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WHEN EARS DECEIVE YOU

PROCESSING OF AUDITORY INCONGRUENCE IN MUSICIANS

preliminary results

INTRODUCTION

Errors are an inevitable part of the learning process. When playing music, musicians expect to hear a particular pitch as a result of a particular body movement, such as pressing a key on a piano. A sound of a different pitch is perceived as an error. These errors in auditory feedback are used by musicians to monitor the accuracy of their musical performance and facilitate learning.

The aim of this project is to investigate the processing of errors, understood as a mismatch between the expected and perceived auditory feedback, in musicians. For this purpose, we developed a highly ecological, MRI-compatible keyboard instrument and used it in an fMRI task involving auditory incongruence.

METHODS

- Sixteen musicians (female, age 19-26 years old)
- Highly ecological MRI-compatible keyboard instrument (Fig.1)
- Altered auditory feedback fMRI task:
  - 8 musical scales listened to and then played, 3 times each
  - auditory feedback of one key per scale replaced with a sound corresponding to a neighbouring key (e.g. G -> G#) in half of the trials (Fig.1)
  - participants couldn't look at their hands (no visual feedback) and were not presented with musical notation, only the names of the scales (e.g. C major)

Fig.1. A photograph demonstrating the MRI-compatible keyboard developed for the experiment. Convex green stickers are used as tactile indicators. In the altered auditory feedback condition, while playing a scale (here: C major), the expected pitch (G) differs from the perceived pitch (G#) for a single key (marked in red).

ANALYSES

To quantify the correctness of musical performance, the order of key presses was recorded. Each key was assigned a unique single-character code, and each scale trial was converted to a string and then compared to a perfect performance using Levenshtein ratio, understood as:

$$L_{ratio} = 1 - (L_{distance} / string\ length)$$

where $L_{distance}$ is the number of substitutions, additions or subtractions of single characters required to transform one string into the other[1]. Statistical comparison was conducted using one-way repeated-measures analysis of variance.

Neuroimaging data were preprocessed with fMRIPrep version 21.0.0 and SPM12, analysed using SPM12. In the playing condition/feedback condition, we directly compared altered and correct auditory feedback trials using one-sample t-tests. A voxel-wise height threshold of $p < 0.001$ (uncorrected) combined with a cluster-level extent threshold of $p < 0.05$ (FWE corrected) was applied.

RESULTS

At the behavioural level, we observed no difference in the correctness of playing the scales, which was nearly perfect for all trials (Fig.2). Neuroimaging data analyses showed increased activation bilaterally in the visual cortex, in the left supplementary motor cortex, and in the inferior frontal gyrus (pars triangularis & pars orbitalis) (Fig.3).

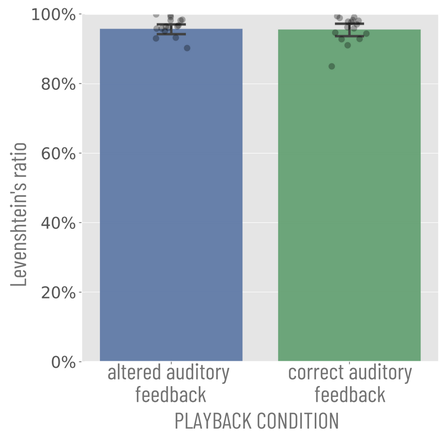

Fig.2. No significant differences in the correctness of scales between the altered auditory feedback (blue) and correct feedback (green) conditions as measured with Levenshtein's ratio. Error bars represent 95%CI. Dots represent individual means per participant.

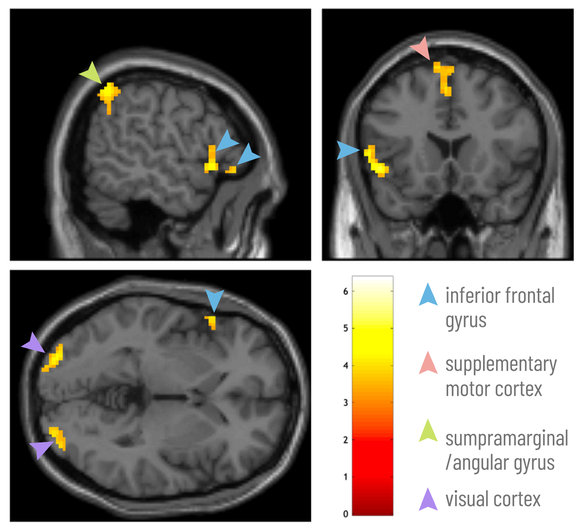

Fig.3. Significant clusters in the comparison between altered auditory feedback > correct feedback.

DISCUSSION

The performance of scales was nearly perfect for both playback conditions.
Playing scales is a relatively simple exercise, highly familiar for all musicians. Thus, the perceived incongruence between the expected and the actual auditory feedback can be attributed to the experimentally altered auditory feedback, not mistakes in performance.

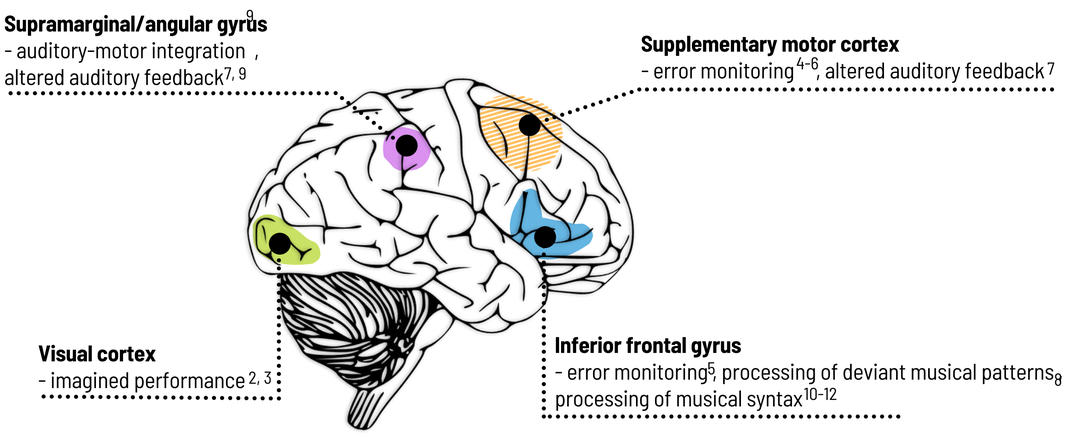

Fig.4. A summary of the neuroimaging results.

Neuroimaging data revealed a stronger involvement of regions related to visual processing while playing with altered auditory feedback compared to the correct feedback. Considering that the musicians could not look at their[2]hands, this might reflect an aspect of multisensory integration and visual imagery .
Moreover, we observed a stronger involvement of regions related to error monitoring and fine motor control (supplementary motor cortex, inferior frontal gyrus), altered auditory feedback in a musical task (supramarginal gyrus, supplementary motor cortex) and the processing and musical syntax (inferior frontal gyrus) (Fig.4.).

Despite the lack of behavioural differences between the altered and the correct feedback conditions, these results point to the strong involvement of the prefrontal-parietal network and visual areas in tone error monitoring in musicians.

REFERENCES

1. Levenshtein, Vladimir I. Soviet physics doklady. Vol. 10. No. 8. 1966.
2. Meister, Ingo G., et al. Cognitive Brain Research (2004)
3. Tanaka, Shoji, and Eiji Kirino. Frontiers in human neuroscience (2017)
4. Tabu, Hayato, et al. Neuroscience research (2011)
5. Rae, Charlotte L., et al. Neuroimage (2014)
6. Li, Chiang-shan Ray, et al. Journal of Neuroscience (2006)
7. Pfordresher, Peter Q., et al. Brain research (2014)
8. Habermeyer, Benedikt, et al. Human brain mapping (2009)
9. Segado, Melanie, et al. NeuroImage (2021)
10. Maess, Burkhard, et al. Nature neuroscience (2001)
11. Koelsch, Stefan. Music that works (2009)
12. Bianco, Roberta, et al. Cerebral Cortex (2021).

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