Middle Frontal Gyrus as a Potential Neural Indicator for Musical Imagery

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Introduction

Musical imagery is an expert learning strategy with potential to enhance performance, reduce physical overuse and decrease anxiety. The aim of our research is to explore the neural basis of this learning strategy and develop indices to monitor its effectiveness. In this study we scanned professional musicians during imagery and simulated motor performance of a memorised musical extract. We predicted that both performance imagery and motor performance would activate the parietal lobes and the motor system (i.e. SMA, cerebellum, premotor BA6), excepting primary motor cortex, which would only be activated by simulated performance (Lotze et al, 2003). We also predicted that there would be distinct differences in frontal lobe activation, due to differing cognitive and/or attention requirements of the two tasks.

Methods

A two-condition block design was used for each task. Prior to scanning, a novel musical extract was memorised, in which both hands performed the same rapid sequence, one octave apart, maintaining one hand position in order to avoid arm movements (see figure 1A). All five fingers were involved sequentially. A 3T whole-body scanner (Verio, Siemens, Erlangen, Germany) was used for image acquisition. 118 Functional volumes were acquired using an interleaved EPI gradient echo sequence (TR/TE/flip angle=3000ms/30ms/90°, slice thickness=3mm, 36 slices, FOV=24 cm, matrix size=64×64). The first three images were discarded. All data were analyzed using BrainVoyager QX (Brain Innovation, Maastricht, The Netherlands). Functional images were realigned, spatially smoothed with a Gaussian kernel of 6mm FWHM, corrected for linear trends, and a high pass filter with a frequency cutoff of 128 seconds was used to remove low frequency drift in the data. Processed functional data were coregistered with corresponding individual high-resolution anatomical images (1×1×1mm) and interpolated into Talairach space (Talairach and Tournoux, 1988).

Results

In Figure 1 we present results for a 42 year old professional pianist who reported vivid imagery throughout. With the exception of primary motor cortex (M1), which was activated only during performance, the motor system of the brain was activated similarly for both the imagery and performance of the piano extract (i.e. bilateral premotor (BA6), SMA and cerebellum) (see figure 1B). Similar regions in the inferior parietal lobe were also activated bilaterally during both tasks. The lack of activation in M1 during the imagery task provides evidence that no covert movement occurred. Thus the principal difference in activation between the two conditions was that performance imagery produced bilateral activation of Middle Frontal Gyrus (MFG) (see figure 1B and figure 1C upper middle panel) whereas simulated performance produced only right sided activation of MFG (see figure 1C lower middle panel). See figure 1D for the time course of the BOLD signal in the MFG in both conditions, compared to fixation.

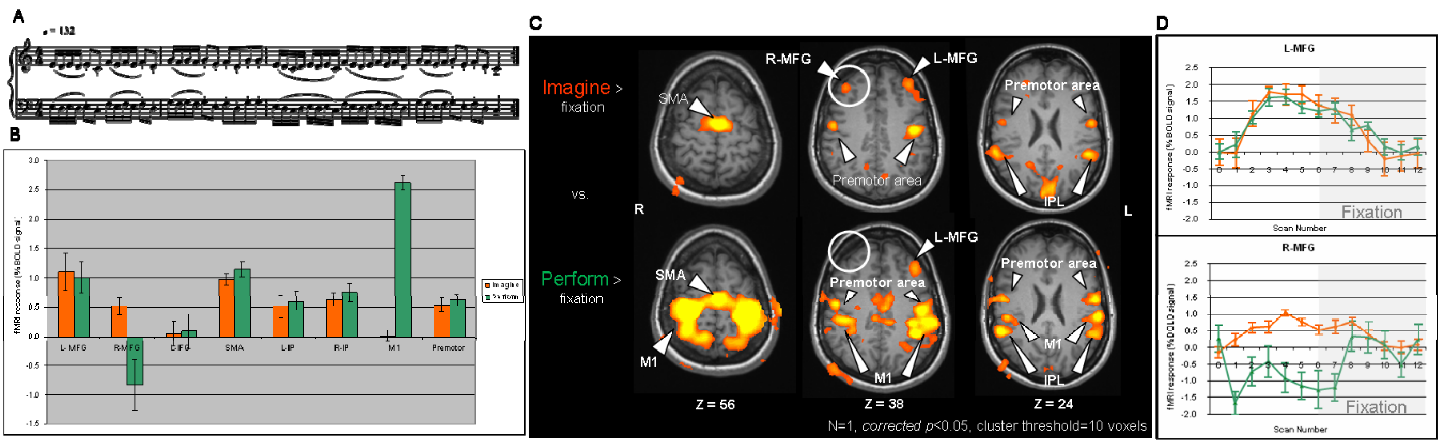

Fig. 1. A: Musical score of the imagined/performed extract. B: Significantly activated regions for imagery and performance (both versus fixation, N=1, corrected p<0.05, cluster threshold=10 voxels). C: average % BOLD signal of ROIs. D: Time course of BOLD signal of L-MFG and R-MFG. SMA: supplemental motor area, MFG: middle frontal gyrus, M1:primary motor cortex, IPL: inferior parietal lobe.

Discussion

For this professional pianist with vivid imagery skills, motor performance showed left sided activation of the MFG, while performance imagery showed bilateral activation of the MFG. We are currently considering two possible interpretations of this finding. Firstly, there may be a fundamental difference in the cognitive processing requirements for imagery as compared to performance. Secondly, there may be a shift of attention, or change in level of attention, for imagery as compared to performance. Feedback provided by the participants studied to date suggests that it is the quality of attention that is different between task conditions. That is, although ideally a musician would wish to focus attention on all aspects of their performance (e.g. musical expression, motor control, auditory feedback) they may tend to focus on motor execution in particular. However, in the case of imagery, attention turns to the planning of finger movements, the imagined sound and the spatial orientation on the instrument, which is less demanding in terms of motor control but may be a more cognitively demanding task. We suggest that it is this change/increase in attention that causes the increased (i.e. change from unilateral to bilateral) activation of MFG. This interpretation is consistent with a report by Bollinger et al (2010) that the right posterior MFG region has been specifically identified as being active during the expectation period of spatial attention tasks and the report by Pedersen et al (1998) that the left MFG is associated with motor readiness.

Conclusion.

MFG is thus a potential neural substrate for musical imagery and could provide an index to monitor the effectiveness of imagery as a learning strategy.