

NX-421: Neural signals and signal processing

MINI PROJECT

For this mini-project, we propose 3 variants and you will only do the one assigned to your group. Each of the 3 variants has a practical part that corresponds to your methods and a theoretical part that you should address and integrate in your report and recordings. Make sure you properly familiarize yourself with the instructions before you proceed.

The hand-in format is that of recorded presentations (video). Recordings should last a **maximum of 5 min.** The deliverables should also include a **written report** and a **code repository**.

Recordings Guidelines:

- Use zoom recording option
- The speech needs to be shared evenly across group members (i.e. each member should speak)
- Presenting flow:
 - Briefly present the dataset and the motivation of the mini project
 - Answer succinctly questions in the given order first starting from **(part 1)**'s practicals then theoreticals followed by **(part 2)** in a similar fashion

Written reports Guidelines:

- **4 pages max** (including images), single column, font-size 11px in Arial.
- **Submit the code** you used for solving the mini-project.
- Please, **do not** upload datasets, images or any additional content.

All deliverables should be submitted on Moodle.

Deliverables are due on **Thursday 7th November at 16:00.**

Note that this is a sharp deadline, no extensions are allowed.

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Description

Part 1 (Suggested time allocation 17th October - 29th October)

As a researcher you are interested in studying the neural processing of emotionally provocative auditory stimuli. Specifically you want to figure out what regions of the brain are activated when subjects are listening to positive compared to negative emotional musical and nonemotional - nonmusical stimuli (pure neutral tones) during fMRI scanning.

The dataset that you will use is accessible through openneuro (<https://openneuro.org/datasets/ds000171/versions/00001>).

In this dataset, participants listened in blocks of 33 seconds to positive or negative music. Music blocks were interleaved with 33 seconds of pure tone listening, following the paradigm described in Lepping, et al., 2015 (see Fig.1 of bibliographical reference [1]). The last 3 seconds of each musical block was used to make sure participants were paying attention, where they had to press a button to indicate if they found the samples to be positive or negative.

Your research question is to assess the difference of processing of music in auditory content. The acquired dataset was not preprocessed, so take into consideration at least 2 minimum preprocessing steps (motion correction and smoothing).

In order to tackle your research question you will be investigating the listed practical and theoretical questions.

Important: The dataset includes two groups of subjects and two sorts of tasks but for this project only **control subjects** and **task-music_run** will be explored.

Practicals (part 1)

Using what you learnt in the tutorials, tackle the following questions:

- 1) Concatenate all runs of interest of sub-control01 together (make sure to standardize each session before concatenation!). Apply preprocessing on all (minimum steps are motion correction and smoothing, you can decide to apply any other step you deem appropriate). You are free to either use *fMRIPrep* or more minimal *FSL*-based code as you see fit. Justify why you selected each step.
- 2) Specify the experimental design matrix to use for this subject and include this matrix (as a figure) in your report.

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- 3) Run the GLM at the level you deem reasonable and show the beta/statistical maps of each of your regressors.
- 4) Using the results of the GLM analysis and contrast vector of your choice, create the activation corresponding to the impact of positive against negative music. Please include the contrast you obtain, and report in which brain region you find maximal contrast **based on AAL atlas parcellation**.

Theoreticals (part 1)

Answer the following questions, and justify your answers (you do not need to provide the code, only theoretical answers):

- 1) Can you do the second level analysis on this dataset (all subjects)?
- 2) For this second level analysis, what contrast could you consider and to which experimental question does it give an answer to?

Part 2 (Suggested time allocation 29th October - 7th November)

Note that this part is split into 3 variants, you are assigned to one of the following variants according to your group letter.

Now you proceed to do a confirmatory analysis by employing multivariate pattern analysis methods. The goal is to find spatial maps derived from these methods and investigate which spatial map would include the regions found in the GLM analysis.

You know that different methods exist to find these spatial patterns:

- Principal Component Analysis (**variant 1**)
- Independent Component Analysis (**variant 2**)
- K-means clustering (**variant 3**)

Practicals (part 2)

Variant 1

1. Apply PCA on the subject fMRI runs.
2. Select a number of components of your choice to keep and justify.
3. Show each of the selected PCA components separately overlaid on the anatomy, in axial view only. *Note-You should assign to each PCA a number or letter to help identify it.*

Variant 2

1. Apply ICA on the subject fMRI runs.
2. Select a number of components of your choice to keep and justify.
3. Show each of the selected ICA components separately overlaid on the anatomy, in axial view only. *Note-You should assign to each ICA a number or letter to help identify it.*

Variant 3

1. Apply K-means clustering on the subject fMRI runs, considering one volume as one sample.
2. Select a number of clusters of your choice to keep and justify.

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3. Show each of the obtained centroids separately overlaid on the anatomy, in axial view only. *Note-You should assign to each centroid a number or letter to help identify it.*

Theoreticals (part 2)

Answer the following questions, and justify your answers (you do not need to provide the code, only theoretical answers):

1. You found several components. Do some of them match with relevant functional brain networks (see bibliographical reference [2])?
2. What about components that are NOT relevant networks (e.g. noise) ? How could one identify them (see bibliographical reference [3, 4]) ? [Bonus]
3. Compare the regions obtained in practical part 1.3 from GLM procedure and the spatial patterns obtained in your multivariate pattern analysis method from practical part 2.3 . Now given the original question (i.e to figure out what regions of the brain are activated) would you perform GLM or multivariate pattern analysis method? When would you apply one and when would you apply the other? Please, justify your answers.

References

- [1] Lepping RJ, Atchley RA, Chrysikou E, Martin LE, Clair AA, et al. (2016) Neural Processing of Emotional Musical and Nonmusical Stimuli in Depression. PLOS ONE 11(6): e0156859. <https://doi.org/10.1371/journal.pone.0156859>
- [2] Yeo, BT Thomas, Fenna M. Krienen, Jorge Sepulcre, Mert R. Sabuncu, Danial Lashkari, Marisa Hollinshead, Joshua L. Roffman et al. "The organization of the human cerebral cortex estimated by intrinsic functional connectivity." *Journal of neurophysiology* (2011). <https://doi.org/10.1152/jn.00338.2011>
- [3] Pruim, R. H., Mennes, M., van Rooij, D., Llera, A., Buitelaar, J. K., & Beckmann, C. F. (2015). ICA-AROMA: A robust ICA-based strategy for removing motion artifacts from fMRI data. *Neuroimage*, 112, 267-277. [10.1016/j.neuroimage.2015.02.064](https://doi.org/10.1016/j.neuroimage.2015.02.064)
- [4] Behzadi, Y., Restom, K., Liau, J., & Liu, T. T. (2007). A component based noise correction method (CompCor) for BOLD and perfusion based fMRI. *Neuroimage*, 37(1), 90-101. [10.1016/j.neuroimage.2007.04.042](https://doi.org/10.1016/j.neuroimage.2007.04.042)