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Research Article

Functional Organization of Familiar Melody Recognition as Revealed Using Octave-Generalization of Melodic Structure

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Abstract

This fMRI study investigates the brain structures that underlie the process of music recognition with familiar melodies. Based on the "mysterious melody" illusion [1]. In our experiment, we tested how the brain recognizes well-known melodies. We also identified the different places of activation in the brain when listening to identical tunes which were the same but had been distorted.

Seventeen (n = 17) subjects were initially screened for normal music ability and normal hearing. Firstly, in a scrambled version they listened to a popular melody without lyrics. However, this melody was not presented rather in a conventional way that they would be able to recognize. The melodies were presented in a cross three different octaves in this phase. Subsequently, in the second phase, we asked them to listen to the same melody again but this time we used the original melody or another very similar melody. Finally, we presented them with the scrambled melody again and asked the participants after each presentation to rate the extent to which they recognized it for the final time, using a four-point scale. Consequently, we were able to compare how the brain responds in each of the phases. In doing so, we compared brain activation after each presentation of stimuli. This study identified activation in the bilateral auditory cortices, bilateral superior temporal lobes, bilateral frontal orbital cortices, in the right precentral gyrus and left inferior frontal gyrus, all of which have been implicated in the neural pathways of melody recognition.

Keywords: *Functional Organization; Octave-Generalization; Bilateral Superior*

Introduction

This fMRI study investigates the brain structures that underlie the process of music recognition with familiar melodies.

Materials and Methods

Behavioral stimuli

Consisted of 80 famous melodies (Frescobaldi 2.0.5) presented in different versions. Melodies were selected according to which were the most recognisable. 36 Participants were asked to listen to famous melodies with octave-scrambled versions of these melodies. The pitches of some octave-scrambled versions had been temporally re-ordered. Each trial consisted of a pre-reveal, reveal and a post-reveal presentation. On each presentation, the participants were asked to rate how familiar they found the melody on a 4 point scale (it was limited to 4 points to provide comparability with measures which can be taken in the fMRI environment).

Appropriate statistical tests were performed in order to decide which of the scrambled conditions were most appropriate to use in the main fMRI experiment.

Methods

Screening of participants using Montreal Battery of Amusia [2].

Suitable participants take part in the fMRI. Interleaved Silent Steady State [3] method of data acquisition.

Experimental design

The study is entirely a within-subjects design. Each participant take part in two conditions. A total of 60 different stimuli used. The total scan time was approximately 45 minutes (Figure 1). The duration of each trial was approximately 42 seconds. In each trial, participants listened to an octave-scrambled version of a melody (pre-reveal condition) following which they asked to indicate how familiar they find the melody on a 4-point scale ranging from "Not at all familiar" to "Completely familiar". After this, participants on 50% of trials, listen to an octave unscrambled version of the same melody (reveal condition) or, on 50% of the trials, an appropriate control stimulus (control condition), followed by a rating of familiarity. After this, the octave-scrambled (post-reveal) version of the melody played again, followed by a familiarity rating.

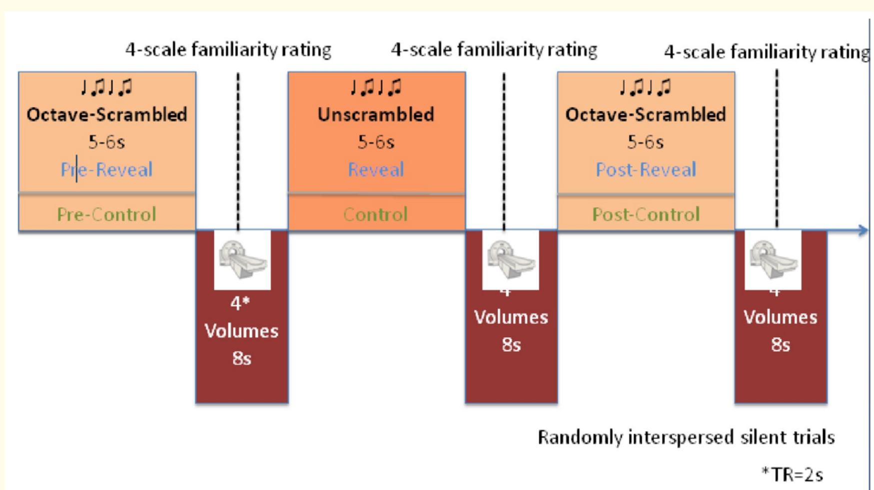
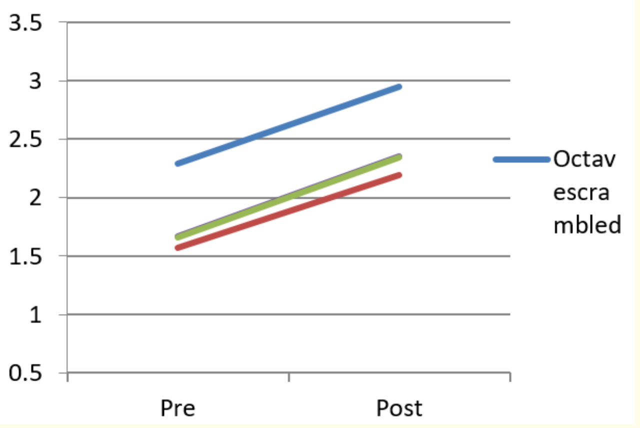


Figure 1: *Experimental design.*

Results

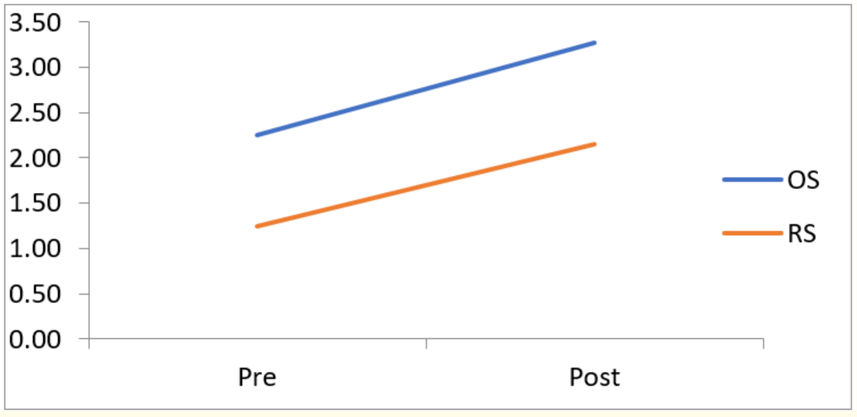
The graph shows the means for the pilot behavioural. It shows the recognition of familiarity in all conditions (pre and post). Obviously, octave scrambled is the most recognizable from the other conditions while random octave scrambled is on the lower. Specifically, its worthy that the shuffled version and the random octave scrambled version are close to overlap between the pre and post conditions.



Graph 1

fMRI behavioural data

Repeated t-tests showed that there was significant effect on the position (pre, post) $F(1,16) = 76.83$, $p < 0.001$ and on the type (Octave scrambled, random scrambled), $F(1,16) = 105.52$, $p < 0.001$. Although, there is no interaction for position and type. $F(1, 16) = .883$, $p > 0.001$.



Graph 2: *Graph of means of fMRI behavioural data. The results are similar to the pilot behavioural results.*

Reveal vs baseline

The reveal vs baseline contrast reveals significant activation in the superior temporal gyrus supplementary motor cortex, cerebellum, the lingual gyrus and the occipital pole, taken from the MNI stereotaxic space.

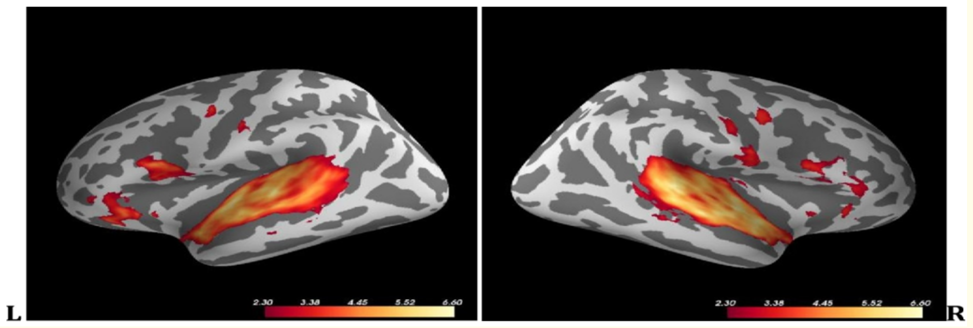


Figure 2

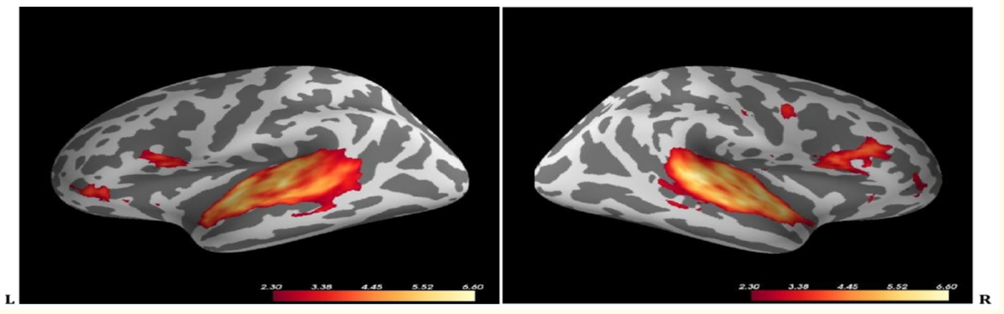


Figure 3

Post octave scrambled vs baseline

The post octave scrambled vs baseline contrast reveals significant activation in the superior temporal gyrus, Heschl's gyrus, paracingulate gyrus, cerebellum (right), precentral gyrus, cerebellum (left) taken from the MNI stereotaxic space.

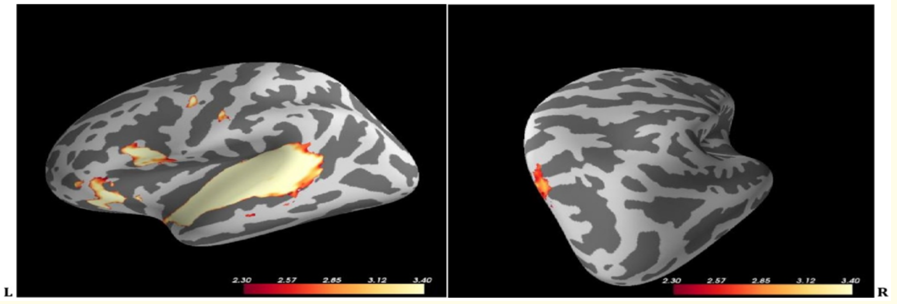


Figure 4

Random scrambled-Octave scrambled

The random scrambled-octave scrambled contrast reveals significant activation in postcentral gyrus in the precuneus and in the supplementary motor cortex taken from the MNI stereotaxic space.

Discussion and Conclusion

The fMRI analyses of the original melody vs. "baseline" (silence) revealed activity in the bilateral auditory cortices, bilateral superior temporal lobes, bilateral frontal orbital cortices, right precentral gyrus and left inferior frontal gyrus.

The fMRI contrast of interest, based on the interaction term, revealed differential activity in the right inferior parietal lobe, right angular gyrus and left intraparietal sulcus. These findings support the recruitment of a bilateral network of supramodal brain. In the behavioural test we contrasted the effects of four different categories of melody which depended on behavioural ratings of the familiarity of melody. The results from the behavioural test showed that in the post-reveal category, the ratings of familiarity were significantly better for the octave-scrambled condition than for the other conditions (randomised-note, retrogradation, shuffled note.

The results confirmed our hypothesis about finding different activation in the pre-reveal and post-reveal stages for the neural processes of melody recognition. Specifically, we have observed activation during the condition of original melody to the baseline in bilateral auditory cortices, bilateral superior temporal lobes and bilateral frontal orbital cortices. Furthermore, significant activation was also observed in the right precentral gyrus and left inferior frontal gyrus, which are involved in the neural pathways of the melody recognition. Our results are supported by previous studies by Peretz [4] and Zattore., *et al*. [5]. They found that tonal pitch information included the neural system and right frontal and temporal cortices. However, they also found activation for the recognition of melodies in STC. Additionally, they observed that there was interaction in both cerebral hemispheres. In Peretz's [2] study, they found significantly greater activation in the right Superior Temporal Sulcus when participants were listening to the familiar melodies. Our study confirms their prediction of activation in the inferior frontal gyri and the planum temporale, when the subjects listened to familiar melodies in different sequences. These first studies found activation in the right superior temporal gyrus and they suggested that when we listen to familiar melodies relative to unfamiliar ones, there is evidence of bilateral activation in the Superior Temporal Sulcus (STS). These findings have been generalized to other melodies, as well as melodies created using real instruments [6], in contrast to the tones used in the first study [1].

It is also worth emphasising that other studies have shown activation in the frontal and temporal areas when the pitch information was relative to time [7], evidence which is related to our results but in different conditions. In this study, the main contrast was between the familiar, unfamiliar and scrambled versions. Additionally, we found activation in the bilateral temporal lobes. It is significant that interactions between the frontal and temporal cortices have been examined for working memory and tonal pitch, especially the Superior Temporal Gyrus (Samson and Zatorre, 1988). The temporal lobe contains the hippocampus and plays the basic role for long term memory "modulated" by amygdale and also has a fundamental role in high-level processing. Within this study, the activation of the inferior frontal gyrus is an especially interesting activation, because many studies suggest that it plays a basic role in syntactic processing. From this point of view we can see that it plays a role in both recognising familiar melodies and syntactic processing.

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