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Lab report

Functional MRI

Grade ?
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1. Introduction

MRI is one of the key techniques to obtain structural data in humans. For some scientific studies not only structural but also processes are of interest. Here, functional MRI (fMRI) is used to combine structural and dynamic imaging. Fields where fMRI is used are typically the analysis of different tasks (visual, auditory, motoric, speech etc.) and their effects on certain brain regions. Other fields of research outside of neuroimaging are the investigation of joint movement and cerebrospinal fluid (CSF).

2. Materials and Methods

Echo Planar Imaging (EPI) is a method to obtain 2D slices in MRI. The whole slice can be acquired with one echo train within 30ms for a 64x64 matrix after a single slice selective RF excitation. The k-space is sampled in a meandering pattern due to changing the frequency encoding gradient and performing a short switch on the phase encoding gradient. Since all echoes are obtained during different echo times the total acquisition time needs to be smaller than the T_2^* relaxation time. If this is not the case the signal is lost at the end of the acquisition time. Furthermore, the spatial resolution is negatively influenced since the point-spread function (PSF) is changed by the overlaid signal decay.

Blood Oxygen Level Dependent (BOLD) measurements are techniques where fMRI is used to obtain functional brain images. Active neurons are in need of more glucose and oxygen than inactive neurons. The blood releases more oxygen close to active neurons (hemodynamic response). This leads to a difference in magnetic susceptibility between oxygenated and non-oxygenated blood. This difference can be detected with a EPI sequence due to their difference in T_2^* signal. These signal changes are at around 5% for 6s at resting state which explains why fMRI is susceptible to artifacts and complex post processing algorithms are needed.

The experiments for fMRI can be designed in the two following ways: block design and event related design. When using the block design, the stimuli is shown to the patient in blocks and multiple measurements are taken. Here the patient had to open and close her right hand for 30s, then open and close her left hand for 30s and then think about opening and closing her hand for 30s.

For an event related design, the stimuli is presented in a randomised or pseudo-randomised order to the patient. Our patient got a visual stimuli of a radial checkerboard design in a random order and press the button when she sees it. The measurement was performed with three different parameters. First with a slow design and 13 flashes, then with a fast design and 36 flashes and then with a fast design (36 flashes) and a multi band EPI.

3. Evaluation

3.1 Measurements with block design (first volunteer)

Describe the measurement parameters of the EPI-sequence:

The following parameters were used for the first experiment:

Parameter: 36 slices, 3.2 mm +0.8 mm gap, 64x64 matrix, FoV 192x192 mm²

TR 2500 ms, TE 30 ms, 130 volumes, 5 m 25 s, block 10, BABABABABABAB

One block is defined as opening and closing left/right hand or thing about this motion.

Calculate percent signal change for all regions:

The raw data is in the appendix. The data was visualized with heat maps for better understanding.

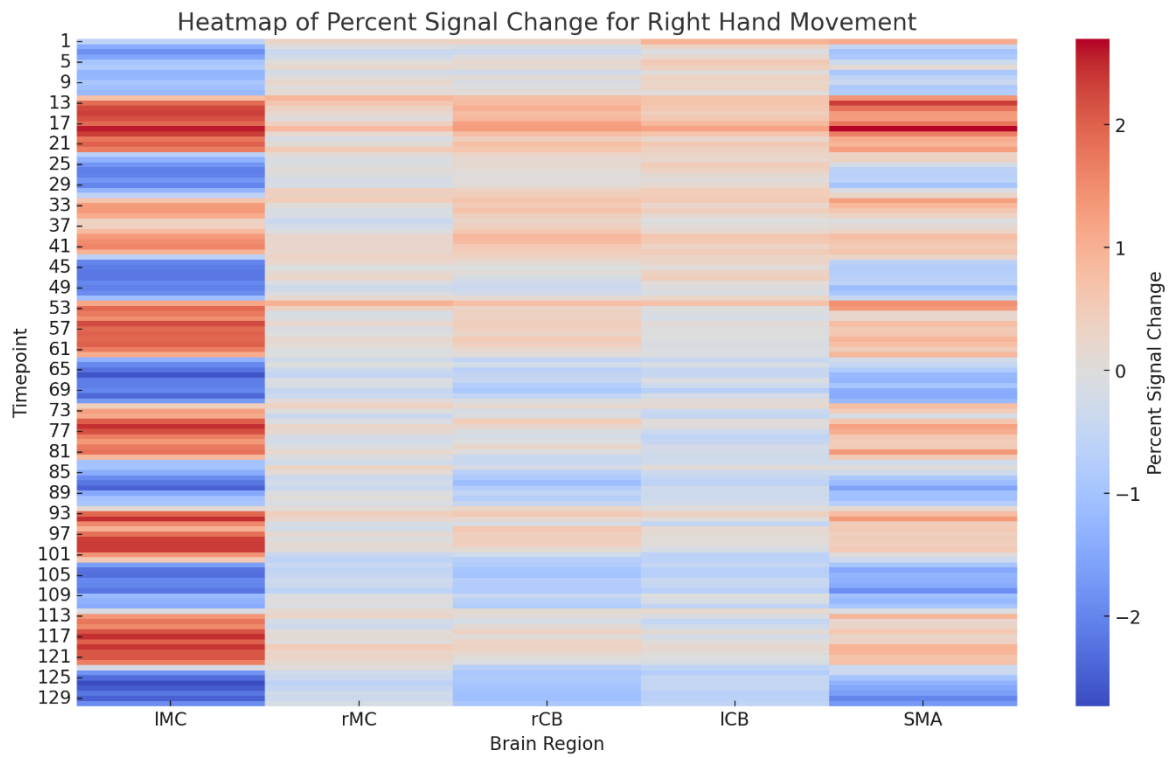


Figure 1 Heatmap of the Percent Signal Change for the right hand movement

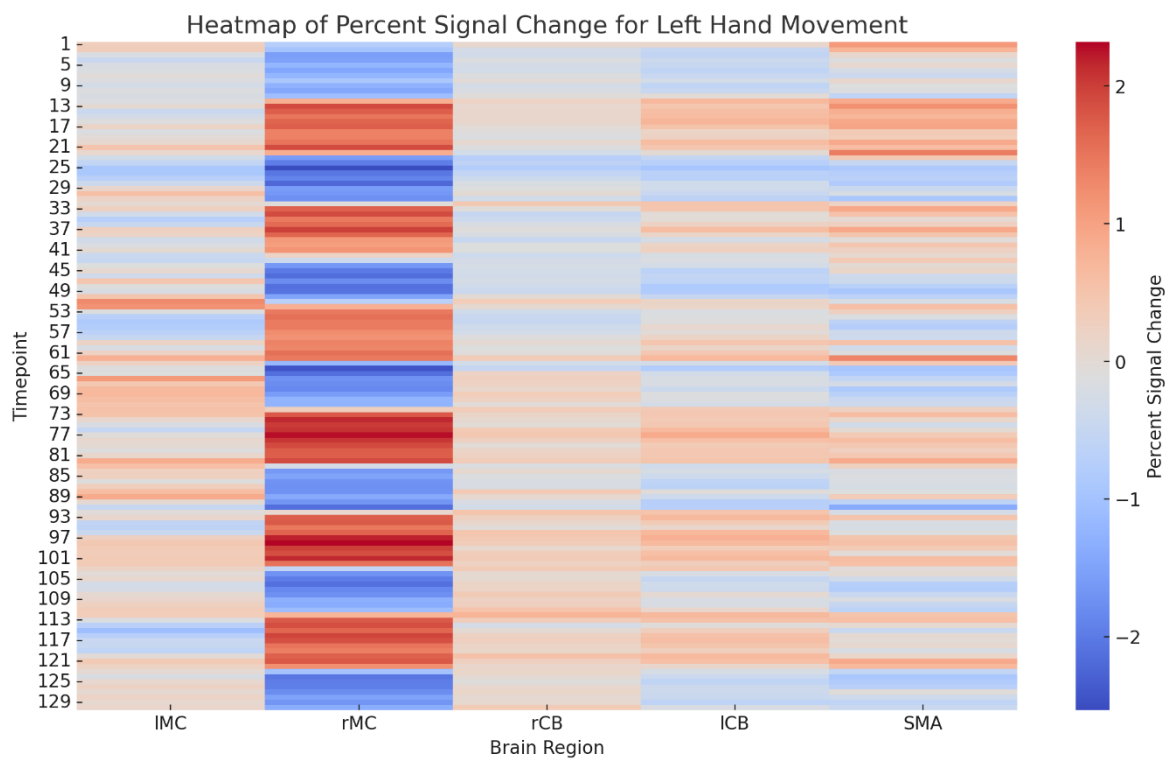


Figure 2 Heat Map for the Percent Signal Change for the left hand movement

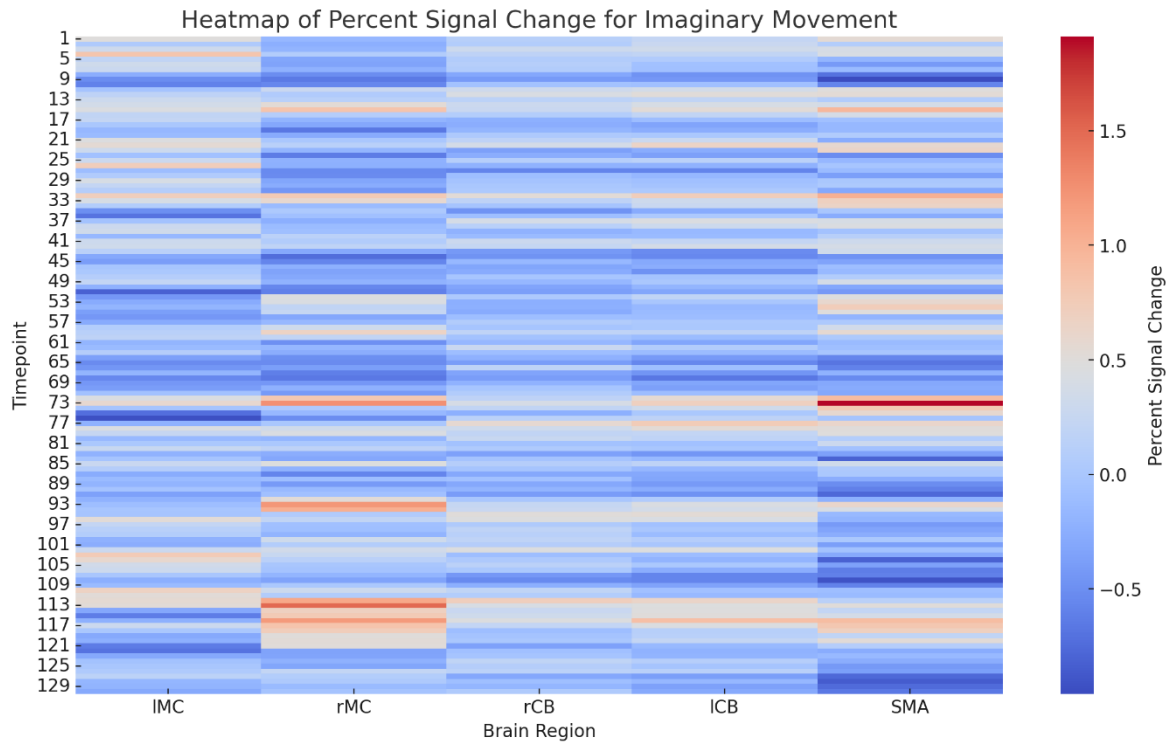


Figure 3 Heat Map for the Percent Signal Change for imaginary Hand Movements

The heatmaps visualize the percentile signal change in depending on the task. In Figure 1 it becomes visible that rMC, rCB and ICB only show small changes since their colors are all quite close together. SMA shows bigger changes in signal change and therefore blood oxygen and IMC shows the biggest fluctuation. In both IMC and SMA the block design can be recognized in the heat map since multiple timepoints show an increase or an decrease of signal. For the right hand movement (Figure 2) only rMC shows a larger fluctuation in blood oxygen. The block design is visible again. For the imaginary movements (Figure 3) the heatmap shows only a small number of increased signals and presents overall more similar signals. The block design can not be identified.

Extract t-values for the ROIs with Neuro3D:

Plots made with python were prepared for better visualization.

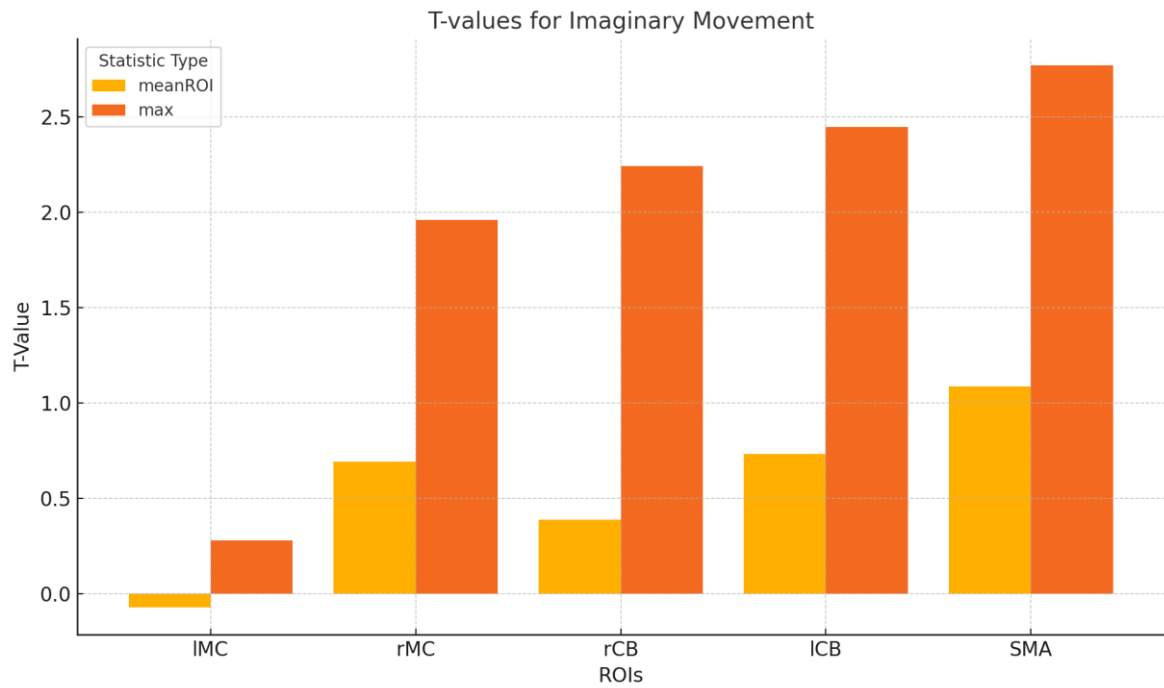


Figure 4 plot of the t -values for imaginary hand movements

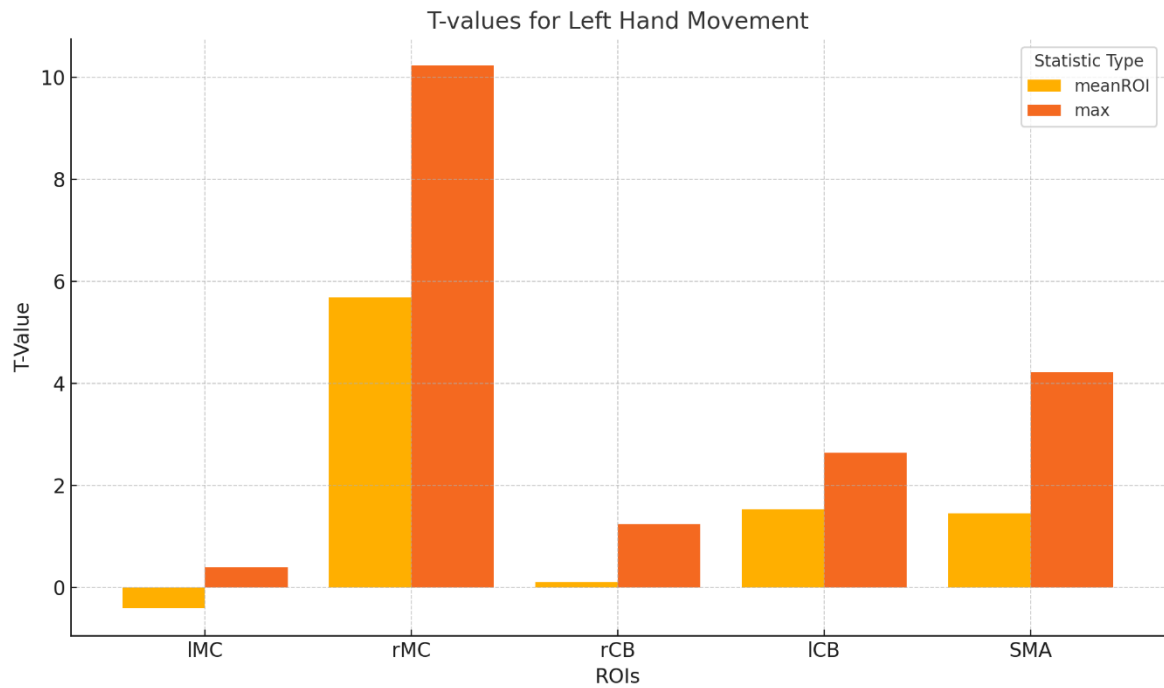


Figure 5 plot of the t -values for left hand movements

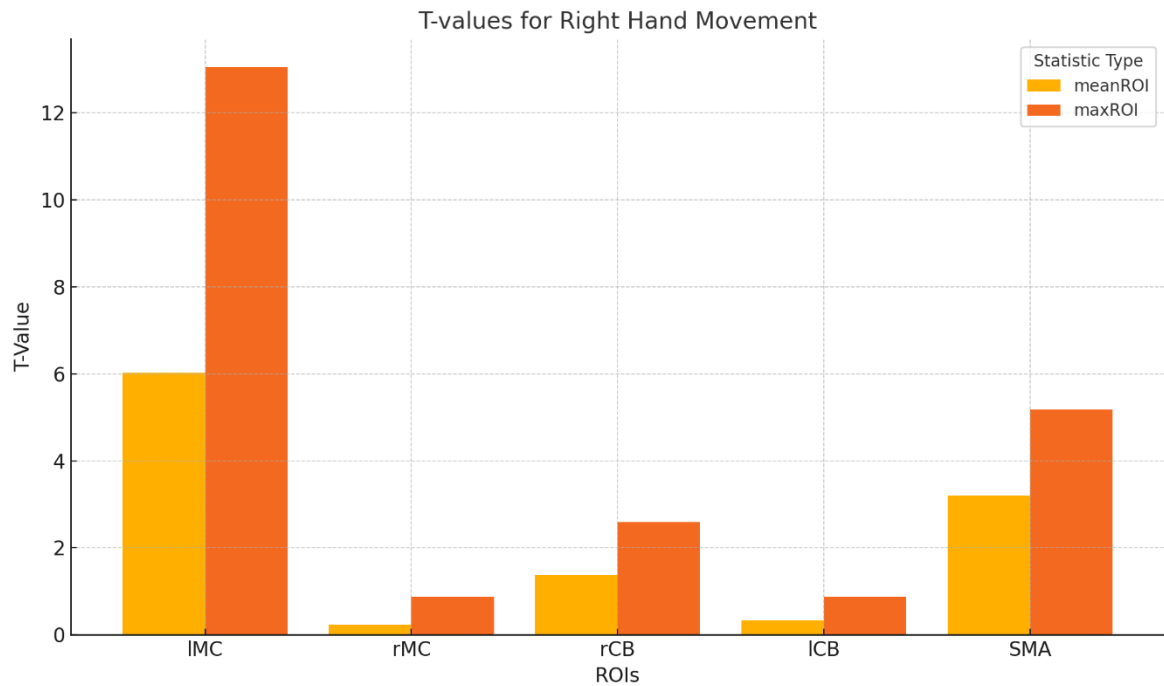


Figure 6 plot of the t-values for right hand movements

In figure 4 the t-values for imaginary movements are all quite low which indicates that those regions show only low engagement during the task. For the left-hand movements (Figure 5) only the rMC shows a t value big enough to be considered engaged for this task. All other regions have low t-values. The data of the right hand movement shows a large t-value for the IMC and rather smaller values for all other regions indicating an involvement of the IMC in this task.

•Describe the main results for the different tasks:

For left hand movements the heatmap (Figure 2) shows a strong signal change in the rMC. The pattern also fits the block design of the experiment. The t value for the rMC high at around 10 indicating a strong involvement of this region. This also matches the expectations of this experiment since the rMC is responsible for the movement of the left side of the body.

For right hand movements the heatmap (Figure 1) shows a strong signal change in the IMC and a high t value for the IMC. In the heatmap the block design is visible. This suggests that the IMC was strongly involved in this task. The IMC is strongly involved in planning tasks which matches the expectations for this brain region in this task. Since the IMC was not quantified during this experiment but should have also showed strong involvement.

For the imaginary movements the heatmap (Figure 3) does not show any large change in signal and the block design is not clearly visible. Only the IMC has a higher t value of around 6 which is lower than the max t value for the other two measurements. Since imaginary movements produce lower percent signal change it is possible that the noise of the measurement had a tremendous influence here and the data is therefore inconclusive.

5.2 Measurements with event related design (second volunteer)

Make a sketch of the setup

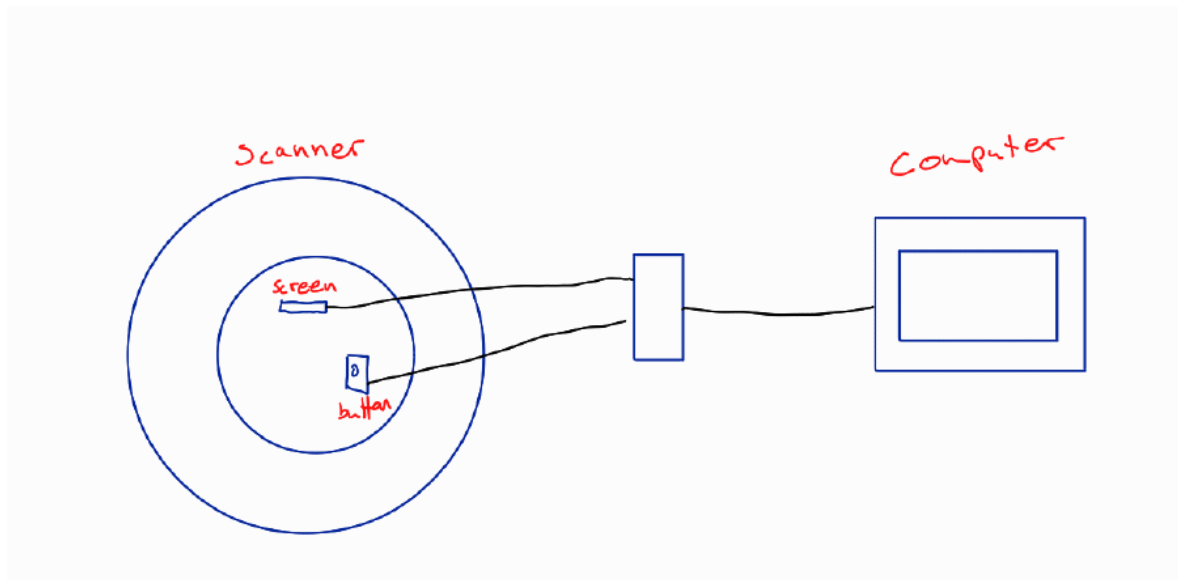


Figure 7 sketch of the setup

Calculate percent signal change for all regions

Raw data is in the appendix. The percent signal change was visualized using heatmaps for better understanding.

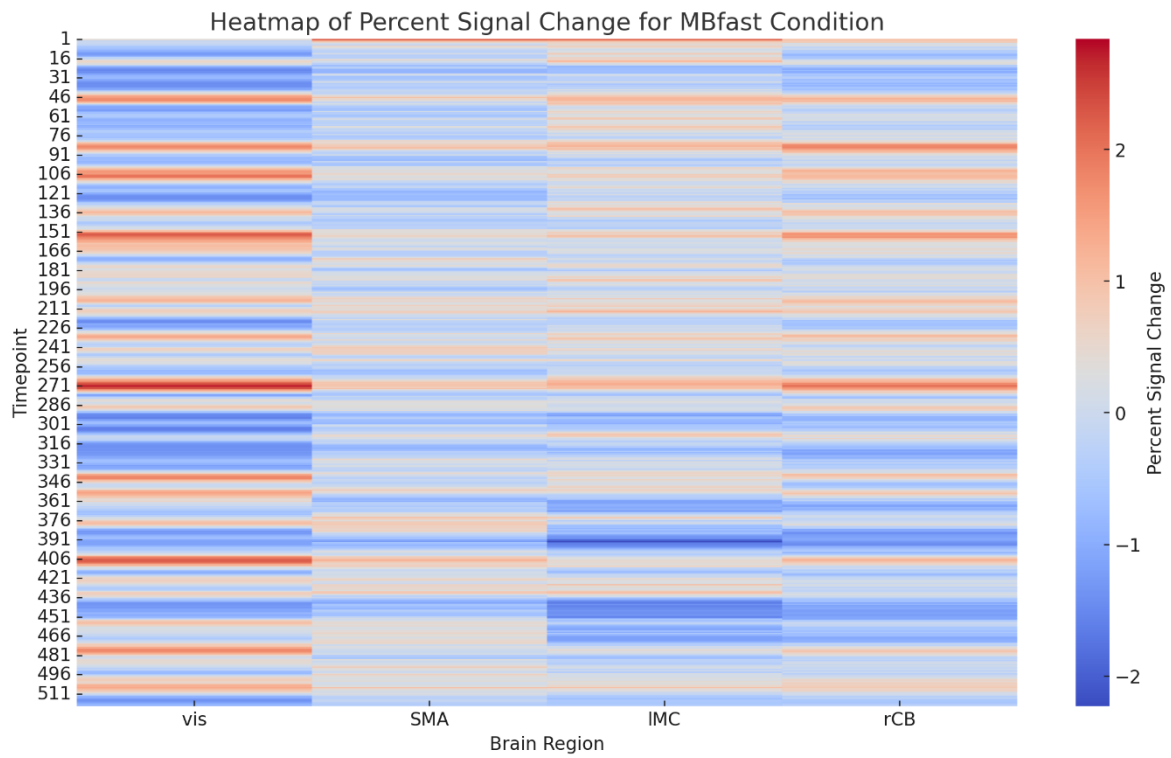


Figure 8 Heatmap of Percent Signal Change for MB fast Condition

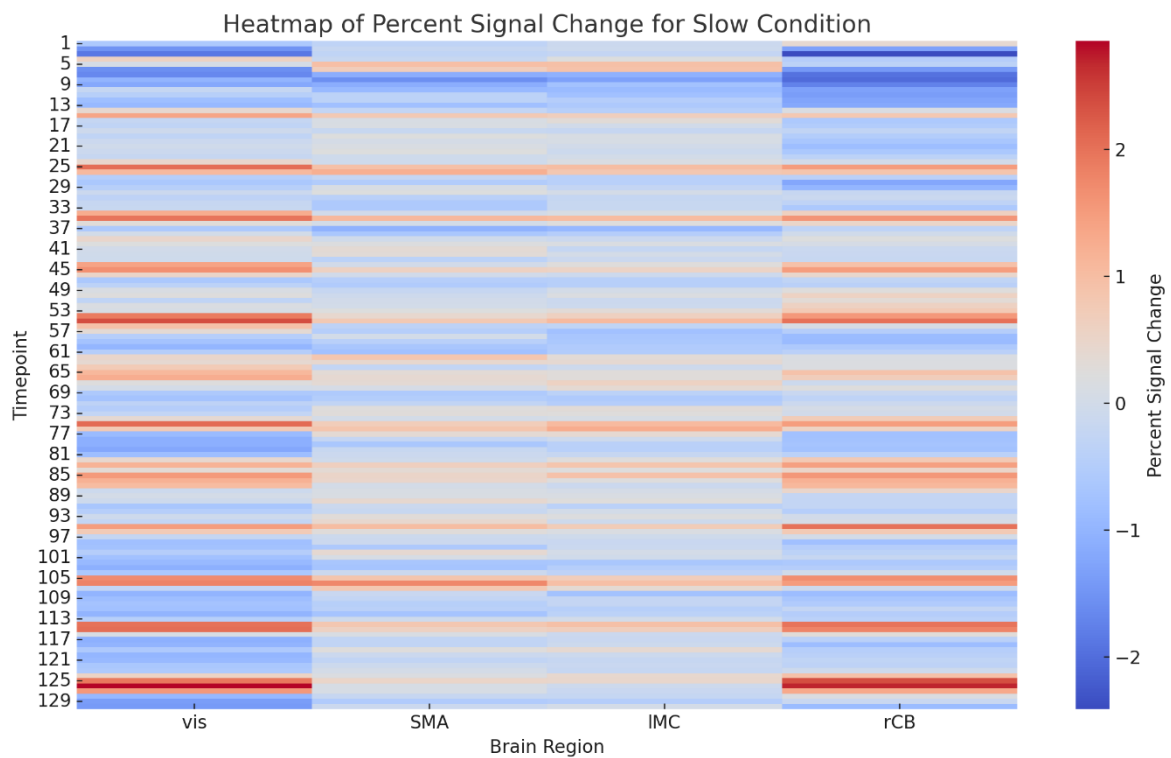


Figure 9 Heatmap of Percent Signal Change for slow Condition

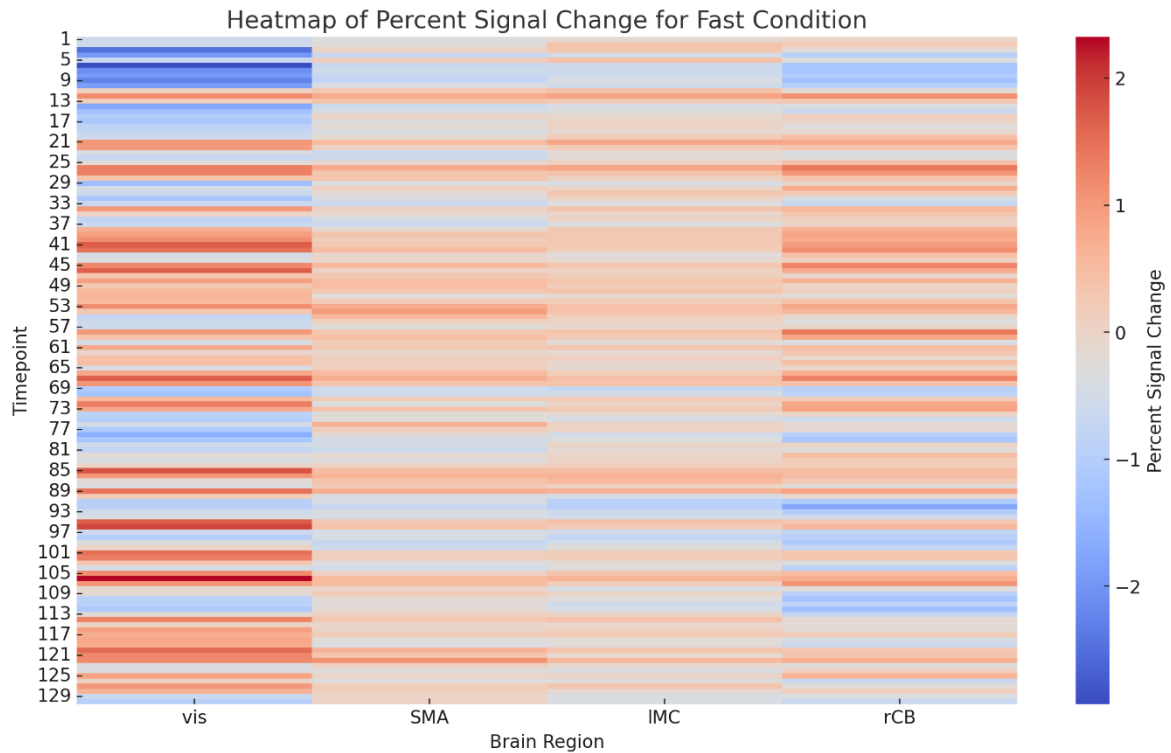


Figure 10 Heatmap of Percent Signal Change for fast Condition

In the Heatmap for the slow condition (Figure 9) it becomes visible that in SMA and IMC there was only small percent signal change while vis and rCB regions show larger signal changes. A repetitive pattern is visible which is likely caused by the visual stimuli.

Both fast and fast MB heatmaps (Figure 10,8) show that the vis area shows most signal fluctuation while the rCB region also shows some smaller fluctuations in the fast condition. SMA and IMC both only display small signal changes. A repetitive pattern is also visible here.

Extract t-values for the ROIs with Neuro3D:

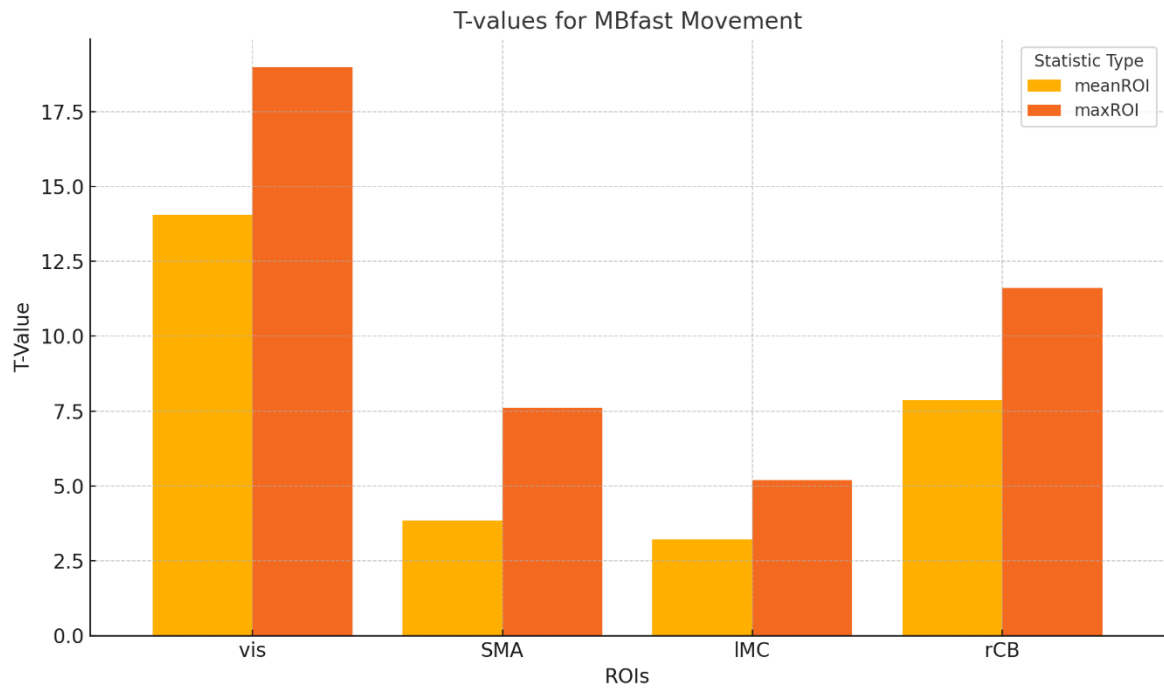


Figure 11 T-values for MB fast movements

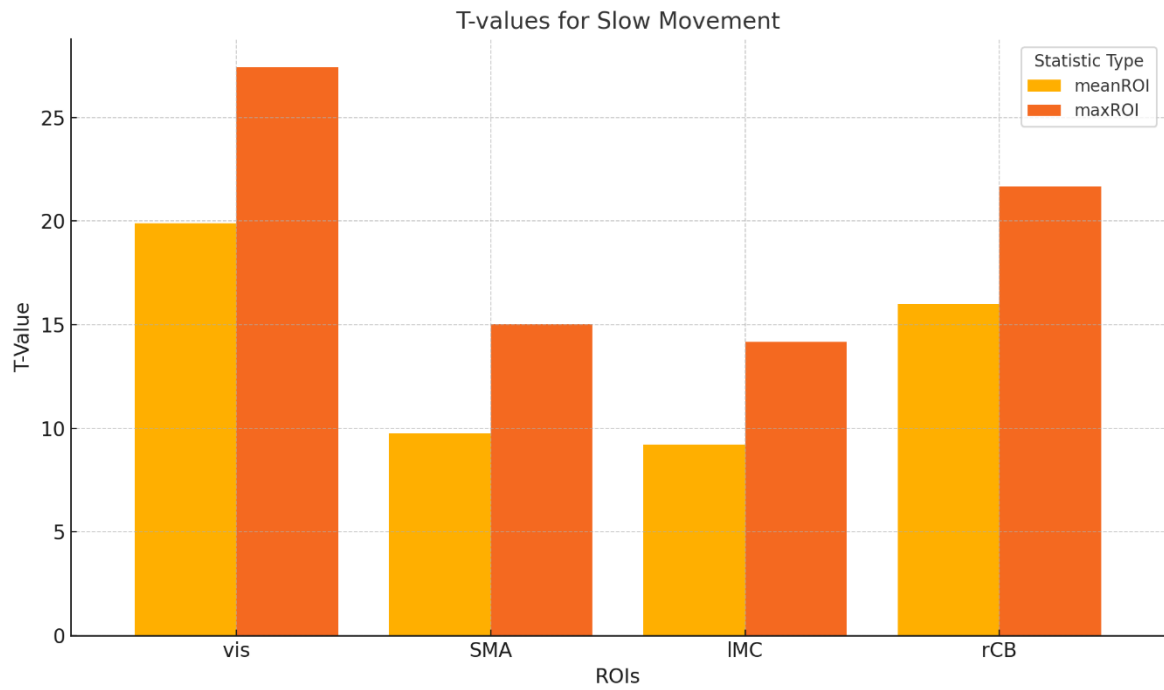


Figure 12 T-values for slow movements

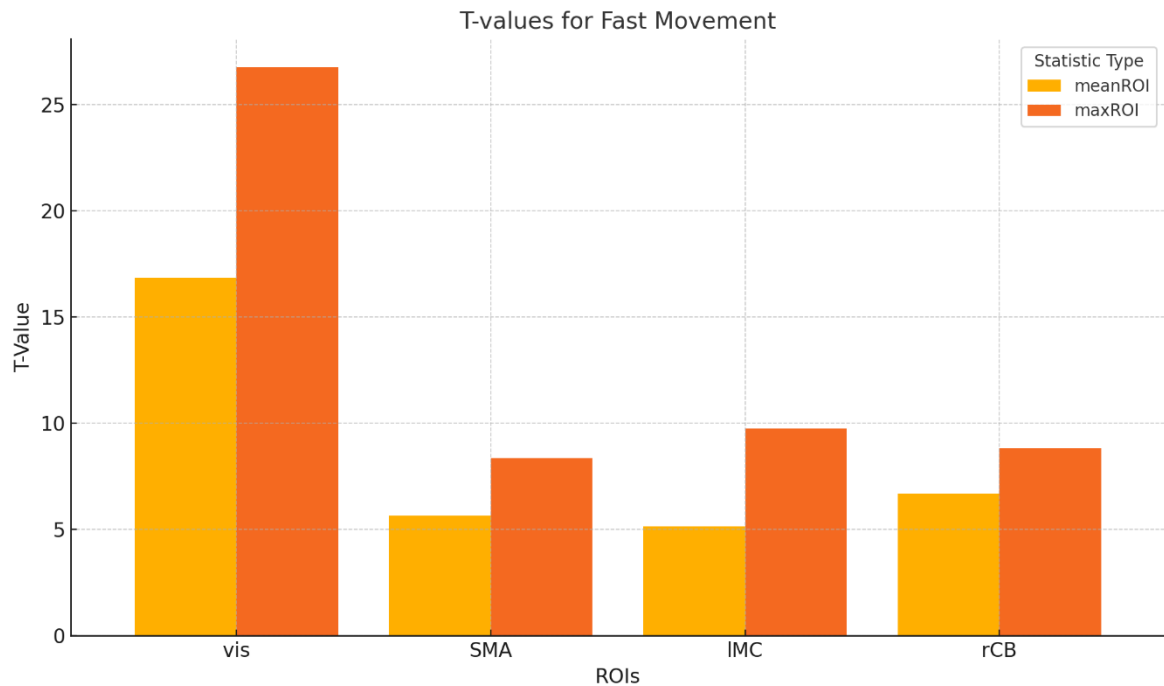


Figure 13 T-values for Fast Movements

Describe the main results for the different tasks:

For the slow movement condition all regions show a t value around 10 which indicates strong involvement while vis and rCB show the highest values.

For the fast condition only SMA and rCB do not show a t value above 10. IMC has a mean ROI value of around 10 and vis has a t value of over 15 which both indicates strong involvement in the task.

In contrast to that the fast MB condition only shows a strong involvement for the vis area while all other areas stay below 10.

Describe the main results for the different tasks

When taking the information from both the heat maps and the t value data together it becomes visible that both vis and rCB are highly engaged which was expected since the visual centre is used to see the checkerboard pattern and the rCB is needed to press the button. The fast MB condition shows different values than the fast condition because it enhances the precision of the measurement decreases the noise in fast measurements. That is why the IMC

seems to be engaged in the fast measurements while it becomes clear that it is less engaged in the fast MB measurements.

4. Discussion and conclusions

In the first experiment the block design can be recognized in the heatmaps which indicates a good signal to noise ratio. The conclusions that brain regions are active that are typically activated right or left-hand movement seems plausible. Only the values for imaginary movement show too much noise to draw conclusions. The signal for imaginary movement is expected to be lower than the signal of proper movement but it should still be possible to see activation of brain regions. For better results the sensitivity of the heatmap could be changed. Motion artifacts could also play a role and the task itself is also difficult to perform for the patient.

In the second experiment it becomes clear that for faster tasks a multiband echo leads to a better signal to noise ratio and more reliable data. Here, all brain regions associated with the task showed an increased signal and the design of the experiment is also visible in the heatmap.

5. References and Appendix

Raw data: [Appendix](#)

fMRI lab instructions