Imaging melody and rhythm processing in young children

Katie Overy, Andrea C. Norton, Karl T. Cronin, Nadine Gaab, Dave C. Alsop,1 Ellen Winner2 and Gottfried Schlaug2,CA

Music and Neuroimaging Laboratory, Department of Neurology, Palmer 127; 1Center for Advanced MRI, Department of Radiology, E/AN226, Beth Israel Deaconess Medical Center and Harvard Medical School, 330 Brookline Ave, Boston, MA 02215; 2Department of Psychology, McGuin Hall, Boston College, Chestnut Hill, MA 02467, USA

CA Corresponding Author: gschlaug@bidmc.harvard.edu

Received 13 May 2004; accepted 14 May 2004

DOI: 10.1097/01.wnr.0000136055.77095.f1

In the adult brain, melody and rhythm processing have been found to show different hemispheric dominance, with the right hemisphere apparently more sensitive to melody and the left hemisphere to rhythm. We used a novel, child-friendly scanning protocol to examine the neural basis of melody and rhythm processing in young children (mean age 6 years 4 months, n=33). FMRI data were acquired using a sparse temporal sampling technique, taking advantage of the natural delay in the cerebrovascular response to neuronal activity. We found that this group of young children showed some differential specialization for melody and rhythm processing, but to a lesser extent than previously reported in adults. These results suggest that hemispheric specialization for musical processing may develop with age.

Key words: Auditory; Children; fMRI; Imaging; Melody; Music; Rhythm

INTRODUCTION
Melody and rhythm form the basis of musical organization [1]. They allow small perceptual auditory units to be organized into highly structured auditory sequences that the brain can easily recognize and comprehend. Stylistic norms for such auditory sequences are developed within every human culture and are learned from the earliest stages of infancy [2], possibly even in utero [3]. Examination of the neural basis of melody and rhythm processing in young children thus has the potential to offer important insights into the developing musical brain.

Research with adults has suggested that the brain is differentially specialized for melody and rhythm processing, with the right hemisphere predominantly involved in melody processing [4], and the left hemisphere predominantly involved in rhythm processing [5]. It is currently unknown whether such hemispheric specialization is also present in young children. fMRI is an ideal tool with which to examine this question, but conducting such research with young children presents a challenge. Children can be intimidated by the noise of the scanner environment and can find it difficult to remain still for the long time periods required for data collection. In addition, fMRI scanner noise can interfere with attention to auditory stimuli and can cause unwanted neural activation. Thus, we designed a child-friendly fMRI scanning protocol using a sparse temporal sampling technique with clustered volume acquisitions, taking advantage of the inherent delay in the cerebrovascular response to neuronal activity. Our aim was to investigate whether or not children show the same hemispheric specialization for melody and rhythm processing as reported in adults.

MATERIALS AND METHODS
Participants: Thirty-four right-handed children aged 5–7 years were recruited for the study, as part of a larger longitudinal study examining the potential effects of music training on cognitive and neural development [6]. One child’s data set was removed from the analysis due to her extensive movement and talking throughout the scanning session. The resulting group of 33 children had a mean age of 6 years 4 months and included 21 males. Handedness was assessed using standard behavioral measures [7]: each child was asked to write their name, use a spoon, throw a ball and use a toy hammer. If three out of these four tasks, including writing, was performed with the right hand, the child was considered right-handed. All children and parents gave informed, written consent to take part in the study, which was formally approved by the Internal Review Board of our institution.

Musical stimuli and tasks: The musical tasks required a same/different judgment of two short musical phrases, indicated by a button press response. Five different pitches were used for the musical stimuli, corresponding to the first
between 1.25 and 3.25 s after the end of the musical stimuli points, such that the onset of the first axial slice varied the musical stimuli were jittered between 3 different time the scanning repetition time (TR) was kept constant at 15 s, avoiding any interference with the auditory stimuli. While trial, thus reducing the amount of scanner noise and volume set was acquired after each musical discrimination in the cerebrovascular response to neural activity, one Data acquisition: Echoplanar functional imaging data were saved as raw data for later off-line reconstruction. An additional one minute phase encoded reference scan was performed prior to functional acquisition. Reconstruction of the images was performed with in-house software, which included a geometric distortion correction performed using information obtained from the reference scan. Pre-processing and analysis was conducted using SPM99 (Wellcome Dept. of Cognitive Neurology, London, UK; www.fil.ion.ucl.ac.uk/spm/). Spatial normalization to a standard atlas was performed by matching the T1 weighted images to a pediatric template created from 28 children's anatomical images. The identical transformation was then applied to the functional data, after realignment, and smoothing was applied with an 8 mm FWHM kernel. Condition effects were estimated according to the general linear model at each voxel in brain space [9]. The effect of global differences in scan intensity was removed by scaling each scan in proportion to its global intensity. Low frequency drifts were removed using a temporal high-pass filter with a cutoff of 200 s. No low-pass filter was applied and the data were not convolved with the haemodynamic response function (HRF). A box-car function was applied with an epoch length of 1 to the fMRI time series (12 acquisitions within each run), and no temporal derivatives were applied (for more details see [10]).

RESULTS

Task performance: Performance on the musical discrimination tasks during scanning did not differ from performance in the initial practice session one week prior to the scan (60% and 57% accuracy, respectively, t=0.8 p=0.4), demonstrating that the scanner environment did not have an adverse effect on performance.

fMRI data: The functional data from all 33 children were combined into a fixed effects group analysis, in order to

FIG. 1. Task design. Diagram to show the three task conditions: rhythm, melody and silence.

FIG. 2. Sparse temporal sampling technique. Diagram to show the method of data acquisition at three different jitterpoints. Diagram to show the

5 notes of the C major scale (fundamental frequencies 264, 297, 330, 352 and 396 Hz). In order to avoid any potential familiarity with instrumental sounds, we selected a neutral musical timbre with a marimba-like quality (Cubasis Universal Sound Module no. 13). Each tone had an attack of 5 ms and gradually tailed away for the rest of the duration. In the melody condition phrase pairs were presented at a steady pulse with tone durations of 500 ms, and the pitch of each tone varied to form melodic contours. In the rhythm condition phrase pairs were presented on a single pitch (which varied between trials) and the duration of each tone ranged from 125 ms to 1500 ms to form rhythmic patterns. Thus, each condition (across all trials) had the same number of tones and overall pitch content. In the silence condition, children simply performed a bilateral button press. In order to limit the button press to the same time point in each condition and every trial, a short noise burst was used to cue the response (Fig. 1).

Trials were grouped together to create short, child-appropriate runs of 3 min (each consisting of 8 musical trials and 4 silence trials), and runs were alternated between the melody and rhythm conditions. The musical trials in each run consisted of 3 same and 5 different phrase pairs. This unequal distribution of same/different task items meant that a child who could not detect any differences, and thus pressed same on every item, would score only 37.5%. The children learned and practiced the tasks ~1 week prior to the scanning session.

Data acquisition: Functional images were acquired on a 3T General Electric magnetic resonance imaging scanner using a gradient-echo EPI-sequence with an echo time of 25 ms and a 64 × 64 mm matrix. Using a mid-sagittal scout image, 26 slices were acquired over 1.75 s with a voxel size of 3.8 × 3.8 × 4 mm. Taking advantage of the inherent delay in the cerebrovascular response to neural activity, one volume set was acquired after each musical discrimination trial, thus reducing the amount of scanner noise and avoiding any interference with the auditory stimuli. While the scanning repetition time (TR) was kept constant at 15 s, the musical stimuli were jittered between 3 different time points, such that the onset of the first axial slice varied between 1.25 and 3.25 s after the end of the musical stimuli

FIG. 2. Sparse temporal sampling technique. Diagram to show the method of data acquisition at three different jitterpoints. Diagram to show the

DISCUSSION

The neural basis of melody and rhythm processing were found to be very similar in this group of young children. However, once statistical analysis was limited to the superior temporal gyrus, a small region in the right STG, the results suggest that hemispheric specialization for melody and rhythm processing may be less strong in young children than in adults.

This interpretation is consistent with the results of other studies showing developmental differences between children and adults in music processing. For example, adults have been found to detect non-diatonic interval changes more easily than diatonic interval changes, while infants show no such distinction, detecting interval changes of both types equally well [16]. EEG research has shown that components of the auditory evoked potential (AEP) to single violin tones change throughout childhood and adolescence, with the P1 component decreasing and the N1b component increasing between the ages of 3 and 18 years [14]. In addition, an increased appearance of the N100m response to piano tones has been found to correlate with age in children aged 7–12 [15]. Such findings also suggest that the neural basis of musical processing may change throughout development.

CONCLUSION

The young children in this study showed very similar activation patterns for melody and rhythm processing. A higher activation for melody processing compared to rhythm processing was found in a small region near the right primary auditory cortex, as previously seen in adults, but this result was only significant after statistical analysis...
was limited to the superior temporal gyrus. No differential activation was found when rhythm processing was contrasted with melody processing. These results suggest that hemispheric specialization for melody and rhythm processing may develop with age.

REFERENCES

Acknowledgements: We would like to thank Stephan Koelsch for helpful discussions at the outset of this project. The research was supported by grants from the National Science Foundation (BCS-0132508), the International Foundation for Music Research and the Grammy Foundation. Dr. Overy acknowledges support from the Harold Wingate Foundation and Dr. Schlaug acknowledges support from a Doris Duke Clinical Scientist Development Award and an award from the Dana Foundation.
<table>
<thead>
<tr>
<th>Query No</th>
<th>Details Required</th>
<th>Authors Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>No queries</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>