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ERP responses to cross-cultural melodic expectancy violations

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In this preliminary study, we measured event-related potentials (ERPs) to melodic expectancy violations in a cross-cultural context. Subjects ($n = 10$) were college-age students born and raised in the United States. Subjects heard 30 short melodies based in the Western folk tradition and 30 from North Indian classical music. Each melody was presented in its original and deviation form, and subjects were asked to judge the congruence of the melody. Results indicated that subjects found the Indian melodies less congruous overall and were less sensitive to deviations in the Indian melody condition. ERP data were partly consistent with the behavioral data with significant P600 responses to deviations in both cultural conditions, but less robust in the Indian context. Results are interpreted in light of previous research on listeners' abilities to generate expectancies in unfamiliar cultures and the possibility of overlap in the scale systems influencing the findings.

Keywords: culture; melodic expectancy; event-related potential; music cognition

Introduction

Music, like language, is a universal phenomenon occurring in virtually every known human culture. Humans seem predisposed to process musical information and can make relatively sophisticated musical judgments from an early age[1] and without formal training.[2–4] Unlike language, music's abstract and nonreferential nature can lead to a perception that musical understanding easily crosses cultural boundaries where language cannot. Unlike language, music's abstract and nonreferential nature can lead to a perception that musical understanding easily crosses cultural boundaries where language cannot. While the presence of music may be a cultural universal, even a cursory overview of the world's diverse musical practices suggest that musical understanding is not. Even a shared definition of the word *music* across cultures is difficult, if not impossible to find.[5] Within a given culture, what functions as music is often highly contextualized, adhering to a specific set of conventions particular to that culture. Consequently, exposure to those cultural conventions is likely to shape an individual's understanding of music at a cognitive level.

Research into cross-cultural music cognition has found evidence for both the universality and particularity of musical thought and behavior. Early research into the cross-cultural perception of tonal hierarchies in music of India,[6] Indonesia,[7] China,[8] Finnish folk music,[9] and Sami yoiks[10] found that cultural outsiders could in fact derive tonal hierarchy profiles and melodic expectations from minimal exposure to another culture's music, but that their judgments revealed some biases of their home culture and a lack of sensitivity to some cultural conventions. A more recent study by Curtis and Bharucha[11] sought to expose listeners' cultural biases more explicitly. Using a recognition memory paradigm, they presented listeners with melodies based on either a Western or Indian scale but with one scale tone missing. After hearing each melody, they played a single tone and asked listeners to identify whether they had heard that tone played in the melody. Western listeners were more likely to "remember" hearing a tone from the Western scale even when the melody was played in an Indian

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scale context. Research into the role of culture in memory has revealed a consistent in-culture bias for recognition memory for listeners from multiple cultures[12–15] suggesting that prior exposure shapes our ability to process and retain musical structure. Bimusical individuals, on the other hand, perform equally well on memory tasks in both their "home" cultures, further strengthening the argument that enculturation shapes music cognition.[15]

When individuals listen to a piece of music, they do not just passively take in information from the piece, they use that information to make predictions about what will come next. Those predictions or *expectancies* are based in part on the content of what they are listening to and in part on their prior experiences with music.[16] The more familiar a particular style of music, the stronger the predictions are regarding what comes next. Expectancy plays a crucial role in the ability to understand the structure of music and derive enjoyment from it. If the music does not make sense, then there is no clear sense of what is coming next and it is unlikely to hold one's interest. Conversely, if a piece of music is too familiar or repetitive, interest also wanes. Emotional responses to music are often a result of the tension between what is expected and what actually happens.[17,18]

When our expectations for a piece of music are violated, it initiates an event-related electrical response in the brain. The nature of the brain response depends on the nature of the deviation. Previous research with Western music has documented that listeners respond to an out-of-key note with a late positive (P300 or P600) event-related potential (ERP) component when they are actively engaged in listening.[19–21] An ERP study by Brattico *et al.*,[21] featured both passive and active music listening tasks. In the active task, subjects were asked to respond to out-of-tune or out-of-key notes that were inserted in random spots intact melodies. They found that listeners responded behaviorally by rating deviant versions of the melodies as significantly less congruous than originals. Neurologically, subjects responded to both types of deviations with a P600 event related potential. In all of the ERP studies mentioned thus far, listeners were detecting deviations to melodic expectations formed within a culturally familiar context. Because different cultures have different tonal systems, it is not clear whether listeners can detect melodic expectancy violations outside of a familiar cultural context and whether such deviations would elicit a similar brain response.

Two previous cross-cultural ERP studies have explored listeners' ability to detect out-of-key notes in a scale context using an oddball paradigm.[22,23] A study by Bischoff Reninger *et al.*[23] explored whether Western encultured listeners could detect out-of-key notes within a Javanese *pélog* scale. They had two groups of Western-born musicians, one group with no exposure to Javanese music, and one that had taken lessons in Javanese music at a U.S. university. They found that both subject groups could detect scale deviations in both conditions both behaviorally and with a P300 response to deviant tones, suggesting that mere exposure to a standard allows listeners to construct expectancies for out-of-culture examples. However, listeners with no exposure to Javanese music exhibited smaller P300 responses than those with exposure to the other culture. In both prior studies, scale tones were presented in an oddball paradigm that focused on detection of change from a standard. The judgments do not represent the contextualized tonality judgments that are typical of most music listening. To test the influence of enculturation on top–down processes of music cognition, judgments would need to be contextualized in a melodic framework requiring the inference of underlying scale components for expectancy formation. We applied the procedures of Brattico *et al.*[21] measuring both behavioral and brain responses to out-of-key notes in a melodic context, but using melodies from two different cultures as the stimuli. The purpose of this initial study was to explore the influence of cultural background on U.S.-born listeners' ability to respond to expectancy violations in intact melodies from two cultural contexts. The hypotheses were:

(1) Participants will rate North Indian melodies in any condition as less congruous than Western melodies.
(2) Participants will respond to out-of-key deviations in Western melodies with a P600 ERP response.
(3) Participants will not show a P600 response to similar deviations in North Indian music.

Methods

Participants for the study were college-aged adults drawn from a university subject pool. The mean

age of the participants was 20.2 years with a range of 19–22 years and the average amount of musical training was 6.7 years with a range of 0–13 years. Participants had to have been born and raised in the United States and could not be of Indian descent.

All participants listened to synthesized presentations of 30 European folk song excerpts and 30 excerpts from the *alap* portion of different North Indian *ragas*. All melodies were heard in their original form and in deviation form (120 total). Deviations for both sets of melodies occurred on a strong beat after at least one measure of music. Deviations were created by changing a target note by one semitone. The direction of the change was initially determined at random, though modifications were made if the direction of change moved to another note within the same scale or *thaat*. The target notes were purposely not tonic pitches or notes that had occurred with great frequency to minimize alternate cues regarding scale membership.

Original melodies and deviations were heard in two blocks of 30 melodies for each culture. Within each block all 30 melodies from each culture were heard, 15 in deviation form and 15 in original form. The order of the melodies within each block, the order of blocks within each culture, and the order in which each culture was presented to participants were randomized into four distinct presentation orders.

Continuous electroencephalogram (EEG) was recorded from 29 scalp electrodes referenced to the left mastoid, using a bioamplifier (SA Instrumentation Co., Encinitias, CA) (bandpass 0.01–100 Hz, 3 dB cut-off) with a sampling rate of 200 Hz. Electrodes were positioned at extended 10–20 locations at midline, medial lateral, and lateral locations. Two additional electrodes were used to monitor for horizontal and vertical eye movements. Averaged ERPs were calculated off-line from trials free of artifact. Of particular interest was the P600 effect. Therefore, ERPs were quantified as mean amplitudes within a 500–800 ms window, which represents the typical temporal window for the P600.

Participants were first briefly familiarized with the apparatus and the judgment task. They then heard the melodies over speakers at a range of 62–66 dB SPL, with an average peak level of approximately 65 dB SPL. The speakers were positioned on either side of a computer monitor that provided a fixation point during listening and instructions to rate the melodies after each hearing. Subjects pressed a button after rating each melody to hear the next melody.

Results

Hypothesis 1 predicted that participants would find Indian music significantly less congruous than Western music. We conducted a repeated measures analysis of variance on participants' ratings of congruousness across the two cultural styles (Western/Indian) and the two melody conditions (original/deviation). The analysis revealed a significant main effect for culture with Indian music rated as significantly less congruous than Western ($F[1, 9] = 26.04$, $P < 0.001$) (Fig. 1). There was a significant main effect for condition as well with deviation melodies rated as less congruous than the original versions ($F[1, 9] = 27.97$, $P < 0.001$), however a significant condition by culture interaction ($F[1, 9] = 15.17$, $P < 0.01$) suggests that participants were less sensitive to deviations in the culturally unfamiliar melody context.

We also predicted that our subjects would respond to melodic deviations in Western music by exhibiting the same late positive component found in earlier studies, but would not exhibit a similar sensitivity in the Indian melody context. An analysis of the ERP data found a significant main effect for condition for the Western melodies ($F[1, 9] = 18.09$, $P < 0.01$), as well as a significant condition by midline interaction ($F[2, 18] = 5.69$, $P < 0.05$), suggesting a widely distributed P600 response with the strongest activation in the posterior regions. There was no corresponding main effect of condition for Indian music, but there was a significant condition by midline interaction ($F[2, 18] = 5.26$, $P < 0.05$), indicating that subjects did respond to the Indian deviations, but their response was less robust. Figure 2 shows the difference waves for the Western versus Indian deviation conditions across the two cultures, which visually demonstrate the difference in the magnitude of the responses.

Discussion

The behavioral results show that listeners are less sensitive to melodic expectancy violations in the music of unfamiliar cultures compared to their own culture. The ERP data were more mixed, with subjects exhibiting a late positive component

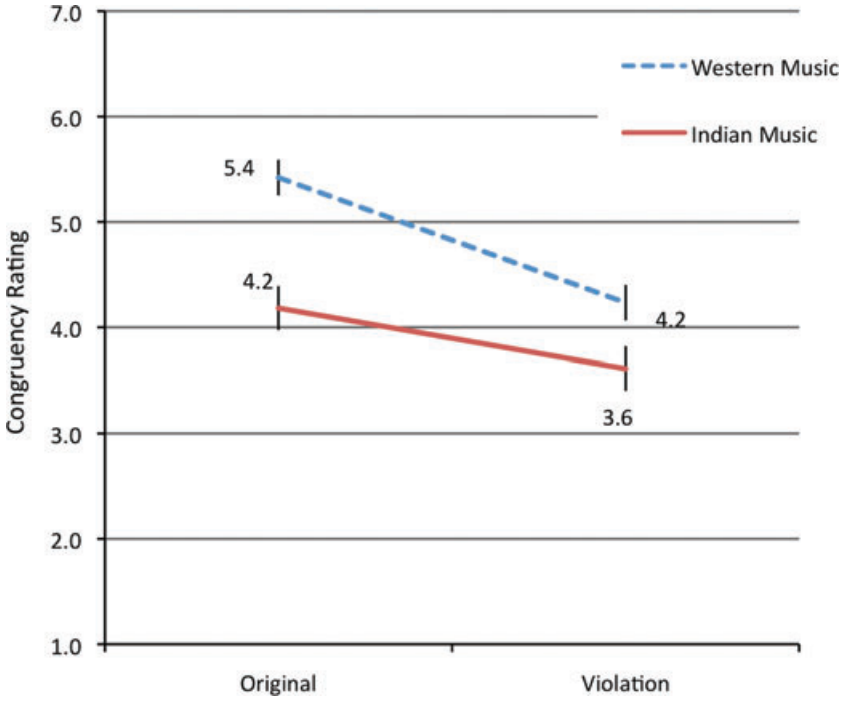

Figure 1. Participants' ratings of congruousness on a seven-point Likert scale across culture and melody condition.

in response to deviations in both cultural conditions, though less robust in the culturally unfamiliar context. This finding was similar to the weaker P300 response of out-of-culture listeners to scale deviations in a previous study.[23] The results provide some support for the idea that listeners can, with minimal exposure, internalize certain patterns in culturally unfamiliar music that allow them to respond to stimulus changes. This is consistent with findings from tonal hierarchy research that listeners can respond to the distribution of tones in culturally unfamiliar music[6–10] and with the aforementioned ERP study of cross-cultural scale perception.[23] However, we are cautious about endorsing such an interpretation because there are some possible confounds that may have influenced these results.

We predicted that Western listeners would not respond to melodic expectancy violations in culturally unfamiliar music. However, to the extent that the out-of-culture stimuli contained elements of Western musical structures, listeners might apply their in-culture schema to the interpretation of out-of-culture music. This misapplication of encultured schemas to out-of-culture music has been demonstrated in both behavior[10,11] and brain[13,24] responses for previous cross-cultural studies. Although Indian *ragas* are not scale-based in the same way that Western melodies are, they do represent underlying collections of pitches or *thaats*. North Indian music has 32 possible scales that are called *thaats* (though only 10 are in frequent use). Some of these *thaats* have tone sets that correspond to Western major and minor scales. For example, the *Bilawal thaat* corresponds to the Western major mode. To the extent that the Indian stimuli activated subjects' Western schemas, our listeners may have responded to a deviation, but of a Western rather than Indian melodic structure. Subsequent research needs to clarify the extent of this theoretical intersection between the two systems and either choose *ragas* based in *thaats* that do not resemble Western scales or include the possible intersection as a variable in the analysis.

Because Indian listeners were not included in the initial phase of this exploratory study, we cannot determine conclusively how well the notion of melodic expectancy "violation" was operationalized for North Indian music. Although the stimuli were based on existing *ragas,* and the deviations were

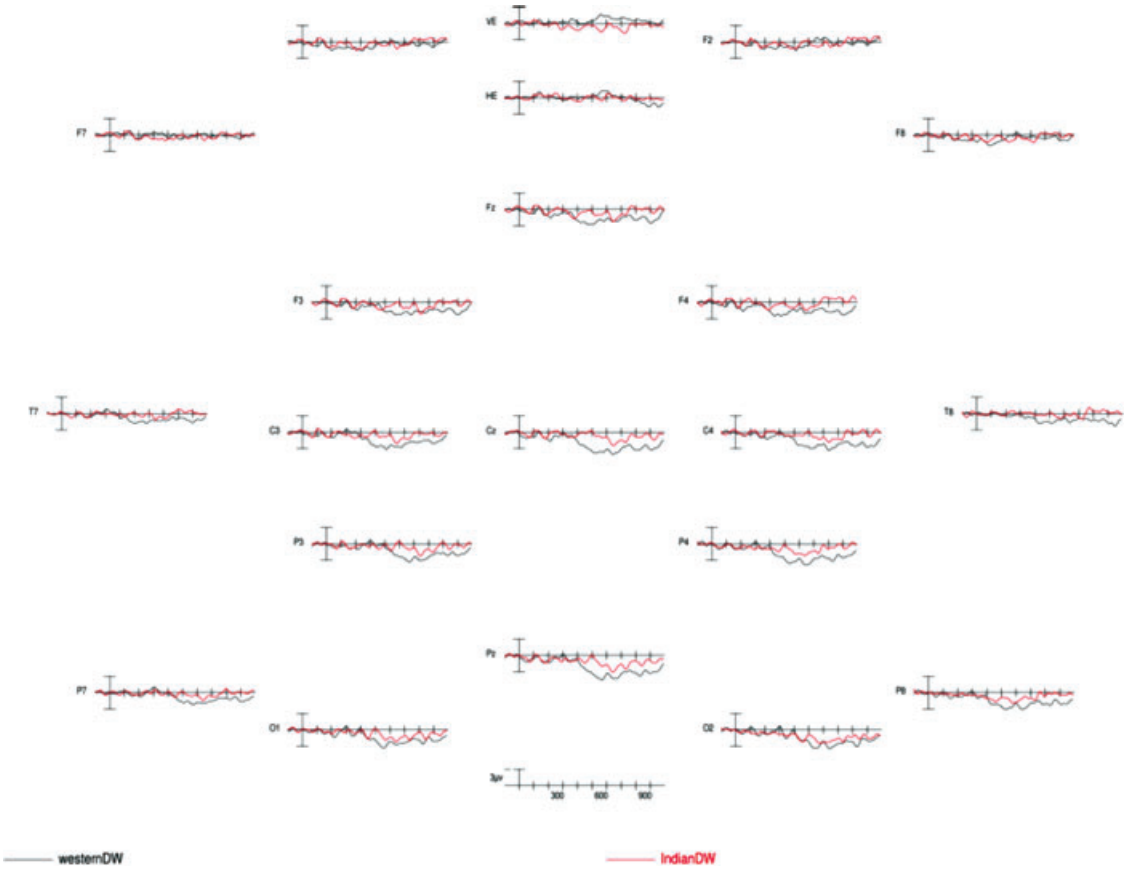

Figure 2. ERP difference waves in response to deviations in Western and Indian music listening conditions demonstrating a late positive component but with a different magnitude and distribution by condition.

created by an in-culture colleague, the limitations of ERP may have interfered with results. ERP stimuli typically last for a few seconds because subjects need to listen to a large number of stimuli for signal averaging purposes. On the other hand, the typical time scale of an Indian *raga* unfolds over minutes not seconds. Given that North Indian musical structure is melody based, it is unclear how long a *raga* needs to be heard to generate strong expectancies with in-culture listeners. These questions should be resolved in the next phase of our investigation by conducting a fully comparative ERP study involving the music and participants from both cultures.

The interaction of cultural background with basic cognitive processes like expectancy formation and memory is an important area for future research in the cognitive neuroscience of music.[25] Results can tell us something about the role of culture in shaping music cognition and the nature of musical learning. Once we understand differences between in-culture and out-of-culture responses to music, we can begin to track an individual's learning. Such tracking has already been accomplished in second language learning, finding that even short-term intensive exposure can change subjects' brain responses to a new language.[26] In music, such information could help educators to determine what types of experiences contribute to better learning of unfamiliar musical systems.

From a theoretical standpoint, ERP can be a powerful tool to test theories of expectancy formation. For example, researchers have developed some statistical profiles of Western melodic movement based on large databases of songs.[17] Such profiles should predict how strongly listeners respond to deviations of cultural rules, predictions that can be tested using ERP. With such tools, we might be able to quantify the "cultural distance" between two musical styles

in a way that could predict how easily members of one group could learn the music of the other.

The issues encountered in this study also reveal some of the potential challenges of cross-cultural comparative research. When theories such as melodic expectancy have their genesis in Western notions of scale and key, it can be difficult to realize those concepts authentically in non-Western musical styles. In order for any theory of music cognition to apply broadly to human music cognition, it must operate within these different cultural contexts. Cross-cultural research has the potential to clarify our understanding of human music cognition in ways that transcend individual cultural conventions.

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Conflicts of interest

The authors declare no conflicts of interest.

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