TRAINING NON-MUSICIANS ON A MUSICAL TASK – AN FMRI STUDY

Nadine Gaab
Gottfried Schlaug
Dept. of Neurology, Neuroimaging Laboratory,
Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, USA

ABSTRACT

Several studies using various brain mapping techniques showed differences in auditory processing comparing musicians to non-musicians. It is unclear whether these differences are due to differences in brain structure or intensive musical training. 7 non-musicians (training group) underwent fMRI-scanning twice (separated by 5 days of auditory training) while performing a pitch memory task. Subjects listened to a sequence of 6-7 tones lasting 4.5 seconds and were required to make a decision whether the last tone or second-to-last tone compared to the first tone was "same" or "different". The control condition was a rest condition with alternating button presses. Using a variation of a sparse temporal sampling technique, a set of 24 axial slices (4x4x6mm voxel size) was acquired after each auditory stimulation (TR = 17sec.) with varying the delay time between auditory stimulation and MR-acquisition over a 7sec interval. Non-musicians significantly improved in their %correct responses after the training. The training group was matched for performance score as well as gender to a group of musicians who underwent the same fMRI-experiment. In comparing the non-musician group prior to the training sessions with the musician group, we found more leftsided primary auditory cortex activation in the non-musician group whereas musicians activated more auditory storage areas. Comparing both groups after the training showed that the activation pattern in the non-musician group was more similar to the musician group; nevertheless, the non-musician group had even stronger left-sided temporal lobe activation than the musician group. A performance difference between non-musicians and musicians was present prior to the training, but not afterwards. A greater left-sided auditory activation pattern develops after training in non-musicians. This would lend support to the notion that functional differences between musicians and non-musicians can be explained at least in part by training.

1. INTRODUCTION

Structural and functional differences comparing musicians with non-musicians have been found in perisylvian brain regions using morphometric (Schlaug et al. 1995, Keenan et al. 2001, Schneider et al. 2002) and functional brain mapping techniques while subjects performed various auditory tasks (Mazziotta et al. 1982, Onishi et al. 2001, Besson et al. 1994, Platel et al. 1997). The existing literature suggests that musical training modifies the laterality of activation pattern with more left-sided activation in musically trained subjects. However, most of these studies exhibited a performance difference between musicians and non-musicians in these musical tasks and it is possible that the difference in performance could also explain the group difference in lateralized activation. Other possible explanations are that musicians use different cognitive strategies or have specialized musical abilities (e.g., absolute pitch) that could potentially account for between-group functional differences. In addition, anatomical differences may exist between musicians and non-musicians, likely due to the intense and long-term auditory and motor training of musicians. These anatomical differences, if present, might also account for functional differences.

In this study, we aimed to investigate whether non-musicians can be trained in an auditory task and whether their activation pattern after the training would change to a more musician like functional pattern.

2. MATERIALS AND METHODS

2.1. Subjects

A group of 7 non-musicians and 14 musicians without absolute pitch participated in the study after giving written consent. The non-musician group was part of a larger auditory training study. None of the non-musicians had any specific musical training or were trained in playing a musical instrument. The 14 musicians were matched to the non-musicians in terms of performance score and gender in the given task. With regard to this experiment, we defined musicians as those who had a formal music education and regularly played a musical instrument. None of the subjects had any history of neurological or hearing impairment.

2.2. Experimental paradigm

The non-musicians were scanned twice separated by 7 days while performing a pitch memory task which was contrasted with a motor control task. The musicians were selected from a larger group of subjects in order to match them with regard to performance rate to the non-musicians. They underwent the scanning procedure only ones. During the pitch memory task, subjects were instructed to listen to a sequence of individual sine wave tones (either 6 or 7 tones) with a duration of 4.5s for each sequence. Each tone was 300 msec long with an attack and decay rate of 50 msec and a pause of 300 msec separated tones from each other. Our target tones corresponded to the frequencies of semitones of the Western musical scale (based on A= 440Hz). In the pitch memory task subjects had to compare either the last or the second to last tone (depending on the visual prompt "second last" or "very last") to the first tone. Then subjects were asked to make a decision whether these tones were same or different. The motor control task was a rest condition with eye fixation. Subjects were asked to press a button depending on a short visual prompt

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("right" or "left"). All subjects were made familiar with the pitch memory task for approximately 10 min prior to the initial MR session using samples of the stimulation material. All subjects performed above chance at the end of this testing phase. The behavioral performance during the fMRI session was calculated as correct responses (in %).

2.3. Training

Training for the 7 non-musicians took place on 5 consecutive days between the two fMRI scanning sessions. The training subjects performed the pitch memory task for an hour with two short breaks in between. They were provided with their performance score at the end of each training session.

2.4. FMRI scanning

Functional magnetic resonance imaging (fMRI) was performed on a Siemens Vision (Siemens, Erlangen, Germany) 1.5 Tesla whole-body MRI scanner. A gradient-echo EPI–sequence with an effective repetition time (TR) of 17s, an echo time (TE) of 50 ms and a matrix of 64x64 was used. Using a midsagittal scout image, a total of 24 axial slices 4x4x6 mm voxel size) - parallel to the bi-commissural plane - were acquired over 2.75s each 17s. In addition, we acquired a high resolution T1 weighted scan ($1mm^3$ voxel size) of each subject for anatomical co-registration. We used a variation of a sparse temporal sampling technique with clustered volume acquisition to circumvent interference of auditory brain activity due to scanner noise. In addition, the stimulus-to-imaging delay time was varied between 0 to 6 seconds in a jitter-like fashion to explore the time course of brain activation in response to the perceptual and cognitive demands of this pitch memory task (Gaab et al. 2003). For the purpose of this study, we clustered the first four time points and the subsequent three imaging time points. FMRI data were analyzed using the SPM99 software package (Institute of Neurology, London, UK).

3. RESULTS

3.1. Behavioral results

The pre-training performance score of non-musicians was 69.57% (SD = 7.27) and increased to 84.57% (SD = 3.72) after one week of training. The mean performance score for the musicians was 80.14% (SD = 7.18). There was a significant difference between musicians and non-musicians prior to training, but not afterwards.

3.2. FMRI results

Group contrasts showed only differences in the initial imaging time points (0-3s after the end of the auditory stimulation). Both groups showed extensive superior temporal gyrus activation including Heschl's gyrus (HG), Planum Temporale (PT), and the supramarginal gyrus (SMG) bilaterally and smaller activation of the superior parietal lobe and inferior frontal gyrus.

In comparison to the non-musicians before the training, musicians showed more activation of the left supramarginal gyrus (Talairach coordinates: -50/-36/21; $p<0.001$, uncorrected). Contrasting the pre-training scans of the non-musicians with the musicians, revealed more left-sided activation of Heschl's gyrus for the non-musicians ($p<0.05$; FDR-corrected).

The trained non-musicians in comparison to the musicians showed more left-hemispheric primary and secondary auditory activation (Talairach coordinates: -51/-26/8; $p<0.05$, FDR-corrected). Contrasting the musicians non-musicians showed more activation of the superior parietal lobule on both sides ($p<0.001$, uncorrected for multiple comparisons).

4. CONCLUSION

Musicians had more activation of the left supramarginal gyrus (SMG) than the non-musicians (prior to pitch memory training). We found recently in a larger group analysis that the supramarginal gyrus activation was positively correlated with good performance in a pitch memory task. Several neurophysiological and lesion studies revealed the importance of the SMG - particularly on the left - for short-term auditory-verbal memory processes and phonological storage (e.g., Salmon et al., 1996; Paulesu et al., 1993, Celsis et al., 1999). The increased activation of the SMG found in the better performing non-musicians (Gaab et al., 2003) as well as in professional musicians indicates that these individuals are activating a brain region that might be particularly suited for short-term memory processes of verbal and non-verbal information.

Contrary to that, the untrained non-musicians had more activation of primary auditory cortex than trained musicians. Primary auditory cortex has been found to be important in pitch discrimination tasks (Tramo et al., 2002). Thus, the difference in the activation pattern might indicate a difference in strategy as well as a difference in performance. Musicians might rely more on a region particularly suited for short-term auditory memory. They might try to memorize the first tone for a comparison with the last or second-to-last tone. The non-musicians might try to continuously discriminate between tones without effectively storing the first tone in memory.

After a week of training in the pitch memory task, non-musicians now showed more activation of primary and secondary auditory areas on the left in comparison to the musicians. Several studies have shown a left more than right hemispheric processing depending on musical expertise (Kimura et al., 1964; Johnson et al., 1977 and Bever and Chiarello, 1974; Mazziotta et al., 1982; Hassler, 1990; Messerli et al., 1995; Evers et. al., 1999; Ohnishi et al., 2001). Our data would support the notion that training non-musicians in a musical task can lead to a change in the hemispheric activation pattern.

Musicians in comparison to the group of trained non-musicians showed more activation of the superior parietal lobule on both sides. This finding is consistent with previous studies in other domains showing a decrease in activation in parietal associative cortex either after training or as a result of practice (Kassubek

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et al. 2001; Jenkins et al. 1994; Petersen et al. 1998; Pardo et al. 1991). Those studies interpreted their results with e.g. habituation in the course of increased familiarity with the general conditions, reduced arousal, an automaticity i.e. decreased dependence on attentional and working memory resources as a consequence of practice.

In conclusion, we have shown evidence that auditory training can lead to changes in the functional network subserving a pitch memory task. Trained non-musicians showed a more similar functional network compared to the musician group than untrained non-musicians. Nevertheless, differences in strategies might explain the remaining differences in regional activation.

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