Neural Correlates associated to Good/Bad Images in fMRI

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1 Introduction

1.1 Purpose

The overarching goal of the conducted project is to strategize the methods acquired throughout the coursework by performing an MRI scan. This process involves retrieving structural, resting, and functional states for the application of various processing and analytical methods. A primary focus of the project is to gain a comprehensive understanding of the methods involved in acquiring an MRI scan based on the MRI sequences predefined on the scanner. Once all datasets are acquired, the objective is to apply relevant techniques such as brain extraction, segmentation, and arterial spin labeling.

In the case of this project, the neural response of emotionally balanced visual stimuli is investigated. The experiment utilized a carefully curated dataset of images categorized as highly positive, highly negative, and neutral to examine brain activation patterns associated with emotional processing. A multimodal approach is applied, combining structural, functional, and perfusion imaging techniques to provide an analysis of brain structure and function in the context of emotional processing.

2 Methodology

2.1 Data Acquisition

Images are acquired from a 28-year old male volunteer utilizing a Siemens Prisma MRI scanner with a magnetic field strength of 3T. A 64-channel birdcage head coil is used to acquire images of the brain during both resting state and functional tasks. The data was recorded with a repetition rate (TR) of 1900 ms and an echo time (TE) of 2.52 ms for a total acquisition time of 24 minutes. A total of three datasets were acquired during the data acquisition process, including: structural, resting state, and task. Structural data provides an overview of the anatomy of the brain using T1-weighted and T2-weighted images. Obtaining resting state images entails capturing images when the participant is at an idle state where no task is being performed, however, the patient remains awake. In contrary, the task involves introducing a stimuli to the participant and measuring their corresponding response. This is further explained in the succeeding section.

2.2 Experimental Design for Functional Task

The experiment was conducted by utilizing the equipment presented in Figure 2. The video monitory, Figure 2a was used to monitor the response of the participant in real-time given by the bi-manual cylinders (Figure 2b). Positive and neutral responses were characterized by the blue button, whereas negative responses were indicated by the yellow button.

The functional task sessions investigated the emotional responses and associated brain regions corresponding with an emotional driver. The stimuli are divided into three categories, with images eliciting either highly negative, highly positive, or neutral responses. A total of 100 images were shown to the participant, 40 of which were negative and positive, and 20 of which were neutral.

(a) Negative image (b) Positive image (c) Neutral image

Figure 1: Presented stimuli images

Figure 1 shows an overview of the presented stimuli. The participant viewed a series of images presented on a video monitor while in the scanner. The trial lasted 24 minutes, with the stimulus displayed for 8 seconds at a TR and TE of 1900 ms and 2.52 ms, respectively. The functional task employed a three-class dataset derived from the Image Sentiment Polarity collection on Kaggle [1].

Table 1: Task structure parameters

Time Per Trial	14 seconds
Stimulus Duration	8 seconds
Total Acquisition Time	$\approx 24min$

2.3 MR Imaging Protocol and Analysis

When working at close proximity with the MRI scanner, it was ensured that both the participant and group members adhered to the MRI safety protocols. This involves considerations such as the removal of all metallic materials prior to entering the MRI zone.

Brain extraction on T1-weighted and T2-weighted tasks was achieved using the **ITK-SNAP** software for semi-automatic active contour segmentation. The process entailed adjusting the contrasts of the regions of interest relating to the brain. This tool allows for the ability to segment and visualize the corresponding results. For T1-weighted images, the original file was adjusted in **FSLeyes** to contain the field of view spanning the upper neck to the top of the head. Both T1-weighted and T2-weighted images were extracted using **FSL**.

The Independent Component Analysis (ICA) was performed using **FSL - Melodic ICA** in conjunction with **FSL BET** for brain extraction. Data selected as the input to **Melodic** with the main structural image being the extracted T1-

Table 2: Data acquisition parameters

Patient Gender	Male
Age	28-years old
Height	5.6 Feet
Weight	220 lbs
Handness	Right Handed
Magnetic Field Strength	3 Tesla (T)
MR Manufacturer	Siemens
Manufacturer Model Name	Prisma
MR Acquisition Type	2D
RF Coil	64-channel birdcage
Coil Type	64-channel birdcage
Imaging Frequency	123.25 Hz
Slice Thickness	2 mm
Echo Time	2.52 ms
Acquisition Time	24 min
Repetition Time	1900 ms
Flip Angle	79
Voxel Size	2mm x 2mm x 2mm
Number of Trials	100
Time Per Trial	24 seconds
Equipment Used	Video Monitor; Two Button Response

weighted image. The process entailing acquiring functional MRI (fMRI) task and analysis involves the utilization of of **FSL** for brain extraction and **FSL - FeatQuery**. This involves registering the extracted T1 structural image with the MNI template of **FSL FLIRT**.

Finally, resting-state arterial spin labeling (ASL) acquisition and analysis is performed by leveraging the tools in **FSL ASL BASIL** software. For functional tasks, **PsychoPy** was used to design functional tasks and facilitate the experimental workflow, enabling the download of all relevant files generated during the experiment. These files were subsequently processed and analyzed using **FSL** and **ITK-SNAP** for imaging analysis. A combination of the aforementioned softwares allow for the successful application and statistical translation of the acquired raw MRI data for both structural and functional tasks.

(a) fMRI monitor

(b) Bi-manual cylindrical buttons

Figure 2: Equipment used

3 Results

3.1 Pre-Processing

Images acquired from the MRI scan are susceptible to artifacts and effects of noise. It is expected that the participant may exhibit minute movements during the scanning processing which may impede the final result. To minimize any artifacts relating to movement, motion correction is applied. Additionally, for improved statistical power, slice timing correction is applied as the TR value is greater that 1 second. Spatial smoothing is also applied in the pre-processing stage for the reduction of noise while simultaneously preserving valid activation regions. Other complimentary methods include the normalization, temporal filtering, B_0 unwarping, and brain extraction of data.

3.2 Tasks

3.2.1 Task 1: Acquiring Structural MRI Sequences

The following task entails acquiring T1-weighted with an Magnetization Prepared Rapid Gradient Echo (MPRAGE) sequence and T2-weighted structural images with a FLAIR sequence. The method of scanning is ensured to take place from the top of the head to the upper neck.

Figures 4 and 5 represent the extracted brain segments of T1-weighted and T2-weighted images, respectively. This is achieved using **ITK-SNAP** throughout the extraction and segmentation process, removing the outer skull. Figure 4b showed excellent contrast between gray and white matter, allowing for precise delineation of brain structures. It showed clear differentiation between gray and white matter, detailed cortical and subcortical structures visible, and whole-brain coverage from the top of the head to the upper neck. This segmentation is crucial for tissue-specific analyses and partial volume correction in functional studies.

T2-weighted images, Figure 5b, provide different tissue contrast, enhancing the visibility of certain brain structures and pathologies. We can observe enhanced contrast for CSF and white matter, improved visualization of potential white matter lesions or edema, and the complementary information to T1-weighted images for comprehensive structural analysis. The combination of T1 and T2-weighted imaging provides a robust foundation for anatomical reference, tissue segmentation, and potential detection of structural abnormalities.

3.2.2 Task 2: Acquiring Resting-state MRI and Analysis

A resting-state Blood Oxygen Level Dependent (BOLD) fMRI sequence is acquired by taking into consideration an optimal TR of the BOLD sequence. Per the information tabulated in Table 2, the TR value is set to 1900 ms. Prior to acquiring the resting state MRI, the field map presented in Figure 3 is conducted for distortion correction. In terms of determining the ICA of fMRI, devices such as a pulse oximeter and respiration belt will assist in retrieving relevant information. The pulse oximeter allows for quantifying a patient's pulse and blood oxygen saturation during MRI scans [2]. An MRI safe respiration belt measures exhibited changes in the thoracic or abdominal circumference during respiration [3]. Such measurements provide supplemental information for developing an accurate and optimal ICA.

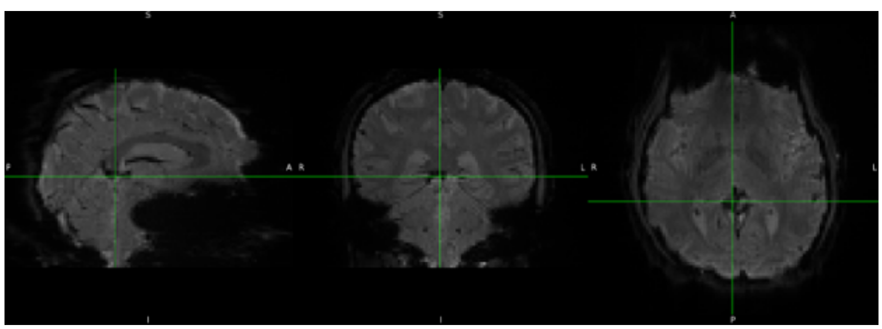


Figure 3: Fieldmap

3.2.3 Task 3: Designing and Planning a Functional Task

A carefully designed functional task was implemented to investigate neural responses to emotionally balanced visual stimuli. The task was programmed using **PsychoPy**, a widely-used software for creating psychology experiments. The code ensured randomized presentation order to prevent habituation effects and timing control for stimulus onset and duration along with integration with MRI scanner triggers for accurate synchronization. The visual stimuli presented on an MRI-compatible video monitor inside the machine and the response collection was done using two MRI-compatible button boxes, one in each of the participants hands with one being for positive and the other being for the negative response. The stimuli were presented according to the design parameters defined in Table 3.

3.2.4 Task 4: Acquiring Functional MRI Task and Analysis

Table 3: Functional task design parameters

Event Stimuli	8 seconds
Inter-Stimuli	1 second
Block Stimuli	4 seconds
Inter-Block Stimuli	1 second
Total Trial Time	14 seconds

A task based functional BOLD MRI sequence is obtained to quantify the statistical changes exhibited by the participant. Based on the preceding task, three sets of events were used to create *.txt* files structured with three columns of onset, duration, and amplitude. Three events were set to represent neutral images, highly positive images, and highly negative images with a double gamma hemodynamic response (HRF). To observe the activation of each individual EV, five contrasts were defined to compare highly negative and neutral images, and highly positive to neutral images. This prompted the rendering of the general linear model (GLM) presented in Figure 7. Using the Harvard Oxford Subcortical Axis, amygdala and ventral striatum masks were generated

Table 4: Featquery response

	Amygdala		**Ventral Striatum**	
Event	**Threshold**	**Unthresholded**	**Threshold**	**Unthresholded**
Neutral	12	605	0	922
Positive	30	605	0	922
Negative	26	605	0	922
Positive>Neutral	0	605	0	922
Negative>Neutral	0	605	0	922

3.2.5 Task 5: Acquiring Resting-State ASL Acquisition and Analysis

Table 5: Perfusion values

Region	**Observed Perfusion rate (mL/100g/min)**	**Expected Value (mL/100g/min)**
Grey Matter	101.471670	80-120
White Matter	80.780649	10-40
Cerebral Spinal Fluid	118.056711	≈ 0

Arterial Spin Labeling (ASL) data was acquired using a pCASL sequence. Perfusion values were calculated for grey matter, white matter, and cerebrospinal fluid. A perfusion value of 101.47 ml/100g/min was obtained for grey matter, indicating normal blood flow and metabolism in the cortical and subcortical grey matter regions. Whereas a value of 80.78 ml/100g/min was acquired for white matter, which is greater than the normal perfusion value threshold reported in the literature. Normal perfusion rates range between 20 ml/100g/min and 40 ml/100g/min. This behavior can be attributed to partial volume effects. A perfusion value of 118.06 ml/100g/min was acquired for the cerebral spinal fluid (CSF). This is notably higher than the expected range as

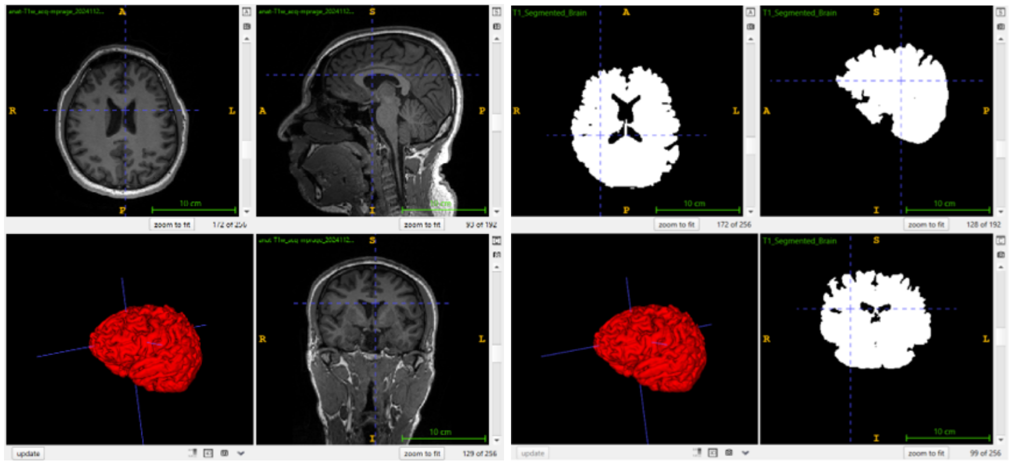
CSF typically yields low or negligible perfusion due to non-vascularized tissue. The attained values may be indicative of external effects such as noise contamination in the CSF signal or partial volume effects from surrounding grey matter.

Conclusion

The conducted projected provided an extensive comprehensive analysis of a 28-year old male participant. Data was acquired for structural MRI where the brain was segmented and extracted using T1 and T2-weighted images, allowing for a comparative assessment of grey and white matter in both image subtypes. Moreover, resting state MRI was conducted to assess the BOLD fMRI sequence of the volunteer, taking into account parameters such as TR and TE. It was inferred that supplementary equipment such as the pulse oximeter and respiratory belt will allow for detailed and accurate measurement of the relevant vital signs for enhanced processing. An integral part of the project was to design and organize a functional task which involved projecting a series of emotionally inducing responses to determine the neuronal response of the participant. Every image was randomly presented to evoke a raw response. A GLM was designed using a double gamma HRF with five contrasting events for rendering statistical observations. Finally, ASL data using a pCASL sequence culminated in perfusion values of 101.47ml/100g/min, 80.78 ml/100g/min, and 118.06 ml/100g/min for grey matter, white matter, and CSF, respectively. These indicate that a normal perfusion value was obtained for grey matter. However, it was inferred that the perfusion of white matter and CSF yielded a greater value than the expected threshold. This behavior may be attributed to partial volume effect or hindrances of noise.

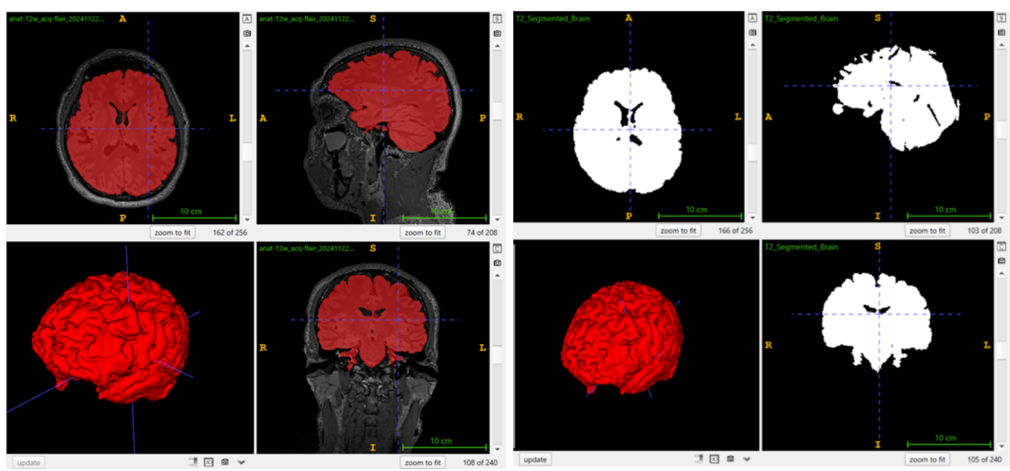
Throughout the experimental process, certain challenges relating to the functional task were faced. For instance, the total time needed for accomplishing the task effectively was undermined and there miscalculated. Additionally, certain images of the stimuli were projected twice by the end of the acquisition process. This led to a delay in time as well as minor disruptions as the participant was familiar with the projected image. Nevertheless, these challenges were negligible and did not lead to arbitrary changes of the task or corresponding results.

Appendix



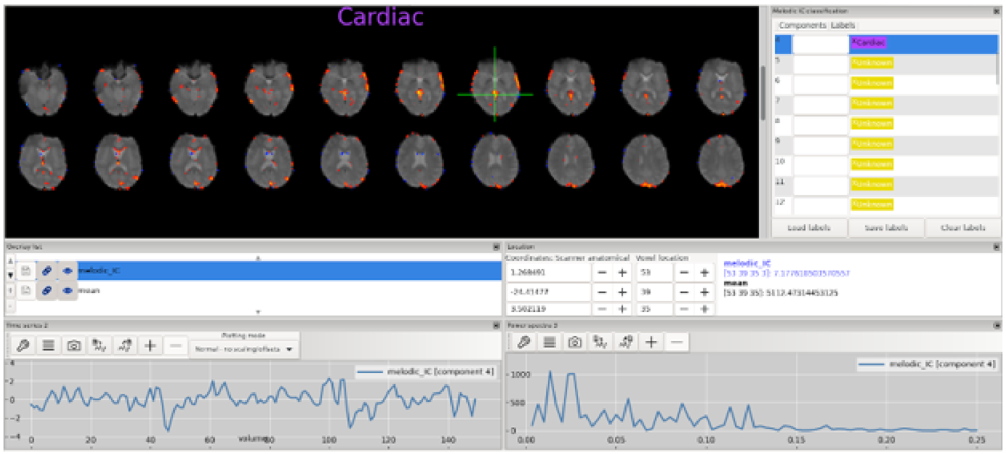
(a) Unsegmented T1-weighted image　　(b) Segmented T1-weighted image

Figure 4: Task 1: T1-weighted images



(a) Unsegmented T2-weighted image　　(b) Segmented T2-weighted image

Figure 5: Task 1: T2-weighted images



(a) Cardiac

(b) Respiratory

Figure 6: Task 2: ICA results

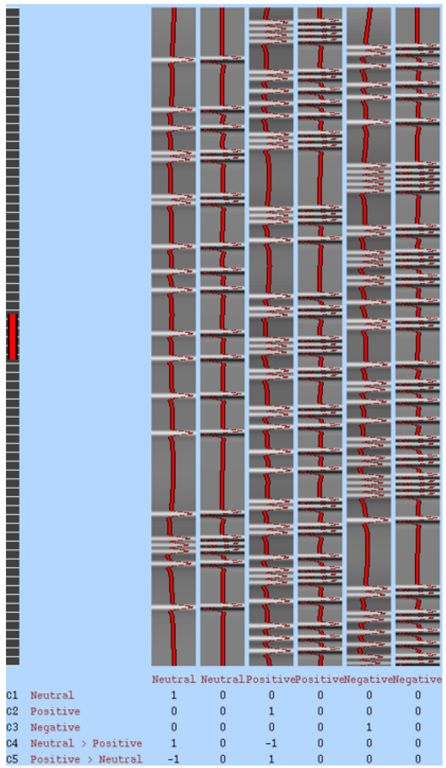


Figure 7: Task 4: General linear model

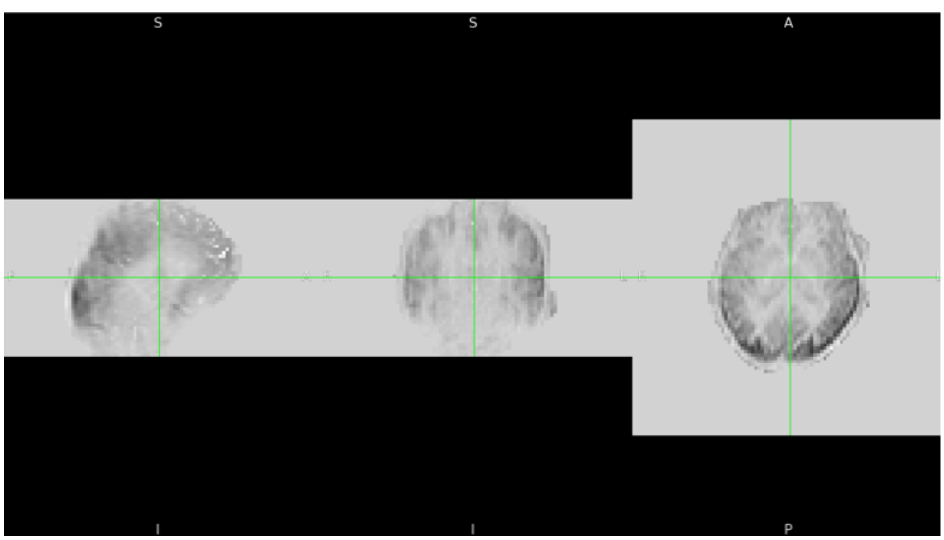


Figure 8: Task 5: Perfusion images – label then control

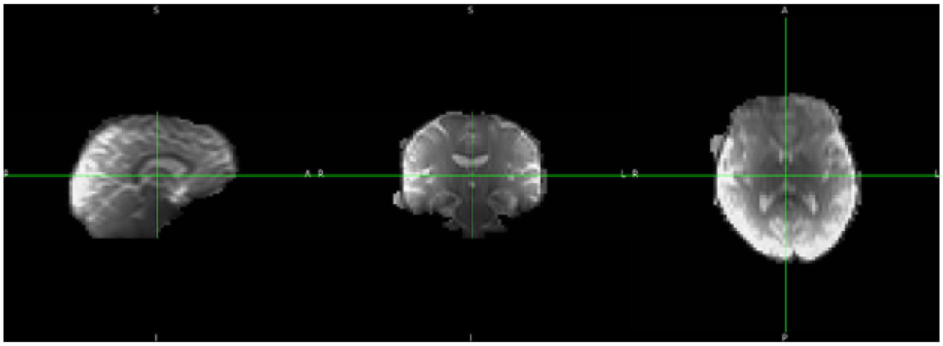


Figure 9: Task 5: Calibration image

References

[1] mexwell, “Image sentiment polarity.” [Online]. Available: https://www.kaggle.com/datasets/mexwell/image-sentiment-polarity

[2] [Online]. Available: https://www.alimed.com/mri-pulse-oximeter.html?srsltid=AfmBOor8q242I4EY2v3zG3an1BvxF6kVN2d8WuijjhcN6O8vz8afZKN_

[3] [Online]. Available: https://www.adinstruments.com/research/human/respiratory/respiratory-belts?srsltid=AfmBOopP5imSnqKaAJrT3zD2nDzJZlpD517njy_EmdZpnPr4m3uUATCN