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INVITED REVIEW

Cross-cultural studies of musical pitch and time

Catherine Stevens*

MARCS Auditory Laboratories, University of Western Sydney,
Locked Bag 1797, South Penrith DC NSW 1797, Australia

Abstract: This review describes cross-cultural studies of pitch including intervals, scales, melody, and expectancy, and perception and production of timing and rhythm. Cross-cultural research represents only a small portion of music cognition research yet is essential to i) test the generality of contemporary theories of music cognition; ii) investigate different kinds of musical thought; and iii) increase understanding of the cultural conditions and contexts in which music is experienced. Converging operations from ethology and ethnography to rigorous experimental investigations are needed to record the diversity and richness of the musics, human responses, and contexts. Complementary trans-disciplinary approaches may also minimize bias from a particular ethnocentric view.

Keywords: Music, Cognition, Cross-cultural, Pitch, Rhythm, Universals

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1. INTRODUCTION

Empirical studies of music cognition investigate the processes and mechanisms that underpin perception and production of, and response to, music. From a cross-cultural perspective, the research has been narrowly focused with most researchers concentrating on cognition of pre-20th-century Western tonal music. Music psychologists have now realized the importance of cross-cultural research not only as a test-bed for so-called universal psychological principles in musical structure and music cognition but also to investigate different kinds of musical thought. There is a feeling that time is of the essence to study music cognition in various cultures and/or using different kinds of musical materials. This review organizes and describes recent literature. Space does not permit discussion of philosophical issues such as the origins of music, debates about cultural relativism and cultural uniqueness, and the difficulty of conducting trans-cultural research unbiased by a particular ethnocentric viewpoint or theory [1–6]. The review begins with a definition of terms followed by a summary of findings pertaining to cross-cultural studies of pitch including intervals, scales, melody, and expectancy, and perception and production of rhythm and timing.

Music is defined as temporally patterned human activities, social and individual, which involve production and perception of organized sound and have no evident, immediate fixed consensual reference [1,2,6,7]. Musical cognition refers to knowing music evidenced through recognition, performance or response. It includes short- and long-term memory, attention, problem solving, and aesthetic and affective judgments and responses. By cross-cultural, we refer to comparisons across more than one cultural group, use of musical materials from different cultures, or the search for general mechanisms or universal phenomena in different cultural contexts.

2. PITCH

2.1. Intervals, Scales, and Tuning

One feature common to virtually all of the world's musical systems and therefore a possible "universal" is the use of discrete pitch levels with from five to seven unequally spaced pitches in a scale [8]. To investigate the effects of acculturation and musical sophistication on perception of musical intervals, Lynch *et al.* [9] used interval patterns from Western and Javanese musical scales. Intervals of the Western scale are based on the semitone 1.0595, 2 1/12, or 100 cents. The Javanese pelog scale is not based on a constant frequency ratio and some pelog intervals are slightly larger or smaller than those in Western scales [10]. Western participants were tested in experiments involving manipulation of musical training and familiarity with the musical materials: Western major and minor scales (familiar), Western augmented scales that contain alternating minor 3rds (3 semitones) and semitones (Western but less familiar), and Javanese pelog scales (unfamiliar). Results indicated that perception of mistun-

*e-mail: kj.stevens@uws.edu.au

ings by native Western listeners was influenced by both general musical acculturation and musical sophistication. Non-musicians and amateur musicians recorded lower thresholds for mistunings in culturally-familiar interval patterns than in culturally-unfamiliar patterns. Thresholds were lower again for musicians. Musicians did not differ across Western and Javanese patterns suggesting that skills learned in music training can be applied to music of other cultures.

To scrutinize further the process and chronology of interval and scale acculturation Lynch and Eilers [11] tested healthy six-month and one-year-old Western infants using an operant-head-turn procedure. The infants detected randomly located mistunings in a melody based on interval patterns from Western major, Western augmented, or Javanese pelog scale contexts. The one-year-old infants recorded a pattern of performance similar to that of adults — performing better in the Western major scale context than in either the Western augmented or Javanese pelog scale contexts. Six-month-old infants performed better in the major and augmented scale context than in the pelog scale condition with no reliable difference between major and augmented contexts. Culturally-specific perceptual reorganization for musical tuning, the authors conclude, begins to affect perception between six and 12 months. Performance of the youngest participants points either to less perceptual acculturation or to a predisposition for processing music based on a single fundamental interval — the semitone (see also [12–15]). These findings are concordant with studies that indicate perceptual reorganization for speech occurs by the end of the first 12 months of life e.g., [16,17].

Cognitive responses to improvised music using the Arab modal system (maqam) have been recorded from European and Arab listeners. Ayari and McAdams [18] studied the perception of Arabic improvised music (taqsim). Arabo-Islamic scales are heptatonic. The scales relate to a tuning system, rationalized in the modern era in terms of 24 quarter steps (50 cents) to the octave. Intervals in the scales are generally 2, 3, 4, or 6 quarter steps; 5-quarter steps exist but are rare. In certain modes, some pitches are slightly raised or lowered. Modal perception in the mental organization of a taqsim was examined using tasks such as identification of musical elements, segmentation of the work, verbal descriptions and performed melodic "reductions" of the segments. Reduction refers to reducing sections to a single, small, generative melodic/rhythmic figure. Participants transcribed or sang the figure or the "core structure" of each sequence. Detection of emblematic melodic figures is common practice for Arab musicians. Differences in identifications and segmentations were found between listeners of European and Arabic cultural origins. Both groups of listeners made segmentations on the basis of salient surface features such as pauses and register changes; Arab listeners made segmentations defined by subtle modal changes that went unnoticed by European listeners. The melodic reductions of segments revealed that Arabic modes involve not only a tuning system but also essential melodico-rhythmic configurations emblematic of the maqam.

2.2. Tone Sequences, Melodies, and Expectancy

Experimental studies of music cognition over the past 20 years have investigated the role of expectancy in encoding, organizing and reacting to sequences of musical tones or melodies. Meyer [19] proposed that a piece of music in a familiar genre generates expectancies and the subtle violation of those expectations is emotionally significant [20]. Results suggest that musical expectancies are shaped by rhythmic or metric pattern [21], tonal and harmonic structure [22] and melodic structure [23,24]. Bharucha [20] distinguished between *schematic* and *veridical* expectations. Schematic expectations are automatic, culturally generic expectations that represent the most likely transitions in one's musical culture. Schematic expectations are likely to be learned through exposure to a particular musical environment. Veridical expectations are for the actual next event in a familiar piece even though the event may be schematically unexpected. They would be learned by the system that has learned the particular piece.

Cross-cultural studies have explored whether particular kinds of pitch-based schemas generalize. The implication-realization (IR) model proposed by Narmour [25] is one candidate schema. The concept of tonal hierarchy is another [26]. Narmour's implication-realization (IR) model posits that listeners process all melodic intervals as primitive, bottom-up generative events [25]. These give rise to five universal, Gestalt-like implicative principles: registral direction, intervallic difference, registral return, proximity, and closure. The principles apply to local, note-to-note transitions of melodies and characterize sets of possible continuations or implications suggested by an incomplete musical pattern. Schellenberg [27,28] has simplified the model to two principles, pitch proximity and pitch reversal. The bottom-up rules are relevant to all styles of melody whereas Narmour's top-down rules invoke specific stylistic structures.

Experiments confirm that listeners are sensitive to the IR principles [24,27–29]. A range of musical materials has been used as stimuli including British folk songs, Webern lieder, and Chinese pentatonic songs; performance of American and Chinese participants has been compared (e.g., [27] Experiment 3; [23]). The experimental task consisted of the presentation of fragments of melodies with participants rating how well individual test tones continue the fragments. The IR principles successfully predicted response patterns. Responses did not differ as a function of musical style, formal music training, or cultural background [28].

Krumhansl and colleagues [30,31] have conducted investigations of indigenous music of the Scandinavian peninsula called North Sami yoiks. Krumhansl *et al.* [31], used cognitive methodology and converging operations to investigate melodic expectancy in the structure of, and cognitive response to, North Sami yoiks. The results of experiments that used North Sami yoiks as stimuli and listeners from the Sami culture, Finnish music students who had learned some yoiks, or Western musicians unfamiliar with yoiks, revealed that Western listeners were most influenced by Western schematic knowledge, Sami listeners were least influenced by Western schematic knowledge, and veridical expectations were strongest for Sami participants. Eerola *et al.* [32], refined the study testing participants who had not been exposed to Western music, namely traditional healers of South Africa. The results indicated that data-driven/statistical models are robust in explaining expectancies, regardless of the cultural background of listeners.

A statistical analysis of 18 yoiks specified the probabilities of tone onsets, and two- and three-tone transitions in this style of music [31]. The pattern of tone onsets revealed a pentatonic scale, and two relatively strong reference tones. There was no evidence of the cadential motion characteristic of Western tonal music. The two- and three-tone transition matrices revealed that wide interval leaps are quite common and these are often the consonant intervals of perfect fourths and fifths. Krumhansl *et al.* [31], concluded that tonal organization of yoiks does not comply with principles of Western tonal music. They argued that the behavioural data show that listeners are sensitive to the statistical distribution of tones and higher order statistics such as two- and three-tone transitions. Significance lies in the conclusion that there is a core set of psychological principles that underlie melody formation and whose relative weights appear to differ across musical styles (p. 14).

Data obtained from behavioural experiments and a self-organizing artificial neural network were compared with the statistical analysis of a yoiks musical environment [30]. The neural network reflected Narmour's IR principles suggesting that the principles, rather than being innate, might be abstracted from listening to music (see also [33,34]). It is notable that universality does not imply innateness [35]. Evidence supporting an on-line statistical view of human cognition in general, and sensitivity to tonal hierarchies in particular, has also been provided in the context of Indian [36,37], Balinese [38] and Korean Court music [39].

Sandra Trehub, Laurel Trainor and their colleagues have written extensively on possible universal aspects of music cognition as evident in infant and developmental studies [40–42]. For example, Trainor and Trehub [40] proposed key membership as a near-universal feature of music. Implied harmony, by contrast, is rare cross-culturally. Pitting these two musical manipulations against one another in a change detection task, Trainor and Trehub [40] showed that performance of 5-year-old children was affected by key membership but not by implied harmony, whereas performance of 7-year-old children and adults was affected by both key membership and implied harmony. A statistical explanation is offered: key membership is learned from the frequency of occurrence of certain notes and the infrequent occurrence of others. As in language, near-universal features may be acquired earlier and more easily than unique features.

3. TIMING AND RHYTHM

3.1. Temporal Structures and Forms

The pulsation of African music is very different from the hierarchical concept of measure in Western classical music and the related concepts of metre, strong, and weak beats [7,43,44]. African 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. Carterette and Kendall [7] comment that grouping beats into measures achieved dominance in Western classical music as a consequence of graphic notation (bars) introduced into musical instruction in the 17th Century. Beat or pulsation measure reflects a metronomic sense at the basis of African rhythm but it is not the basis for forming groups of two, three or four as in Western classical measure.

Iyer [45] notes that there has been misapplication of Western music theory and music cognition models of rhythm and metre to West African music. Metre in West African and related musics, he states, is there solidly in the mind of the practitioner and in the mind of the acculturated listener, even if it is not apparent in some objective rendering of the acoustic signal. Iyer states that one learns the main beat, its subdivision, and its metric grouping; and then one learns the rhythm of the bell pattern, which simultaneously groups the main beats into larger units of four and subdivides them into smaller units of four or three. 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. The metre is encoded in the rhythm itself. The way in which this is done 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.

Elegant and parsimonious, Pressing's approach [46] was to define common cyclic structures of pitch and rhythm that are isomorphic under certain restraints. Pressing compared the cyclic structures, using mathematical group theory [47], calling them cognitive isomorphisms. In pitch, restraints are octave equivalence and the perceptual equality of smallest intervals. In time, restraints relate to repeating isorhythms that are based on a uniform fastest unit. Pressing compared scales and time lines in examples from jazz, West Africa, and the Balkans. For example, all of the Western church mode isomorphisms of scale and time lines occur in West Africa — the Ionian pattern 2212221 (3 Ewe groups, and the Yoruba) and the Lydian pattern 2212212 (Ga-Adangme). Using similar parameters, Pressing showed comparable structures in West African time lines and scales, Western tonal music including jazz, and Balkan rhythm. Monahan [48] observed that complex modal organizations of time assist in the formation of sensorimotor schemata and that West African and Balkan children listen to, perform, and ultimately learn such patterns just as Western children learn the diatonic pitch scales of their culture.

Clayton [49] examined the relationship between the concept of tal in North Indian (Hindustani) music and metre in Western music. He identifies some features of tal that may be described in terms of general theories and other features that are more rare. Metre is defined as a pattern of strong and weak beats or as a grouping of beats for the purpose of measuring time. In comparing tal and Western metre, Clayton notes that tal is a special form of metre — a temporal framework acting as a background for rhythmic design. Tal, like metre, is a periodic and hierarchic temporal framework and involves the interaction of two or more streams of pulsation. Audible and visible clues should ensure that the listener and performer cannot misinterpret the tal. Clayton concludes that while metre is not a factor in all music, neither is it restricted to the West.

3.2. Producing Rhythm

Considering the production of rhythm, Pressing *et al.* [50] draw attention to the presence of polyrhythms in world musics. Polyrhythm is a form of rhythmic dissonance, that is, time is divided by two or more differently rated strata. In a polyrhythm, two or more prime metrics divide the same time period [51]. The simplest polyrhythm (2×3 or hemiola) divides the same time period equally by three and two simultaneously [48]. Western music avoids more than one metrical interpretation by marking patterns in 6 either as 3/4 (3 groups of 2) or 6/8 (2 groups of 3). When hemiola occurs, the composer has marked one of the two groupings as primary in the time signature and usually indicates the other level of motion to be superimposed on it by dynamic or phrase markings [48].

Polyrhythms place non-trivial cognitive and motor demands on performers and listeners [50,52]. In Africa, polyrhythms create perceptual entrainment effects in ritual; effects that are linked to multiplicity of perception. One source of perceptual multiplicity in polyrhythms is figure-ground separation — for a polyrhythm consisting of two separate rhythmic streams, elements of one stream act as a ground and the other as the figure. Perceptual organization varies with the individual and the speed, use of accents, attentional strategy, and the frequencies of tones used in the two streams [53]. Figure-ground assignments are interpreted as "unidirectional coupling between oscillators" [50], and the model of timing builds on that of Wing and Kristofferson [54].

3.3. Perceiving Rhythm

The unexpected complexities of cross-cultural research into cognition are tacit in the study by Stobart and Cross [55] into the rhythmic structure and perception in Easter songs of Northern Potosí, Bolivia. The structure and perception of the music of a culture is influenced by linguistic prosody, movement patterns, perceptual constraints and the dynamics of the culture's musical aesthetics. Moreover, there are problems in rhythmic perception for outsiders of the culture — songs are perceived by Western ears as having an anacrusis (i.e., unstressed note at the beginning of a phrase). Their research investigated accent placement in the song accompaniment and analysis of stress patterns in languages in which the songs are sung. Surprisingly, the first syllable of the phrase is treated as a functional downbeat — the anacrusis is absent from these musics despite outsiders' perception. Stobart and Cross, like Hughes [56], caution that metre, as construed within the Western music-theoretic tradition, may not have the universal applicability that is generally assumed for it.

The interplay between music and language has also been examined by Patel [57,58]. Patel and Daniele [58] developed a new quantitative measure for the study of speech rhythm to compare rhythmic patterns in English and French language and classical music. The hypothesis under investigation was that the prosody of a culture's spoken language can influence the structure of its instrumental music. Analysis of rhythm of English and French classical music themes differ significantly using the normalized Pairwise Variability Index (nVPI) and this differentiates the rhythm of spoken English and French. These results, coupled with those of Huron and Ollen [59], provide an empirical basis for the claim that spoken prosody leaves an imprint on the music of a culture.

4. CONCLUSION

Time is running out for research into non-Western music cognition as Western culture and music encroaches on all but the most remote areas of the world. Indeed Huron

[60] argues that there is a danger of preserving "the music" while failing to preserve the conditions in which music might be experienced. He states that we should be as concerned about the loss of cultural diversity for the same reason that biologists worry about the loss of biodiversity — we may not yet know what the loss will mean, only that the loss is irreversible. Although there are many reports of other musics from an ethnomusicological perspective, relatively few focus on cognitive processes and employ the necessary tools afforded by rigorous experimental design and analysis.

This review has described recent studies that have applied experimental principles to the examination of cross-cultural music cognition. The candidate near-universal features of music or processes of music cognition proposed by Dowling and Harwood [8] and Sloboda [61] appear valid in light of more recent research. Possible universals are: elementary auditory grouping strategies, a stable reference pitch, the division of an octave into scale steps, the use of reference pulses, and induction of rhythmic patterns by an asymmetrical subdivision of time pulses. Carterette and Kendall [7] speculate that the spectrum of musical cultures arises from choices and elaborations of a few universals.

Cross-cultural research into music cognition accounts for only a small number of published articles. There is much to be studied both to test assumptions of contemporary theories of music cognition and to identify unique or universal features of musical environments. Researchers will need to be creative in applying a range of interdisciplinary methods including ethology and ethnography, analysis of musical materials, through to rigorous and ingenious design of experiments that test particular hypotheses developed in the field. Theories of music cognition and related notions of human communication and creativity will be richer for these efforts to understand transcultural phenomena and cognitive processes.

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Catherine (Kate) Stevens was born in Sydney, Australia in 1964. She graduated from the University of Sydney with BA (Hons I) in 1988 and a PhD (Psychology) in 1993. As an Australian Research Council Postdoctoral Fellow at the University of Queensland from 1993 to 1995, Kate developed artificial neural network models of music perception and investigated episodic memory for music. She is now a Senior Lecturer in the School of Psychology at the University of Western Sydney. Kate is Deputy Director of MARCS Auditory Laboratories (http://marcs.uws.edu.au/) and founding President of the Australian Music & Psychology Society (AMPS), http://marcs.uws.edu.au/links/amps/index.htm. Her research interests include: music perception and cognition, creativity and cognition in contemporary dance, recognition of auditory icons and warning signals, and applied cognitive psychology.