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An fMRI investigation of the cultural specificity of music memory

Steven M. Demorest,[1] Steven J. Morrison,[1] Laura A. Stambaugh,[1] Münir Beken,[2] Todd L. Richards,[3] and Clark Johnson[4]

[1]School of Music, University of Washington, Music Building, Box 353450, Seattle, WA 98195, [2]UCLA Department of Ethnomusicology, Schoenberg Music Building, BOX 951657, Los Angeles, California 90095-1657, [3]Department of Radiology, University of Washington, Box 357115, 1959 Pacific Street, Seattle, WA 98195-7117, and [4]School of Nursing, University of Washington, Box 357260, 1959 Pacific Street, Seattle, WA 98195, USA

This study explored the role of culture in shaping music perception and memory. We tested the hypothesis that listeners demonstrate different patterns of activation associated with music processing—particularly right frontal cortex—when encoding and retrieving culturally familiar and unfamiliar stimuli, with the latter evoking broader activation consistent with more complex memory tasks. Subjects (*n* = 16) were right-handed adults born and raised in the USA (*n* = 8) or Turkey (*n* = 8) with minimal music training. Using fMRI procedures, we scanned subjects during two tasks: (i) listening to novel musical examples from their own culture and an unfamiliar culture and (ii) identifying which among a series of brief excerpts were taken from the longer examples. Both groups were more successful remembering music of their home culture. We found greater activation for culturally unfamiliar music listening in the left cerebellar region, right angular gyrus, posterior precuneus and right middle frontal area extending into the inferior frontal cortex. Subjects demonstrated greater activation in the cingulate gyrus and right lingual gyrus when engaged in recall of culturally unfamiliar music. This study provides evidence for the influence of culture on music perception and memory performance at both a behavioral and neurological level.

Keywords: music memory; cross-cultural music; enculturation

INTRODUCTION

Music is a universal phenomenon occurring in virtually every society with evidence of its presence dating well before recorded history. Except in relatively rare cases of cognitive impairment (Peretz and Hyde, 2003), humans are able to make sophisticated musical judgments and decisions at an early age (Trehub, 2001) and often regardless of formal training (Koelsch *et al.*, 2000; Bigand, 2003; Bigand and Poulin-Charronnat, 2006). Music's universality sometimes overshadows the many, and occasionally extreme, differences among the world's musical traditions and practices (Campbell, 1997). Music is a highly contextualized construction adhering to a specific set of norms and conventions that vary according to the culture in which it resides. It is the interplay between adherence to and deviation from these conventions that creates a sense of musical structure and allows a listener to make sense of and find interest in music (Lerdahl and Jackendoff, 1983; Narmour, 1990; Huron, 2006).

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Correspondence should be addressed to Steven M. Demorest, School of Music Box 353450, University of Washington, Seattle, WA 98195-3450, USA. E-mail: demorest@uw.edu.

While the presence of music in human cultures may be universal, it is unlikely that music is universally 'comprehensible' between cultures. Many would acknowledge the obvious influences of culture on an individual's musical tastes and preferences, and perhaps on their beliefs about the roles and functions of music in society. It is also likely that continuous exposure to music constructed according to particular conventions and structures could shape musical understanding at a cognitive level. While many listeners might profess to 'understand' another culture's music, careful investigation of both the behavioral and neurological level correlates of that understanding may yield a very different picture. Recent research in neuroimaging has begun to look at how culture shapes our responses to the world on a neurological level (Chiao and Ambady, 2007). Given the importance of music as an agent of culture, it is logical to look at the role of culture in shaping the fundamental processes of music perception and memory.

Explorations of cross-cultural music cognition have found that Western listeners demonstrated greater success recognizing changes in Western rather than Javanese scales (Lynch *et al.*, 1990), though differences were minimized when Western pitch sets were presented in less typical (augmented scale) rather than more typical (major scale) constructions (Lynch and Eilers, 1992). Using European, Thai and Turkish scales, similar results were reported by Neuhaus (2003) along with ERP (Event-related potential) data suggesting differences in neural activity related to violations of pitch expectancies for culturally unfamiliar scales. Nor is pitch perception the only aspect of music cognition influenced by culture. Interpretation of rhythmic information may also be culturally based. Listeners have been observed to synchronize differently when tapping along with musical selections from their own culture *vs* an unfamiliar culture (Drake and Ben El Heni, 2003). The authors proposed that cultural familiarity allowed subjects to access larger scale and more diverse rhythmic hierarchies. Research has also found that meter perception can be influenced by culture in listeners as young as 12 months of age (Hannon and Trehub, 2005). Other research has reported differences in rhythmic grouping between native English and Japanese speakers hypothesized to reflect durational characteristics of their respective languages (Patel *et al.*, 2006). Investigating culturally based differences in music description, Morrison and Yeh (1999) reported that college students in China and Hong Kong tended to describe music in metaphorical terms, while students in the USA used technical language more often. While the interpretation, organization or description of musical information may vary depending on one's cultural up bringing, there is little evidence to suggest that the actual processes associated with musical cognition differ between cultural groups. This may be viewed as somewhat analogous to the processing of speech stimuli in which neural systems common across linguistic groups are used to encode and interpret information organized according to the specific rules of each language (Paulesu *et al.*, 2000).

On the most general level, left lateralized regions of the brain (including frontal and parietal areas) are predominantly associated with language comprehension, encoding and retrieval while similar processes associated with music are generally located in analogous regions of right cortex (Martin, 1999; Zatorre, 2001; Janata *et al.*, 2002; Levitin and Menon, 2003; Platel, 2005; Nan *et al.*, 2006). Samson and Zatorre (1992) reported persistent disruption of recall of verbal information among individuals with left-lateralized anterior frontal trauma, while recall of music information was degraded with anterior right frontal damage. For language, successful encoding of novel stimuli has been observed to evoke stronger activation in left inferior frontal areas (Martin, 1999; Baker *et al.*, 2001) as has presentation of nonsense words and words from a familiar but nonnative language (Wu *et al.*, 2007). Left-lateralized language areas have been associated with successful encoding, retrieval and comprehension, while right-lateralized areas, typically associated with nonlinguistic processing, have been observed to be more strongly activated for novel or unfamiliar stimuli. Platel has examined the neural substrates of musical memory in two PET (Positron emission tomography) studies (Platel *et al.*, 2003; Platel, 2005) to explore whether episodic and semantic memory employ different systems. For episodic memory, relating to the retrieval of newly learned musical material, he found bilateral activation in the middle and superior frontal gyri and the precuneus when compared to rest, but lateralized to the right. Right frontal areas have also been implicated in detecting violations of chord expectancies (Koelsch *et al.*, 2000), a result that has been interpreted as reflecting extraction of music-syntactic meaning (Koelsch *et al.*, 2002). However, bilateral activation of the IFC (Inferior frontal cortex) has been observed in the processing of intact rather than scrambled musical stimuli (Levitin and Menon, 2003), suggested to reflect involvement of left inferior frontal regions in the perception of temporal coherence for both music and language.

Unlike unfamiliar languages, culturally unfamiliar music does not necessarily deny listeners opportunity to derive 'meaning' from it (Morrison *et al.*, 2003; Demorest and Morrison, 2003; Clarke, 2005) in the sense that one may create a satisfying and seemingly sensible interpretation of a stylistically unfamiliar musical performance regardless of whether that interpretation is culturally appropriate. On the other hand, much ethnomusicological research is grounded on the assumption that musical interactions are mediated by cultural knowledge, separating the experience of the 'insider' from that of the 'outsider' (Merriam, 1990; Nettl, 1983; Nercessian, 2002). Given the seeming subjectivity of musical interactions, the question remains in what ways does enculturation affect music cognition.

In an earlier study (Morrison *et al.*, 2003), we used fMRI methodology to examine Western listeners' activation responses to previously unheard Western and Chinese classical music examples. Results of a focus memory test (described below), conducted following a functional MR scan and revealed that subjects were significantly better recognizing previously heard music that was culturally familiar regardless of degree of formal musical training. We were not able to assess subjects' brain activity during the later retrieval task, but we did not find any differences in brain activation patterns between the two music listening conditions (Western and Chinese music), though there were significant differences in activation of the right STG (Superior temporal gyrus) based on subjects' musical training. To investigate these seemingly contradictory results further, we replicated the recognition memory task on a broader scale with 150 Western and Turkish subjects born, raised and residing in the USA and Turkey, respectively (Demorest *et al.*, 2008). We observed that both highly trained and untrained listeners from each culture were significantly more accurate remembering music of their 'home' culture and that there were no differences in their performance based on level of musical training. In the most recent study (Morrison *et al.*, 2008), we explored the potential impact of enculturation on the recognition memory of US born fifth-graders compared to adults. In this study, in addition to exploring the influence of culture, we varied the complexity of the musical excerpts. Both groups demonstrated superior recognition for novel music of their home culture regardless of complexity and there were no overall differences based on age.

The persistence of the behavioral memory results suggests several implications for neural activation. If subjects experienced difficulty encoding and/or retrieving culturally unfamiliar music, they may be processing musical information using systems other than those typically associated with music cognition—that is, treating the stimulus as something other than 'music'. Alternatively they may be employing similar music comprehension resources, what Neuhaus termed 'universal listening strategies' (2003, p. 184), but with less success due to the incompatibility of the unfamiliar musical style with the prevailing culture-based listening schemata. This latter explanation is consistent with results of other cross-cultural studies. Nan *et al.* (2006) found that German musicians exhibited poorer performance and higher P3 amplitudes when performing a phrase perception task with culturally unfamiliar (Chinese) music. A subsequent fMRI investigation of the same phrase perception task found greater activation in the right angular and middle frontal gyri and the right posterior insula (Nan *et al.*, 2008). The authors interpreted this increased activation to the greater attention and processing demands of culturally unfamiliar music. This interpretation is supported by a PET study of tone recognition (Holcomb *et al.*, 1998) that found a significant correlation between task difficulty and activation of the right middle and inferior frontal gyri. If listening to and trying to remember culturally unfamiliar music represents a more difficult cognitive task, it should result in increased activation of neural resources typically associated with processing and recall of novel musical information, particularly in areas of the right frontal and parietal regions. The purpose of this study was to explore the influence of enculturation on the encoding and retrieval of both culturally familiar and unfamiliar musical information. The hypotheses being tested were:

(i) Subjects will perform significantly better on a recognition memory task for music of their home culture.
(ii) Subjects will exhibit significantly greater activation during listening and recall of culturally unfamiliar music in regions associated with the encoding and retrieval of novel musical information including the middle and inferior frontal regions lateralized to the right hemisphere. Additional activation may be observed in other areas associated with music memory such as the precuneus.

The primary purpose of the first hypothesis is a behavioral check on subjects' listening participation, but it also represents an extension of an established cognitive effect to the noise and distraction of a scanning environment since in our prior fMRI study (Morrison *et al.*, 2003), memory testing took place outside the scanner. The regions identified for the second hypothesis are based on findings for a variety of musical tasks that involve judgments of novel musical information, tasks that require some kind of episodic memory function to make comparisons (Zatorre *et al.*, 1994; Holcomb *et al.*, 1998; Platel, 2005; Nan *et al.*, 2008;). It is not yet clear which of these areas might show differential activation based on processing difficulties related to cultural familiarity.

METHOD

Subjects

Participants ($n = 16$; 8 males and 8 females) were right-handed adults (mean age 28.6 years with a range of 20.1–45.1 years). All subjects had <1 year of private music lessons and <3 years of ensemble (e.g., choir and orchestra) participation. Western subjects (4 males and 4 females) had been born and raised in the USA and had never lived outside the country for longer than 6 months. Turkish subjects (4 males, 4 females) were born in Turkey and resided there through at least early adulthood (range 17–27 years). At the time of the study, all Turkish subjects had been living in the USA between 1 and 7 years. All subjects were informed of the purpose and procedures of the study and gave written consent for their participation in accordance with the guidelines of the institution's Human Subjects Division.

Materials

Stimuli consisted of nine music examples: three examples from the Western classical tradition, three examples from the Turkish classical tradition and three examples from the Chinese classical tradition (see Appendix A). The Western and Turkish selections were intended to represent the 'home' cultures of the two groups of subjects. Elsewhere we have suggested that the ubiquity of Western music makes it a poor choice for usage as an unfamiliar music style to most groups of listeners (Demorest and Morrison, 2003); based on previous research (Demorest *et al.*, 2008) we selected Chinese music to represent a tradition unfamiliar to both groups. All examples were instrumental to avoid potential confounds introduced by language and lyric content. All were taken from professional commercial recordings and featured similar tempi and texture. Timbral components were unique to each style as dictated by appropriate performance practice, however all examples were performed by small chamber-sized groups that featured woodwind and bowed string instruments. While each example was judged to be representative of its own musical tradition, we selected pieces that were obscure (i.e., not 'famous' pieces) and unfamiliar to the listeners as determined by the judgment of expert performers from each musical culture. Examples consisted of approximately the first 30 s (range 25–33 s) of each piece edited to end at a musically logical point.

SCANNING PROCEDURE

Structural and functional MRI scans were acquired using a GE Signa 1.5 Tesla Scanner (version 5.8) with a custom-built radiofrequency coil and a custom-made magnet-compatible audiovisual system. This audiovisual system consisted of a computer equipped with E-prime software (Psychology

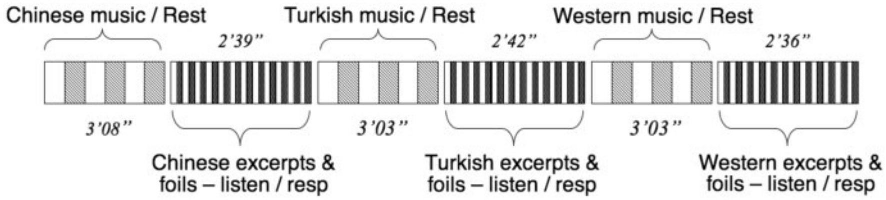

Fig. 1 Scanning protocol: for each music culture, full musical examples interspersed with 30-s rest periods were followed by a 12-item memory test consisting of brief excerpts or foils alternating with 6-s response intervals.

Software Tools, Pittsburgh, PA, USA) to present music stimuli along with visual prompts, an Infocus projector connected to the computer and a back-projection screen placed at the foot of the scanner. Magnet-compatible earphones were also developed that used the magnetic field of the scanner as the speaker force/audio frequency generator.

After being placed in the scanner, subjects received both visual and aural instructions explaining the procedure followed by a sample music excerpt (jazz piano) and two sample memory test items to familiarize the subject with the task and to check that audio, video and button-press apparatus was working properly. The scanner was run during the instruction/practice segment to acquaint subjects with the scanner noise though no data were collected at this time. Following this procedure headphone volume levels were adjusted as needed.

Subjects then listened to the three Chinese music examples interspersed with 30 s of rest (scanner noise only). After listening to the examples, subjects heard 12 short memory test excerpts and were asked to indicate using a button-pressing protocol whether each item was heard during any of the earlier long examples. Test excerpts (six correct excerpts, six foils) were between 4 and 9 s in length. To control for potential differences in surface features or recording quality among the test excerpts both correct excerpts and foils were taken from the pieces used as long examples though the foils were taken from portions not heard previously. To minimize the potential confound caused by motor activity and to ensure subjects maintained attention throughout the entire excerpt, while each test excerpt played subjects were cued by the visual prompt 'listen'. Following each excerpt, subjects were cued to give their response by the visual prompt 'respond' with the 'yes' and 'no' options displayed in the corresponding lower corners of the screen (left = yes, right = no). The Chinese listening/memory test sequence was followed by similar sequences for Turkish and then Western music (Figure 1). The order of presentation for each culture's music (1 = Chinese, 2 = Turkish, 3 = Western) was determined at random prior to the study and was held constant for all subjects.[1] The order of excerpts within each culture was also randomly determined and held constant across all subjects. Each excerpt within each culture was presented only once.

Anatomical scans were axial FSPGR (Fast spoiled gradient-echo) anatomical matching 21 slices, 2D fast spoiled gradient echo pulse sequence, variable band width, flip angle 70°, TR/TE 200/min ms, receiver bandwidth 15.63 kHz, field of view 24 cm, scan thickness 6 mm, interspacing 1.0, range graphically prescribed to cover the entire brain with 21 slices, 256×256 acquisition matrix, frequency direction-right/left, 2 NEX, imaging acquisition time 1 min 18 s. Functional scans were axial EPIBOLD 21 slices, 2D gradient echo echoplanar pulse sequence, number of repetitions brain volumes 407, flip angle 90°, TR/TE 3000/50 ms, receiver band width $\pm$ 62.5 kHz, field of view 24 cm, scan thickness 6 mm, interspacing 1 mm, explicit fat saturation pulse on, 64×64 acquisition matrix, image acquisition time 20 min 21 s.

Imaging analysis

The fMRI data were analyzed using FSL version 4.0 software (fMRIB's Software Library, www.fmrib.ox.ac.uk/fsl) for both the first level (individual fMRI activation) and the second level analysis (group maps). The time series of the fMRI data (after correction for hemodynamic delay) was segmented into parts that included (i) listening to Western, Turkish or Chinese music; (ii) listening to Western, Turkish or Chinese memory test items; (iii) responding to Western, Turkish or Chinese test items; and (iv) rest (time periods when music was not present and memory responses were not requested). We coded Western or Turkish segments as 'culturally familiar' music for Western and Turkish subjects, respectively; Chinese music was coded as 'culturally unfamiliar' for both subject groups. Then, we calculated the fMRI contrast *z*-score maps for each phase within each contrast of interest.

The following pre-statistics processing was applied: MCFLIRT (Motion correction using FMRIB's linear image registration tool) (Jenkinson *et al.*, 2002), nonbrain removal using BET (Smith, 2002), spatial smoothing using a Gaussian kernel of FWHM 5 mm, grand-mean intensity normalization of the entire 4D dataset by a single multiplicative factor and high-pass temporal filtering (Gaussian-weighted least-squares straight line fitting, with sigma = 32.5 s). The following data pre-processing was applied to the input

[1]Demorest *et al.*, 2008 used three different orders of presentation and did find a small but significant culture by order interaction and between-subjects main effect for order that was the result of a different pattern of responses for one order (WTC) *vs* the other two. Subsequent analyses did not find that the order effect had a significant impact on the data as a whole and may have been an artifact. Since it was the only order in which Western music (the most potentially familiar of the three) appeared first, the order was not used here.

data: masking of nonbrain voxels, voxel-wise de-meaning of the data and normalization of the voxel-wise variance. Pre-processed data were whitened and projected into a 67D subspace using probabilistic principal component analysis where the number of dimensions was estimated using the Laplace approximation to the Bayesian evidence of the model order (Minka, 2000; Beckman and Smith, 2004). The whitened observations were decomposed into sets of vectors that describe signal variation across the temporal domain (time-courses) and across the spatial domain (maps) by optimizing for nonGaussian spatial source distributions using a fixed-point iteration technique (Hyvärinen, 1999). Estimated component maps were divided by the standard deviation of the residual noise and thresholded by fitting a mixture model to the histogram of intensity values. As a method to filter out unwanted scanner noise and subject motion/physiology artifacts, initial individual subject analysis was carried out using probabilistic independent component analysis (Beckmann and Smith, 2004) as implemented in MELODIC (Multivariate Exploratory Linear Decomposition into Independent Components) version 3.05. This ICA (Independent component analysis) analysis was only used as a pre-processing step and was not part of the main fMRI analysis. ICA components were excluded based on (i) rimness, a residual motion artifact which shows up as a rim of activation on the edge of the brain and (ii) on/off, a scanner artifact that shows up as alternating slices of activation.

Subsequent individual and groups analyses were carried out using FEAT (fMRI Expert Analysis Tool) version 5.91 using the de-noised data. Time-series statistical analysis was carried out using FILM (FMRIB's improved linear model) with local autocorrelation correction (Woolrich *et al.*, 2001). Registration to high-resolution standard images was carried out using FLIRT (FMRIB's linear image registration tool) (Jenkinson and Smith, 2001; Jenkinson *et al.*, 2002). Higher level analysis was carried out using FLAME (FMRIB's local analysis of mixed effects) stage 1 only [i.e. without the final MCMC (Markov Chain Monte Carlo)-based stage] (Beckmann *et al.*, 2003; Woolrich *et al.*, 2004). The *z*- (Gaussianised T/F) statistic images were thresholded using clusters determined by $z > 3.0$ ($z > 2.5$ for direct comparisons) and a (corrected) cluster significance threshold of $P = 0.05$ (Worsley, 2001). Cluster thresholding was selected that uses a *z*-statistic threshold to define contiguous clusters. Each cluster's estimated significance level [from GRF (Gaussian random field) theory] is then compared with the cluster probability threshold. Significant clusters are then used to mask the original *z* statistic image for later production of color blobs. This method of cluster thresholding and extent of cluster size is a method to control for multiple comparisons (Worsley *et al.*, 1992).

RESULTS

To confirm previous results that individuals demonstrate better memory for culturally familiar music, we calculated

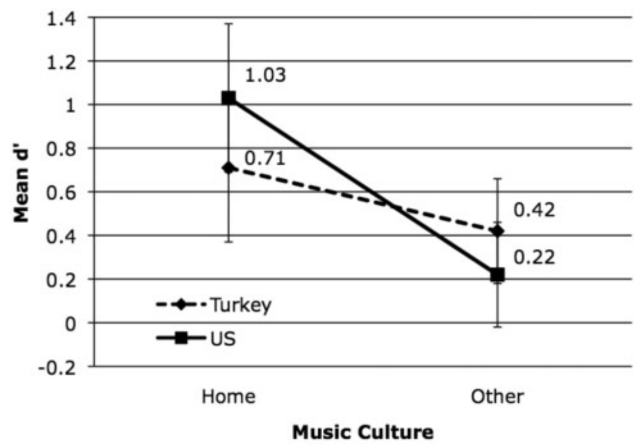

Fig. 2 Behavioral results (mean *d'* and standard error) of the recognition tests for 'home' culture *vs* 'other' culture music.

d' scores for each subject's memory test results using a transformation to adjust for the presence of perfect (six hits with no false alarms) or zero scores (Macmillan and Creelman, 1991). A repeated measures ANOVA with one between-subjects factor (subject culture: USA/Turkish) and one within-subjects factor (music culture: familiar/unfamiliar) revealed a significant main effect for music culture [$F(1, 14) = 4.81$, $P < 0.05$]. There was no main effect for subject culture and no significant interaction. Replicating the findings of previous research (Morrison *et al.*, 2003; Demorest *et al.*, 2008; Morrison *et al.*, 2008), both USA and Turkish subjects were significantly more successful remembering music from their home culture (Figure 2). This confirmation was considered important both to validate subjects' attention to the task and subjects' ability to complete the task in the scanner environment with the presence of scanner noise.

We also hypothesized that listening to and remembering culturally unfamiliar music would result in a greater cognitive load reflected by stronger levels of activation in areas associated with the processing of complex musical information, particularly right-lateralized middle and inferior frontal areas. In an initial analysis, we examined activation maps associated with listening to culturally familiar music (Western music for Western subjects; Turkish music for Turkish subjects) when compared to rest. We observed significant clusters of activation bilaterally in the superior temporal gyrus including planum temporale and Heschl's gyrus extending anteriorly to the planum polare (Table 1). We also compared activation associated with listening to culturally unfamiliar music (Chinese music for both groups of subjects) with rest. Significant activation was again demonstrated bilaterally in the STG similar in extent to that observed in the familiar/rest comparison. We also observed right-lateralized activation in the inferior frontal gyrus, though overlap with STG activation did not allow this to appear as a unique cluster. Reanalysis using a significance threshold of $z > 3.5$ revealed this as a distinct site of

Table 1 Significant clusters ($z > 3.0$) activated for culturally familiar and unfamiliar music *vs* rest during listening (encoding) and memory (recall) tasks

	Coordinates				
	x	*y*	*z*	*z*-value	Voxels
Listening					
Culturally familiar music[a]					
R STG incl PT, HG[b]	64	−18	0	6.57	2154
L STG incl PT, HG[b]	−58	−20	6	4.87	1991
Culturally unfamiliar music[c]					
R STG incl PT, HG[b]	70	−18	4	5.77	3770
L STG incl PT, HG[b]	−42	−34	14	5.04	2068
L cerebellum	−32	−62	−32	4.75	741
Paracingulate gyrus	0	18	44	3.8	171
Memory					
Culturally familiar music					
R STG incl PT, HG[b]	68	−28	4	5.03	892
L STG incl PT, HG[b]	−46	−32	4	4.44	644
R IFG, frontal operculum	40	26	2	3.77	167
Culturally unfamiliar music					
R STG (posterior) incl PT, HG[b]	62	−20	0	5.56	3759
Paracingulate gyrus	2	12	50	4.86	1297
L IFG, frontal orbital cortex	−32	24	−4	4.81	2346
L cerebellum	−28	−62	−32	4.33	1171
R thalamus	12	−4	6	3.95	1347
L STG incl PT, HG[b]	−50	14	28	3.91	757

[a]Culturally familiar music consisted of Western music for Western subjects and Turkish music for Turkish subjects.
[b]STG including planum temporale extending into Heschl's gyrus.
[c]Culturally unfamiliar music consisted of Chinese music for all subjects.
Stereotaxic coordinates (Talairach and Tournoux, 1988) indicate location of maximum *z*-value.

Table 2 Stereotaxic location of significant clusters ($z > 2.5$) activated for culturally unfamiliar music *vs* culturally familiar music during listening (encoding) and memory (recall) tasks (Talairach and Tournoux, 1988)

	Coordinates (maximum *z*-value)				
	x	*y*	*z*	*z*-value	Voxels
Listening (unfamiliar *vs* familiar music)					
All Ss					
R middle frontal gyrus	40	28	34	4.07	2093
Precuneus, posterior	8	−68	30	3.79	896
L cerebellum	−20	−76	−36	3.51	760
Paracingulate gyrus	4	30	34	3.55	570
R angular gyrus	44	−46	38	3.44	624
R frontal pole	36	54	−8	3.39	423
Western Ss only (Turkish *vs* Western music)					
Precuneus, posterior	−10	−66	32	2.86	2650
R middle frontal gyrus	30	46	28	2.81	1692
Memory (unfamiliar *vs* familiar)					
All Ss					
Cingulate gyrus	4	16	34	3.27	373

activation extending anterior to the frontal pole. Significant activation was also present in the paracingulate gyrus and bilaterally in the cerebellum (Table 1). Activation in the precuneus and right angular gyrus was also present but did not pass the cluster threshold.

We directly compared subjects' activation maps associated with listening to culturally unfamiliar music to those associated with listening to culturally familiar music. Areas of greater activation associated with culturally unfamiliar music included the left cerebellar region, right angular gyrus, posterior precuneus and right middle frontal area extending into the inferior frontal cortex for all subjects (Table 2 and Figure 3A). There was no significant activation unique to culturally familiar music. We also compared the difference maps of Western subjects and Turkish subjects separately to determine if there were any areas of activation unique to either group. Neither direction of contrast revealed any significant differences in activation.

A second analysis explored potential differences based on cultural familiarity during the recall task. We first compared activation maps associated with culturally familiar music memory with rest, finding bilateral activation of the STG including the planum temporale extending into Heschl's gyrus. There was also a significant cluster of activation centered in the right frontal operculum (Table 1). Comparing culturally unfamiliar music memory with rest, we again observed bilateral activation of the STG complex as well as frontal operculum extending to the IFG, activation of the paracingulate gyrus and precuneus as well as areas of the left cerebellum and right thalamus. A direct comparison between culturally unfamiliar and familiar music during the memory task revealed significant activation in the cingulate gyrus and right lingual gyrus (Table 2 and Figure 3B) associated with culturally unfamiliar music memory. There was no significant activation unique to culturally familiar music memory. Again, direct comparison of Western and Turkish subjects' difference maps across cultures revealed no significant activation unique to either group.

To further substantiate the results of the group analyses, we examined Western subjects' responses during listening and memory tasks to the Turkish music examples. These pieces effectively constituted a second instance of culturally unfamiliar music for Western listeners. Similar to our findings in the original comparison with Chinese music, Western listeners demonstrated significant activation of the precuneus and right middle frontal gyrus when listening to Turkish music contrasted to listening to Western music (Table 2 and Figure 3C) despite the lower analytical power associated with the smaller sample. Activation in the right angular gyrus and right inferior frontal gyrus was evident but did not reach the cluster threshold. For the memory task, Western listeners demonstrated no significant differences in activation for either the Western memory–Turkish memory or the Turkish memory–Western memory comparison.

DISCUSSION

It was the purpose of this study to test the hypothesis that listening to and recalling culturally unfamiliar music would

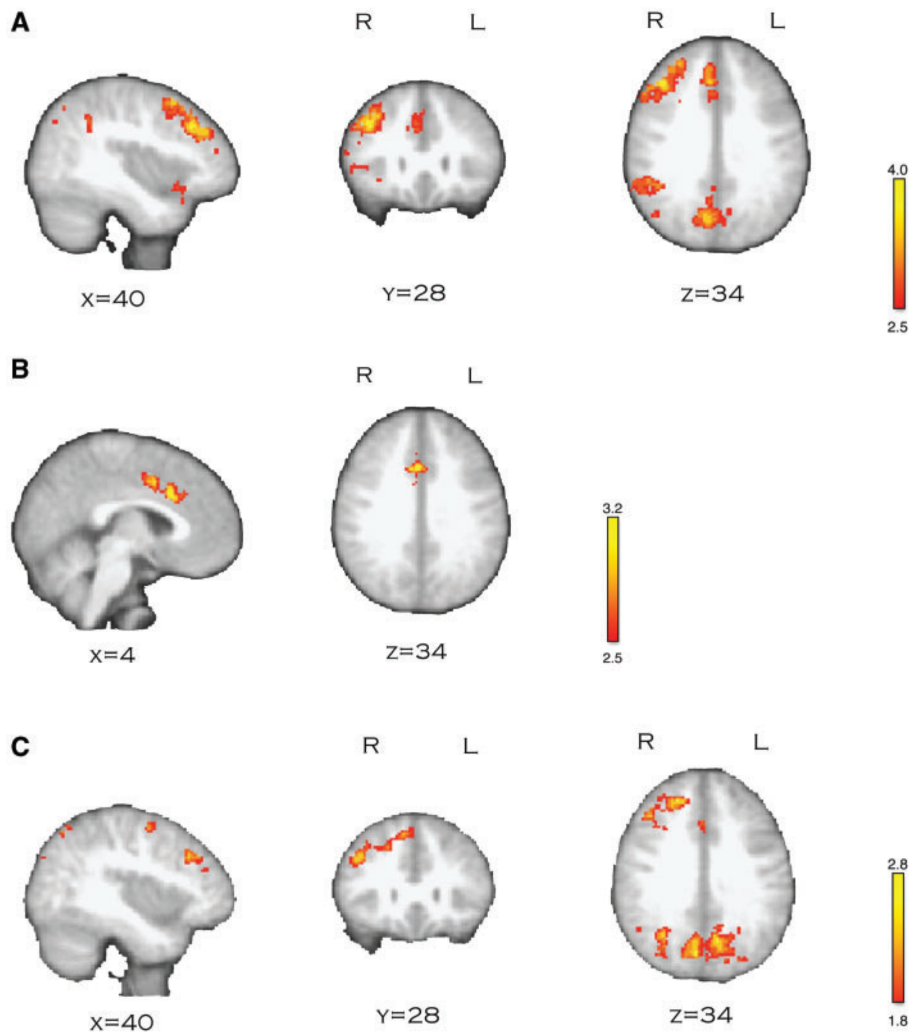

Fig. 3 Difference map showing (**A**) areas of greater activation during listening to culturally unfamiliar music in R angular gyrus (AG), paracingulate gyrus (PG), posterior precuneus (PC) and middle frontal areas extending into the inferior frontal cortex (FC) for all subjects; (**B**) significant activation in the cingulate gyrus (CG) during the memory task for culturally unfamiliar music; (**C**) greater activation of the precuneus (PC) and R middle frontal gyrus (FC) for Western subjects listening to Turkish music; activation in the R angular gyrus (AG) and paracingulate gyrus (PG) is shown though it did not reach cluster significance; for purposes of comparison, coordinates displayed correspond to those shown in Figure 3A.

result in increased activation of brain areas associated with processing of complex musical information. Consistent with our hypothesis, Turkish and Western listeners with minimal formal musical training demonstrated significantly greater activation—particularly in right frontal and parietal areas—when engaged in focused listening for culturally unfamiliar music. Both of these cortical regions have been associated with music processing and memory function (Koelsch *et al.*, 2000; Konishi *et al.*, 2000; Platel *et al.*, 2003; Platel, 2005; Cavanna and Trimble, 2006; Nan *et al.*, 2006; Nan *et al.*, 2008). The findings are consistent with other cross-cultural research showing greater cortical activation during a culturally unfamiliar music phrase tasks (Nan *et al.*, 2008). The location of activation in the right middle frontal region and the right angular gyrus unique to culturally unfamiliar music listening corresponds closely to Nan's findings regarding phrase processing for culturally unfamiliar material, suggesting that a similar processing challenge may be present for both tasks. Increased activation in frontal regions has been observed among individuals engaged in more complex or difficult tasks (Holcomb *et al.*, 1998; Buckner and Wheeler, 2001; Baker *et al.*, 2001) including bilinguals who completed passive listening, verbal recall and fluency tasks in a second language learned later in life (Perani *et al.*, 2003; Wu *et al.*, 2007). Similarly, native language speakers have demonstrated stronger LIFC (left IFC) activation when reading unfamiliar (ancient) but readable versions of their first language (Miura *et al.*, 2005). Halpern and Zatorre (1999) reported involvement of RIFC (right IFC) for the retrieval of songs from memory. Increased activation of bilateral inferior frontal areas has been associated with musical information that deviates from expected structure

(Tillmann *et al*., 2003) but not that which offers essentially no structure to track (Levitin and Menon, 2005).

In addition, we observed significantly greater activation of the right cingulate gyrus for all subjects during the music memory task for culturally unfamiliar music. The cingulate gyrus, along with the prefrontal cortex and precuneus, has been associated with episodic memory for music (Platel *et al*., 2003; Platel 2005) as well as orientation of auditory stimulus (including music) in space (Mayer *et al*., 2006). There were no corresponding differences in activation in areas associated with basic processing of auditory stimuli *vs* rest (e.g. bilateral superior temporal regions), suggesting that the music excerpts were well matched for surface characteristics.

The current results differ from those of our previous study (Morrison *et al*., 2003) in which we reported no significant activation differences between culturally familiar and unfamiliar music listening conditions. Several differences in design between the two studies may have contributed to the differential results. First, in the present study musical examples were presented in blocks of like style (all Chinese, followed by all Turkish and all Western) followed immediately by the associated memory task, while in the previous study examples alternated by style (i.e. one Chinese example followed by one Western example, etc.) with the memory task occurring after the scans were complete. The grouping of musical types in the current study (along with the commensurate predictability of the stimulus presentation) may have allowed subjects to engage a more consistent and focused listening strategy over a longer period of time, ultimately providing more robust activation results.

The present results also differ from those of Levitin and Menon (2003) who found bilateral activation of inferior frontal regions (pars orbitalis, BA 47) for normal rather than scrambled musical stimuli. Whereas Levitin intentionally altered the original musical stimuli to create 'nonmusical' examples lacking metrical regularity, rhythmic patterning and functional harmonic structure, we employed only intact musical examples. This may represent a distinction between nonmusical stimuli and 'differently musical' stimuli, sounds that can be recognized as intact musical material and adaptable to some degree to familiar listening strategies. In the present study, both culturally familiar and unfamiliar music appeared to recruit areas associated with music processing though the latter to a greater extent. We suggest that even in the presence of culturally unfamiliar stimuli, subjects in the present study, unlike Levitin and Menon's subjects, appeared to identify all examples as 'music' and attempted to employ familiar strategies toward their interpretation, encoding and eventual recall.

Subjects' relative success—both in terms of memory test scores and more restricted strength and extent of activation—when listening to culturally familiar examples is also striking because of the likely degree of unfamiliarity with their 'culturally familiar' music examples. Listening regularly to Western classical or Turkish classical music is not common particularly among listeners with little formal training. Nevertheless, the underlying principles of structure common across the broader musical traditions appeared to allow the participants in this study access to schemata that facilitated their retention of musical information, even in a style to which they may not commonly choose to listen. As in our previous studies (Morrison *et al*., 2003; Demorest *et al*., 2008; Morrison *et al*., 2008), subjects in this study were more successful remembering music that was more culturally familiar. These results mirror similar findings reported among experts in other areas such as chess (Gobet and Simon, 1996). Such results have been interpreted as reflecting sophisticated schema formation among individuals with a high level of training in a given discipline. Experts can ascribe meaning to stimuli using sophisticated 'chunking' strategies that facilitate encoding and retrieval of information in an efficient and effective manner. In contrast, certain kinds of 'expertise' in music perception appear to be gained merely through long exposure rather than strictly through formal instruction (Bigand, 2003; Bigand and Poulin-Charronnat, 2006). The intentionality one might associate with the development of skills such as chess playing is not necessarily found in the enculturation process. Rather, over time and through extensive exposure listeners gain sophisticated and particular strategies for engaging with music, schemata that facilitate a deeper level of structural processing even for previously unheard examples. However, these schemata are constructed according to sets of rules and expectations appropriate for a particular musical system, unique to a particular people, place and time. Their engagement during interactions with culturally unfamiliar music appear to be of limited use when listeners are required to generate responses (such as recognition) requiring levels of deeper understanding. This study provides evidence for the influence of culture on music perception and memory performance at both a behavioral and neurological level. The increased levels of activation we observed associated with culturally unfamiliar music listening and recall coupled with subjects' less successful recognition of these examples suggests that listeners do indeed employ familiar listening strategies when encountering 'other' musics, though in ways that are neither efficient nor effective.

Conflict of Interest

None declared.

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APPENDIX A: SOURCE MATERIAL FOR THE MUSICAL STIMULI

Western excerpts

Sonata terza in C minor for treble recorder, strings and basso continuo, by Alessandro Scarlatti in *Baroque Recorder Concertos*, EMI (1987).

- Movement III. Largo
  Concerto for Cello in D, by Joseph Haydn in *Cello Concertos*, EMI (1976).
- Movement II. Adagio

Trio Sonata in G minor, op. 2, no. 6, by Arcangelo Corelli in *Corelli Trio Sonatas*, Archiv (1986).

Turkish excerpts

Saba Pesrevi by Osman Bey in *Mevlana Dede Efendi Saba Ayini*, 1996. Kalan Music: 42.

Ussak Pesrevi by Nayi Osman Dede in *Nayi Osman Dede Mevlana Ussak Mevlevi Rite*, 2004. Çınar Music: Classical Turkish Music Collection 02.

Dilkeside Pesrev by Neyzen Emin Yazici in *Kani Karaca*, Archive Series, 1999. Kalan Music: 147.

Chinese excerpts

All from: A Pick of Guangdong Music D & I 8474 (1996)
Autumn Moon Over the Han Palace
Running Water Under Floating Clouds
Liu Qin Niang