–caregiver bonding (e.g., Trainor, 1996; Trehub & Trainor, 1998). Moreover, 6-month-old infants respond differently to lullabies compared to playsongs (Rock, Trainor, & Addison, 1999), and music listening affects infants' arousal levels during the first year of life (Schmidt, Trainor, & Santesso, 2003). Although it remains unclear whether infants perceive the positive or negative emotional valence of music, in some cases they associate an emotion expressed through music with its concordant facial expression (Nawrot, 2003).

Culture-general cues to emotion

Because infants and young children are generally not yet sensitive to many culture-specific aspects of musical structure, they use different cues to emotion compared to fully enculturated adults. In real music, a wide variety of culture-general and culture-specific cues to emotion are incorporated. For example, tempo is a culture-general cue: a fast tempo is typically associated with high arousal, whereas a slow tempo is associated with low arousal. By contrast, mode is a culture-specific cue: in Western music, major mode is a cue to positive valence, whereas minor mode is a cue to negative valence. Among adults, cues to musical emotions tend to be perceived in an additive and probabilistic manner (Juslin & Laukka, 2003). Among children, culture-general cues are often sufficient for them to decode emotions that are not subtle or nuanced. For example, even 4- or 5-year-olds identify certain emotions (such as happiness) when real music is used instead of experimentally controlled stimuli (e.g., Cunningham & Sterling, 1988; Doherty et al., 1999; Dolgin & Adelson, 1990; Terwogt & van Grinsven, 1991). Children have more difficulty than adults, however, at identifying other emotions such as fear and anger (e.g., Brosgole & Weisman, 1995; Dolgin & Adelson, 1990; Robazza, Macaluso, & D'Urso, 1994; Terwogt & van Grinsven, 1991), presumably because fear and anger are both high-arousal emotions with negative valence.

Most research on children's perception of emotion in music examines explicit knowledge by asking children to identify the emotion expressed by a short piece of music. Emotion perception can also be measured implicitly, such as when 5- to 6-year-olds' interpretation of an emotionally neutral story is influenced by prior listening to happy- or sad-sounding music (Ziv & Goshen, 2006). This finding implies that children spontaneously perceive the emotional tone of music even when they are not asked about it directly. Children also use *nonmusical* cues to interpret the emotional content of music. For example, when 7- and 8-year-olds perform a happy or sad dance to emotionally ambiguous music, they tend to interpret the emotional content of the music such that it matches their expressive body movements (Maes & Leman, 2013). Under some circumstances, nonmusical cues are actually more influential than musical cues. For example, children have a difficult time ignoring the emotional content of lyrics when asked to identify the emotion expressed by music (Morton & Trehub, 2007).

Other research has tried to pinpoint which cues to emotion children use at different ages. One common finding is that 4- and 5-year-olds rely primarily on tempo to identify the emotion **(p.92)** expressed by music, associating a fast tempo with happiness and a slow tempo with sadness (Dalla Bella et al., 2001; Dolgin & Adelson, 1990; Mote, 2011). Even older children (6–12 years) rely more on culture-general than culture-specific cues when making emotional judgments about music (Kratus, 1993), associating excitement with high rhythmic activity and a triple meter, and calmness with low rhythmic activity and a duple meter. They also associate happiness with high rhythmic activity and the use of staccato notes, and sadness with low rhythmic activity and legato notes.

Children also rely on culture-general cues when they are asked to express emotions by singing. For example, 4- to 12-year-olds convey happiness with a faster tempo, a louder singing voice, and a higher overall pitch, but sadness with a slower tempo, a softer singing voice, and a lower overall pitch (Adachi & Trehub, 1998). One interesting finding is that 8- to 10-year-olds are more accurate than adults at perceiving the intended emotion conveyed by their same-aged peers' singing (Adachi & Trehub, 2000; Adachi, Trehub, & Abe, 2004). Presumably, adults focus on culture-specific cues when judging children's expressed emotion through song, even when these cues are unreliable.

One study examined the degree to which adults and 5-, 8-, and 11-year-old children like excerpts of music that convey happiness, peacefulness, fear, and sadness, and how well the listeners could identify the intended emotion (Hunter, Schellenberg, & Stalinski, 2011). The design allowed the researchers to examine the effect of arousal (high or low) as well as valence (positive or negative) on listeners' responses. All age groups were better at identifying high-arousal (i.e., happiness and fear) than low-arousal (i.e., peacefulness and sadness) emotions, but this difference was exaggerated in the younger age groups compared to 11-year-olds and adults. Again, this finding highlights younger children's reliance on tempo as a cue to emotion, because tempo is linked with arousal (faster tempo = higher levels of arousal). Children of all ages also showed greater liking for high-arousal compared to low-arousal excerpts, whereas adults preferred excerpts that conveyed positive (i.e., happiness and peacefulness) rather than negative (i.e., fear and sadness) emotions. In short, culture-general cues such as tempo influence children's perception of musical emotions as well as their music preferences, even during late childhood.

Culture-specific cues to emotion and the role of experience

As children accumulate listening experience, they become increasingly sensitive to culture-specific cues in the identification of musical emotions. By 6 to 8 years of age, children associate the major mode with happiness and the minor mode with sadness (Dalla Bella et al., 2001; Gerardi & Gerken, 1995; Gregory, Worrall, & Sarge, 1996), although younger children may make this link under certain circumstances (Kastner & Crowder, 1990). Because of the long developmental trajectory to acquire knowledge of tonality and harmony (e.g., Costa-Giomi, 2003; Krumhansl & Keil, 1982; Lamont & Cross, 1994), it is unsurprising that children begin to use mode as a cue to emotion during middle childhood.

In many instances, girls outperform boys at the identification of emotions conveyed through music (Cunningham & Sterling, 1988; Giomo, 1993; Hunter et al., 2011; Terwogt & van Grinsven, 1991). One possibility is that girls' better verbal ability (e.g., Fenson et al., 1994) positively influences their performance on emotion-identification tasks. Another possibility is that girls are better at emotion perception in general (e.g., McClure, 2000). A third possibility is that girls accumulate more informal and formal experience with music (e.g., Corrigall & Trainor, 2014), which may enhance their ability to identify musical emotions, at least during childhood.

Despite their superior music-cognition abilities, musically trained children do *not* typically outperform untrained children at the identification of emotions expressed through music **(p.93)** (Adachi, Trehub, & Abe, 2004; Robazza, Macaluso, & D'Urso, 1994; Terwogt & van Grinsven, 1991). In some instances, musically trained children have an advantage (Yong & McBride-Chang, 2007); in others, they have a disadvantage (Giomo, 1993). Because even young children can sometimes identify the emotion expressed through music using culture-general cues alone (Cunningham & Sterling, 1988; Dolgin & Adelson, 1990; Terwogt & van Grinsven, 1991), music training may enhance children's sensitivity to culture-specific cues to emotion, which are not always necessary. In fact, cross-cultural research suggests that both children and adults are relatively accurate at identifying the emotion expressed in an unfamiliar culture's music (Adachi, Trehub, & Abe, 2004; Balkwill & Thompson, 1999; Balkwill, Thompson, & Matsunaga, 2004; Fritz et al., 2009), which implies that culture-general cues are sufficient for the most part. Note, however, that research on the perception of emotions expressed musically typically focuses on the identification of basic emotions (e.g., happiness, sadness, fear), using excerpts that clearly express a particular emotion. One avenue for future research would be to examine the effect of development, cultural familiarity, and music training on the perception of more subtle expressions of emotion in music, or on the perception of so-called aesthetic emotions (e.g., wonder, nostalgia; Zentner, Grandjean, & Scherer, 2008).

Conclusions

Several themes emerge when reviewing the literature on the development of music cognition. First, the use of ecologically valid stimuli—materials that approximate what is found in the real world, such as piano tones rather than sine tones, or real music rather than highly controlled, experimentally created stimuli—typically leads to better performance. As such, there is often a trade-off between stimulus control and ecological validity. Second, children have limited cognitive skills such as shorter attention spans and smaller memory capacities, which make it difficult to study their actual knowledge (i.e., competence) rather than their ability to perform a task on a given day. In order to maximize performance, these limitations can be taken into account by designing engaging and child-friendly tasks, limiting the number of trials that children are required to complete, providing feedback on each trial, keeping instructions simple, and limiting the number of response options that children are offered (e.g., two alternatives rather than a more complex rating scale). Finally, infants and children often reveal knowledge through implicit tasks before they can show explicit knowledge of the same concept.

Research on the development of music perception and cognition is still in its infancy, and some areas remain virtually unexplored. For example, although a good deal of research has been conducted with infants under 12 months, and with children 4 years of age and older, toddlers' music abilities are undocumented for the most part. This gap in the literature is likely due to difficulties in designing procedures that are age-appropriate, a limitation that future research could attempt to resolve. Another area of research that has received little attention is cross-cultural comparisons of children's musical knowledge. Pitch and metrical structures differ across cultures, but our knowledge of children's enculturation to these aspects of music structure comes primarily from children raised in Western cultures. Finally, more research is needed to obtain a better understanding of how music perception and cognition develop naturally during childhood. This knowledge also has potential practical applications, such as helping music educators to design music lessons that build on children's existing skills, although many laboratory-based studies do not have pedagogical implications for real-world settings.

Infants are born with abilities that allow them to acquire musical knowledge (see Trehub & Degé, Chapter 2). They show sensitivity to relative pitch, melodic contour, and musical meter, **(p.94)** which provide the foundation for developing more sophisticated skills. In particular, these early processing biases pave the way for the acquisition of culture-specific knowledge such as harmony perception and the ability to move to the beat of music. Enculturation happens primarily during early and middle childhood as cognitive abilities improve. With the accumulation of listening experience, children gain a better understanding of the structure of their culture's music, as well as its emotional content and meaning.

Author note

Preparation of this chapter was assisted with funding from the Natural Sciences and Engineering Research Council of Canada and from the Social Sciences and Humanities Research Council of Canada.

Reflective questions

1 Western music is based on either the major or the minor mode. When do children acquire sensitivity to the minor mode?

2 What are the relative contributions of informal musical experience and general cognitive development to the acquisition of musical knowledge?

3 What can we conclude about children's musical knowledge when there is a discrepancy between their performance on implicit compared to explicit measures?

4 What aspects of musical knowledge are acquired during the toddler years?

5 When and how do children in non-Western cultures acquire sensitivity to aspects of their culture's musical system?

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