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The Oxford Handbook of

Music Psychology

Edited by
Susan Hallam,
Ian Cross
and
Michael Thaut

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Contents

CHAPTER 2

Universals in music processing

Catherine Stevens and Tim Byron

Introduction and definitions

In this chapter we outline areas of musical processing that may be universal to humans. Music here refers to temporally structured human activities, social and individual, in the production and perception of sound organized in patterns that convey non-linguistic meaning. Music processing refers to the neural contribution in perception, cognition and production of music.

A universal in a domain of human activity such as music implies a static feature of a static environment. Not surprisingly, many ethnomusicologists have railed against a search for similarities at the expense of informative differences, and there is a logical problem with documenting definitive generalities rather than particular instances. The approach adopted here is to emphasize musical processing over content and discuss the psychological processes implicated in understanding and engaging in musical behaviour rather than the content of musical knowledge or action (cf. Harwood 1976; Meyer 1960). Our focus is on the principles by which the brain processes features of musical environments.

To call a process involved in the perception, cognition or production of music 'universal' does not necessarily mean that the process is found in all humans. When we refer to universality, we are using Nettl's (2005) concept of 'statistical universals'. Statistically universal music processing is universal to the great majority of adult humans and cultures. However, there may be statistical outliers—which may take the form of all participants in a particular culture (see Everett [2005] for a culture that may be a statistical outlier in the field of linguistics). Additionally, some people may belong to a different statistical population; for example, those who have been described as having congenital amusia or infants who, for example, lack higher-order cognitive processes not developed until later in life.

Experimental studies of music cognition tend to focus on psychophysical features of Western post-Renaissance tonal music, and samples of participants from a restricted range of countries and cultures. Additionally, most experiments treat music as a purely auditory event and assume implicitly that the use of music in other cultures is similar to the use of music in Western cultures. Both assumptions are inaccurate. Vocal and instrumental music is also visual, motoric and kinaesthetic. All of the arts—oral literature/song poetry, visual arts and performing arts—are integrated, for example, in Australian Aboriginal song (Ellis 1984).

The universal music processes discussed here are hypotheses that require investigation and falsification in as many and varied cultural contexts as possible. The discussion begins with processes of grouping and segmentation, then statistically universal features of musical environments, and finally more general-purpose psychological processes. We illustrate some processes drawing on examples of production of song from particular Australian Aboriginal cultures.

Perceptual principles of grouping and segmentation

The perceptual organization principles of grouping by proximity, similarity, common fate, good continuation, and figure-ground, which appear to operate in the early stages of music perception (Deutsch 1999; Handel 1984; Trehub and Hannon 2006) are candidates for universals in music processing. Perceptual organization of this kind can be demonstrated in very young animals; general grouping rules override learned knowledge about the shape of objects. For example, in visual perception, camouflage exploits this principle (Bregman 1990). Auditory grouping processes are thought to (a) organize acoustic information into music events (simultaneous grouping); (b) connect events into musical streams (sequential grouping); and (c) chunk event streams into musical units (segmentational grouping). These perceptual processes develop earlier than knowledge about the meaning of the events that have been grouped together (McAdams 1989). The suggestion is that these processes may be a basic property of the mammalian nervous system, and thus a likely contender for a universal in music processing.

At the level of sequential grouping, there are several processes which contribute to the perception of grouping. A sequence of tones is perceived as a group or stream when the pitch distance between temporally adjacent tones is small (pitch proximity); tones with distant pitches are segregated into separate streams (Bregman 1990). Whether events are perceived as a group or stream is also influenced by timbre similarity, grouping by temporal proximity, grouping by good continuation, and grouping by amplitude similarity (Deutsch 1999). At the level of segmentational grouping, we may have a universal preference for musical elements that are grouped correctly, though what is defined as correct grouping may be culture-dependent. Experiments investigating segmentation of Western tonal music in 6- and 4½-month-old infants have shown that infants prefer correctly segmented pieces with relatively long notes and downward pitch contours, over incorrectly segmented pieces (e.g. Krumhansl and Jusczyk 1990; see also Nan *et al.* 2006). Infants' correct segmentation of music may occur because music bears a structural resemblance to speech, which infants have learned through exposure, and/or because downward contours and extended durations naturally mark the end of all auditory signals (Thompson and Schellenberg 2006). Grouping principles could be investigated in broader musical contexts. However, that they work from the bottom up suggests that such processes are universal. Grouping likely aids encoding and storage in memory, enables an understanding of new material, and facilitates transmission to others.

The processing of melodic contour, the ups and downs in pitch of a melody, has the hallmarks of universality. It has been argued that efficient computational recognition of melodies uses melodic contour as chunks (Trehub 2000), and it appears that the rises and falls of a melody are part of the framework by which working memory processes melody. An ability to discriminate between short melodies on the basis of melodic contour is present in Western infants (e.g. Jusczyk and Krumhansl 1993) and adults (e.g. Dowling 1978), and may share cognitive resources with the processing of prosodic information (Patel *et al.* 1998). Ethnomusicologists have used different melodic contour shapes (for example, arch shapes) to categorize different kinds of melodies from a culture into different kinds of song (e.g. Kolinski 1970), and to compare cultures based on their use of different kinds of melodic contours (Lomax 1968). In an exploratory ethnomusicological study by Arom and Fürniss (1993) Aka Pygmy musicians were reported to be able to discriminate between melodies on the basis of melodic contour. As the processing of melodic contour appears to be present in Western infants and adults, and can be used to distinguish music by different cultures, insofar as melody is universal, it is likely that the processing of melodic contour in memory is universal.

Features of musical environments and perceptual and cognitive constraints

Most discussions of universals in music from a psychological perspective consider the limits imposed by human perceptual and cognitive processes. The constraints that recur in the literature suggest consensus. However, results on which these accounts are based emanate, in the main, from psychophysical studies involving culturally narrow samples. Regarding pitch first and then time, patterns in musical environments related to human perceptual and cognitive limits that await further cross-cultural scrutiny include the following.

1 Perceptual fusion of harmonic spectra into pitches (Justus and Bharucha 2002).

2 The use of discrete pitch levels (Burns 1999).

3 The semitone as the smallest viable interval. As a semitone is six times larger than the smallest interval that most listeners are able to discriminate (McAdams 1989), human working memory and production limits rather than perceptual discrimination are likely to constrain retention of music constructed from finer-grained musical scales.

4 Musical scales with differently sized steps between consecutive tones. Unequal steps may confer a psychological advantage, allowing tones to have different functions within the scale, such as a reference tone (Balzano 1980).

5 The prevalence of small integer frequency ratios[1] possibly because of their efficiency in auditory perception, i.e., they facilitate encoding, retention of melodies, and enable detection of subtle violations (e.g. Schellenberg and Trehub 1996; but see Balzano 1982 for an alternative view). Such ratios apply not only to fundamental frequencies but also within spectra (Sethares 1998; Tenney 1988).

6 Tones and melodies that are separated by an octave being perceived as similar (Wright *et al.* 2000) although Carterette and Kendall (1999) note that the effect is subtle. The prevalence of octaves in the auditory environment is one possible explanation (Schwartz *et al.* 2003; Trainor 2006); a physiological basis is also debated (Burns 1999).

7 Perception of rhythmic groups of up to 5 seconds in duration—the approximate limit of auditory sensory memory (Darwin *et al.* 1972)—where inter-onset intervals are between 100 and 1500 ms; see Cowan (1984) for the limit exceeding 5 seconds.

8 A regular beat or periodic pulse that affords temporal coordination between performers and elicits a synchronized motor response from listeners (Drake and Bertrand 2001). Importantly, the concept and experience of beat may vary across cultures (Iyer 1998; Stobart and Cross 2000).

9 Small-integer ratios of durations being easier to process than more complex rhythms (Drake and Bertrand 2001). Regular rhythmic patterns may facilitate encoding and retention of gestural, spoken or sung material.

[1] However, Will (1997) gives an example of a cultural context within which frequency differences rather than ratios might constitute the basis for melodic prediction and perception.

Higher-order processes in music cognition

Hierarchical organization and relational processing

So far, we have listed perceptual features of music and bottom-up perceptual constraints relating to music. However, higher-level cognitive processes are also engaged in music cognition, composition, improvisation, and performance in diverse cultural settings. The hierarchical organization of music, and relational processes in music, are possible universal processes in music cognition (see also Chapter 6 this volume).

Music is generally complex, generative, multilayered and hierarchical (Bharucha *et al.* 2006) although exceptions to hierarchical organization include the cyclical structures of Balinese gamelan music (Tenzer 2006) and minimalist music (e.g., compositions by Steve Reich). In general, streams of sound are structured hierarchically within and across dimensions; such structure likely confers a processing advantage. Bharucha *et al.* divide hierarchical representations into tonal hierarchies and event hierarchies. Tonal hierarchies organize tones within a key into stable and unstable pitches; some tones are perceived as more stable, thus more important, than others. Event hierarchies extend

upward from smallest subdivisions of a beat, to beat level, then measure, phrase, period, and large-order forms.

Tonal hierarchies

Evidence of sensitivity to tonal hierarchies has also been established in Balinese music (Kessler *et al.* 1984), Scandinavian North Sami yoiks (Krumhansl *et al.* 2000), and Korean Court music (Nam 1998). These experiments sampled participants from within and outside those musical cultures. The basis of North Indian music, for example, is a set of melodic forms called the rāg that are built on a set of pitch scales called thāts. Tones within rāgs are organized hierarchically by importance, as in Western music. Castellano *et al.* (1984) demonstrated that both Indian and American students are sensitive to the hierarchical ordering of tones in rāgs.

Temporal hierarchies

The pulsation of some African musical styles is very different from the hierarchical concept of measure in Western classical music and the related concepts of metre, strong, and weak beats (Iyer 1998; Magill and Pressing 1997). Instead, this music is measured and is based on pulsations—a sequence of isochronous temporal units that can be realized as a beat. The beat is the analogue of the tactus of Western tonal music. In west African music, the main beat and its metric grouping are articulated in an indirect fashion—not with accentual reinforcement as in Western music, but with suggestion and complexity (Iyer 1998). The metre is encoded in the rhythm itself; it is unambiguous but culturally specific. Iyer provides examples of a standard bell pattern that would be heard phrased in three different ways by three different cultural groups.

Knowledge of temporal hierarchies is also attuned through experience. For example, Drake and Ben El Heni (2003) compared how Tunisian and French subjects synchronized tapping with music from those two contrasting musical cultures. Participants tapped more slowly and with more hierarchical levels with music of their own culture than with music of an unfamiliar musical culture. Musicians and non-musicians did not differ in a spontaneous synchronization task although musicians could synchronize with significantly more hierarchical levels.

Clayton (1997), examining tal, a concept in North Indian (Hindustani) music broadly equivalent to metre, finds similarities and differences between tal and metre. Tal is a temporal framework acting as a background for rhythmic design; it is a periodic and hierarchic temporal framework which involves the interaction of two or more streams of pulsation. Rhythm in Indian music is interpreted with respect to tal; musically untrained Indian listeners would infer tal much as musically untrained Western listeners infer metre. While the conception of metre in Western culture may not be a musical universal, the hierarchical organization of temporal information may be a musical universal.

Examples of hierarchical structure in Australian Aboriginal song

In Central Australia the song series or songline is the largest scale traditional musical form (Barwick 1989). A song series describes the Dreaming journey of one or more ancestral beings. A song performance consists of a number of song items, each of about 30 seconds duration, interspersed with periods of informal discussion. Central Australian songs are characterized by several exact repetitions of a fixed word string or text set to an unvarying rhythmic pattern. The textual and rhythmic components are regarded as two facets of the same structure (Barwick 1989). Each rhythmically articulated text relates to a different stage of the journey described in the associated myth. It is set to a melodic contour said by performers to be the same throughout the series and to embody the essence of the ancestral being whose journey through the country creating and naming present-day geographical features is celebrated in the series. For a performance to be classified as a 'song' it must correctly interlock all three elements—melody, rhythm and text (Ellis 1983). Unison group performance is the ideal and is made possible by inexperienced performers joining in when they have grasped the text words and the appropriate rhythm; they follow melodic cues given by the song leader who performs solo for the first few syllables of each item and who cues changes of pitch within the melody slightly in advance of the group (Barwick 1989). The general melodic shape of the songs in the centre of Australia is, almost without exception, terraced (Ellis 1984); that is, a generally descending melodic line.

Performance involves the structuring of melodic contour according to various textual characteristics. Barwick (1989) argues that the melodic structure and rhythmic/textual structure are conceptually independent despite being performed in a song as an intermeshed sonic stream. Either element is able to be performed in isolation. Some evidence of this includes a) words to describe humming the sound of the Dreaming; b) rhythmically defined humming of verses in order to remember the words; c)wordless definitions of the melody; and d) instances of tapping out the rhythm of the words of a song (Barwick 1989). Thus memory for melody and rhythm is integrated but separable. Barwick describes hierarchical structures in both the melodic and rhythmic/textual dimension of central Australian song referring specifically to the *ngintaka* song series performed by Antakarinya, Yankunytjatjara and Pitjantjatjara people.

Melodic structure refers to the patterns of pitch relationships that recur in the different song items in a series, and the ways in which these recurring tonal patterns are organized into melodic sections, pitch areas, and main tones. In *ngintaka* songlines, there are three related forms of the basic melodic contour: a linear form, cyclical form, and a transposing cyclical form. Barwick describes and illustrates the hierarchical organization of the linear melodic form consisting of an introductory section, preliminary descent, main descent, and concluding section.

The rhythmic organization of the text of *ngintaka* is also hierarchical, reflecting organization of the pattern into text line pairs, text lines, rhythmic segments, and beating cells. The interdependence of melodic and temporal structures in *ngintaka* is reflected in the observation that the decision about which form of the melody to perform, its constitution in melodic sections, and tonal and durational realizations of the sections correlate with different properties of the text to be performed. The choice of linear, cyclical or transposing cyclical melodic form depends on rhythmic organization. Rhythm serves as a mnemonic device for recall of the extramusical information that is associated with a particular song text (Ellis 1984). Barwick (1989) examines the 'point of fit' in combining melodic and rhythmic/textual structures:

> although an item of singing need neither begin nor end at significant boundaries in the rhythmic/textual cyclical, there is always at least one internal point in the sung item at which the major rhythmic/textual and melodic boundaries coincide.
>
> Barwick (1989, p. 19)

This meticulous musicological and structural analysis of *ngintaka* points to the role of *hierarchy* as both an organizational and perceptual process:

> choices relating to the upper levels of the melodic hierarchy (melodic form and section composition), which correlate with structures at the upper levels of the rhythmic/textual hierarchy (overall style of beating accompaniment and repetition organization), have ramifications that extend down to the smaller level decisions about movement around main tones. Performance of the music therefore requires a constant shifting of attention from one level of the system to another.
>
> Barwick (1989, p. 26)

Cognitive processes related to hierarchical organization, grouping and segmentation, expectancy, and entrainment are evident in this example from Australian Aboriginal song.

Development of musical expectancies and abstract implicit knowledge

Musical expectancies

A piece of music in a familiar genre generates expectations based on implicit knowledge about common features of the genre; variations in how these expectations are met or violated are important in determining emotional and aesthetic response to music (Meyer 1956; Tillmann *et al.* 2000). In Western tonal music, musical expectancies are shaped by rhythmic or metric structure (Large and Jones 1999), tonal and harmonic structure (Schmuckler 1989) and melodic structure (Cuddy and Lunney 1995). While it is unclear how broadly these principles apply cross-culturally, the tendency for large intervals to descend is evident in Australian Aboriginal music, Chinese folk songs, traditional Korean music, Ojibwa, Pondo, Venda, and Zulu songs (Huron 2006, although see Vos and Troost 1989), suggesting that melodic expectancies are important in emotional and aesthetic response to music in many cultures.

Differentiation of two kinds of expectations—schematic and veridical—solves a paradox of musical expectation (Bharucha 1994). A familiar piece of music contains no surprises—if the violation of expectations is aesthetically or emotionally important, a piece should become less aesthetically or emotionally interesting with each listen. This is not the case. Schematic expectations are automatic, culturally generic, and develop from assimilation of the music of a genre over years of experience. Veridical expectations refer to the actual next event in a familiar piece even though the event may be schematically unexpected. As schematic expectations are acquired from hearing many individual pieces the two kinds of expectancies will converge but, at times, will diverge, creating the continuing sense of violation in familiar pieces of music as described by Meyer (1956). The capacity to develop expectancies may be a universal process. Huron (2006) posits that implicit, statistical expectations are linked directly to emotional response, eliciting basic neurobiological responses. In his account, statistical learning (e.g., McMullen and Saffran 2004) underlies the development of musical expectations.

A small number of studies have examined expectations in music cross-culturally. Researchers have found listeners are sensitive to melodic expectancies in British folk songs, Webern Lieder, and Chinese pentatonic songs. On occasion, performance of American and Chinese participants has been compared and principles such as 'pitch proximity'—that a second pitch following a first pitch is likely to be close in pitch—and 'pitch reversal'—that listeners expect the direction of the melody to reverse—successfully predicted response patterns regardless of the musical style, or the formal music training, and cultural background of the participants (Schellenberg 1997).

Krumhansl (2000; Krumhansl *et al.* 2000) conducted investigations of an indigenous music of the Scandinavian peninsula, the North Sami yoiks, which are quite distinct from Western tonal music. These experiments used North Sami yoiks as stimuli, with participants including North Sami, Finnish music students who had studied yoiks, and North American musicians unfamiliar with yoiks. Results suggested that Western listeners were most influenced by Western schematic expectations, and that veridical expectations were strongest for Sami participants. However, statistical models of melodic expectancies, specifically melodic continuations, appear robust in explaining melodic expectancies in listeners of North Sami, Finnish or North American cultures. While these findings warrant investigation in other cultures, they nonetheless suggest that melodic expectations are universal, insofar as music is melodic.

Implicit knowledge of musical structures

Abstract, implicit knowledge of musical structures and conventions is acquired by infants and children through mere exposure to a particular musical environment (Bigand *et al.* 2003). Some people explicitly learn the musical theory of their culture, but most acquire implicit knowledge of musical structures and conventions through incidental exposure to the environment.

Implicit learning and Australian Aboriginal song

The process of learning via exposure is evident in descriptions of the performance of Australian Aboriginal song. For example, Barwick (2002) discusses the way rhythmic mode in *Church Lirrga* songs of Wadeye in the Northern Territory is brought into relief by the juxtaposition of contrasting songs: 'The pairing of items in different tempo bands is one of the main ways in which learners become aware of the importance of this dimension of performance' (p. 81). The pairing of slow and fast songs is commonly found in northern Central Australia and the Kimberleys (Barwick 2002). Barwick (1989) alludes to the complexity of dimensions, relations and interrelations that are learned by an Aboriginal song leader:

> in addition to the mass of geographical and mythological detail to be mastered, leading a performance requires a high degree of sophisticated musical awareness, an awareness that is not taught directly, as in western educational practices, but is rather arrived at and internalized through repeated acts of performance.
>
> Barwick (1989, pp. 26–27)

Temporal expectancies, synchrony, and entrainment

Temporal entrainment is a domain-general mechanism and likely universal process in music perception and production (e.g., Clayton *et al.* 2005; Drake and Bertrand 2001; Fraisse 1982; see also Chapter 8 this volume). Entrainment occurs where two rhythmic processes interact with each other, eventually locking in to a common phase and/or periodicity. Such processes play a role in speech production (Goldstein *et al.* 2006) and models of joint action (e.g. Knoblich and Jordan 2003). Large and Jones (1999) argue that neural oscillators entrain to external events such as metres or rhythms. Because this entrainment process underlies temporal perception, periodic events (i.e., repeating rhythms, metre) facilitate the efficient allocation of limited attentional resources, and make synchronization activity (e.g., tapping along or musical activity) more accurate.

Non-periodic metres are common cross-culturally. 'Free rhythms' such as the Indian *alap* or the Turkish *taksim* are improvised and unmetred, while music with accelerating rhythms is found in Japanese Gagaku music and Tibetan monastic music (Huron 2006). The *aksak* metres (e.g., 3 + 2 + 2) of Bulgarian dances (Moelants 2006) and African rhythms are non-periodic. At first glance, non-periodic rhythms may be problematic for theories of entrainment. Jones argues that when there is no explicit pulse a listener might entrain to what they perceive as the median period length (Barnes and Jones 2000). Periodicity is not necessary for the formation of expectations, according to Huron (2006). Instead, listeners need to be experienced with the temporal structure of an event and some element of its temporal structure must be predictable. Regardless of whether accounts of entrainment or accounts of expectation are better at explaining the perception of temporal structure cross-culturally, some form of allocation of attentional resources based on the expectation of temporal information is likely to be universal.

Multimodal processes and integration

In many cultures, music and dance are inseparable. An analysis of the didjeridu-accompanied dance-song genre *Lirrga* from Wadeye in the Northern Territory of Australia, has shown that songs fall into named distinct tempo ranges which correlate with different metres in the vocal part resulting in rhythmic mode (Barwick 2002). The significance of rhythmic modes comes from their association with *dance* (Marett 2005). Thus, one universal process in music cognition might be movement perception and its development (Fraisse 1982; Friberg and Sundberg 1999).

Bharucha *et al.* (2006) have distinguished four primary facets of internal experiences of motion in music cognition: a fundamental sense of self-motion through space; perception of the motion of bodies, not necessarily one's own; movement elicited by abstract structures such as tonality; and a metaphorical, synaesthetic sense of motion. Movement in pitch, time, loudness, and timbre has been described as the interplay of tension and relaxation (Jackendoff and Lerdahl 2006). This metaphor of tension and relaxation may emerge as a universal quality in music cognition given further research cross-culturally.

Music is an example of a perception–action cycle (Janata and Grafton 2003; Keller *et al.* 2007); that is, streams of sensory information forming the basis of goal-directed actions. Evidence of neural simulation and mirroring continues to accumulate—seeing *or* hearing an intentional *action* gives rise to neural activity that is comparable with that underlying *performance* of the action (Keysers *et al.* 2003). Studies of music perception and performance are likely to shed new light on universal processes that are the result of tightly coupled sensorimotor systems.

Conclusion

There is much to do to test assumptions of contemporary theories of music cognition and to identify unique features of musical environments and musical processing. More than 30 years ago, Harwood (1976) called for an emphasis in research on musical processes rather than musical content and suggested that looking at how people learn to listen to and play their community's music is more informative than studying what it is they listen to or play. Researchers will need to be creative in applying a range of appropriate methods to music processing in non-Western cultures; these range from initial ethological and ethnographic phases, to analysis of everyday, multimodal musical events, through to the design of experiments that test particular hypotheses. Clarke and Cook (2004) detail methods for this endeavour. As Cole (1996) notes, such studies will need to 'maintain the integrity of the real-life situations [they are] designed to investigate, be faithful to the larger social and cultural contexts from which the subjects come, and be consistent with ... participants' definitions' (p. 226). Interdisciplinary research that knits together the concerns and methods of the cognitive sciences with those of cultural anthropology, and that involves diverse materials, tasks, and cultural groups, is essential for explanatory and inclusive theories of music cognition, perception, and production.

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