Understanding Learning-Dependent Changes in Functional Connectivity through fMRI and EEG

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Introduction

Functional connectivity, the communication between brain regions, can shift as people learn over time. To explore this phenomenon, one must look at the neural connections between regions as subjects complete a complex multisensory logic task (such as CPRO2, below). While subjects perform this task, we utilized fMRI and EEG to record the blood flow and electrical activity, respectively. We will then be able to process this neural data to calculate the functional connectivity and characterize the learning process.

Figure 1. EEG equipment (left) and fMRI (right) used to collect neural data.

Methods

- Subjects participate in three parts of this study: two fMRI sessions and one EEG session
- CPRO2 fMRI Practice Session:
  - First, subjects will complete an instruction screening of the task
    - Includes written instructions
    - Sample of audio/visual stimuli
    - Several example tasks with incorrect/correct response feedback
  - Subjects will then be brought into the fMRI and will complete a 15-minute rest period
  - After the rest period, subjects will complete 12 runs of the task
    - Each run has 12 blocks and each block contains 3 trials
  - After the task is completed, the subjects will complete a practice session survey
- CPRO2 fMRI Test Session:
  - Same as the practice session, except:
    - There are only 10 runs in the test session compared to 12 runs in the practice session
- CPRO2 EEG Session:
  - First, the RA will take the subject's head measurement (in cm), and soak the appropriate cap in a solution of water, potassium chloride, and baby shampoo for 5 minutes
  - After the EEG cap is soaked, the RA will place the cap carefully on the subject's head and adjust as needed
  - Next, the RA will place the subject under the EGI and take images of the subject with the electrode cap on
    - This determines the 3D location of each electrode
  - While the subject is running through the instructions, the RA will check the impedances to make sure all the electrodes have a good connection
  - Subject then perform the task, which lasts ~70 minutes
  - After the task, the RA checks the impedances again and starts the rest phase, which lasts for 15 minutes
  - After the rest phase, the RA will take the subject out of the "silent box" and take the electrode cap off of the subject's head, and clean the cap

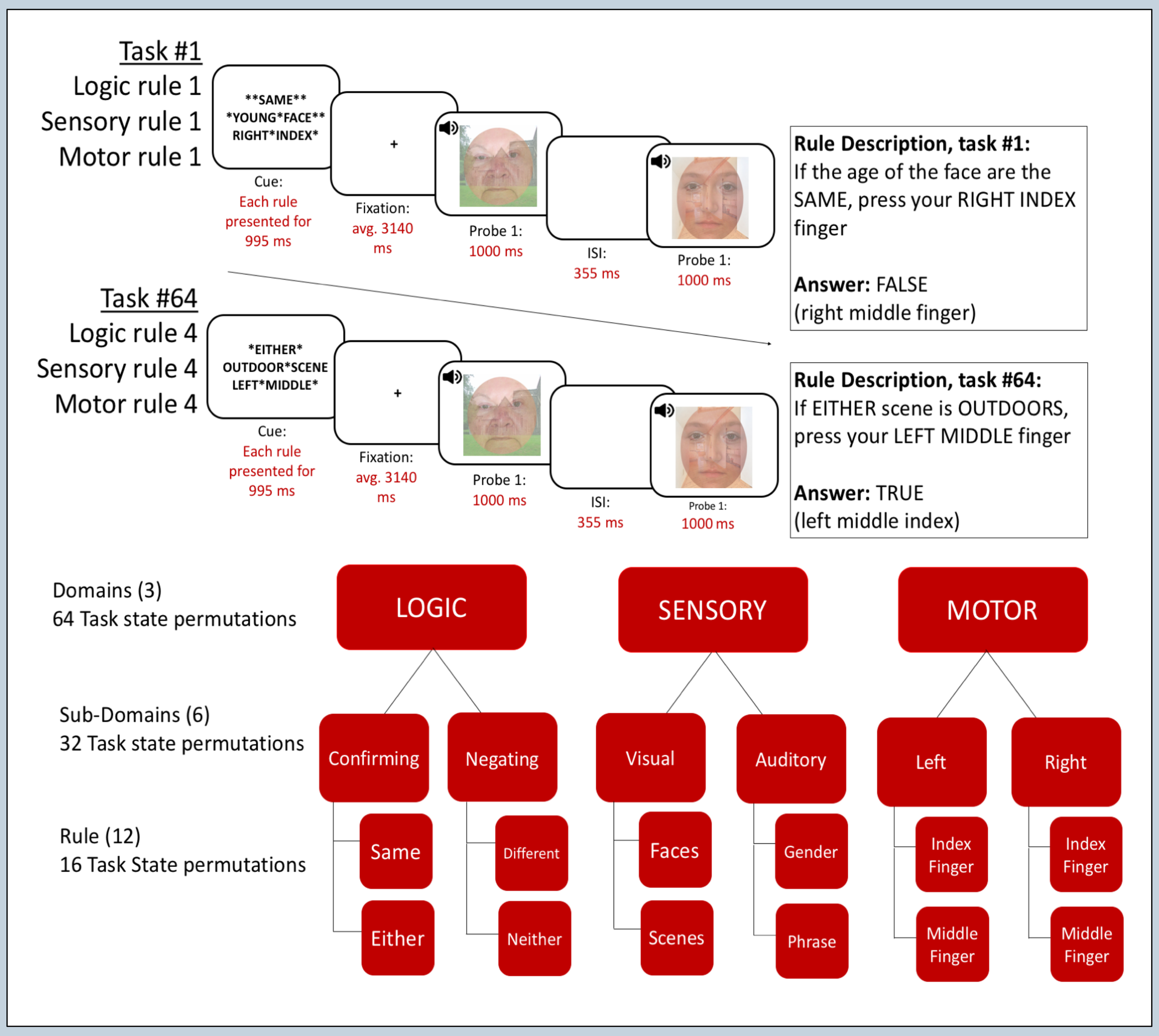

Figure 4. The CPRO2 task paradigm includes 3 different rules: a logic rule, a sensory rule, and a motor rule. Each rule includes 6 different permutations. The logic rule includes same, different, either, and neither. The sensory rule includes faces, gender, scenes, and phrases. The motor rule includes left index finger, left middle finger, right index finger, and right middle finger. For each individual trial, the subject will see one logic, sensory, and motor rule. This tells the subject what to look for in the following set of images that will appear. Each image that appears will feature a young or old face with an outdoor or indoor scene in the background, and an audio of either a male or female voice with a word or non-word phrase. The subject will see/hear two of these kinds of images and make a comparison between the two that's dependent on the task rule that appears in the beginning.

Background

fMRI:

- fMRI allows both researchers and healthcare professionals to obtain non-invasive images of the brain
- fMRI monitors changes in blood flow as measured by the BOLD signal (blood oxygenation level dependent signal)
- BOLD signal reflects changes in neuronal activity in a certain area of the brain
- BOLD signal can be analyzed to calculate functional connectivity, which refers to correlations in activity between brain regions

EEG:

- The electroencephalogram (EEG) records high temporal resolution human brain activity that is comprised of signal and noise which are intermingled with each other
- The signals received are brain signals from local field potentials that propagate to the scalp, while the noise received arise from various sources of artifacts of biological and nonbiological origin
- We can remove noise from the EEG data through various cleaning methods (e.g., ICA decomposition)
- EEG signal can also be analyzed to calculate functional connectivity

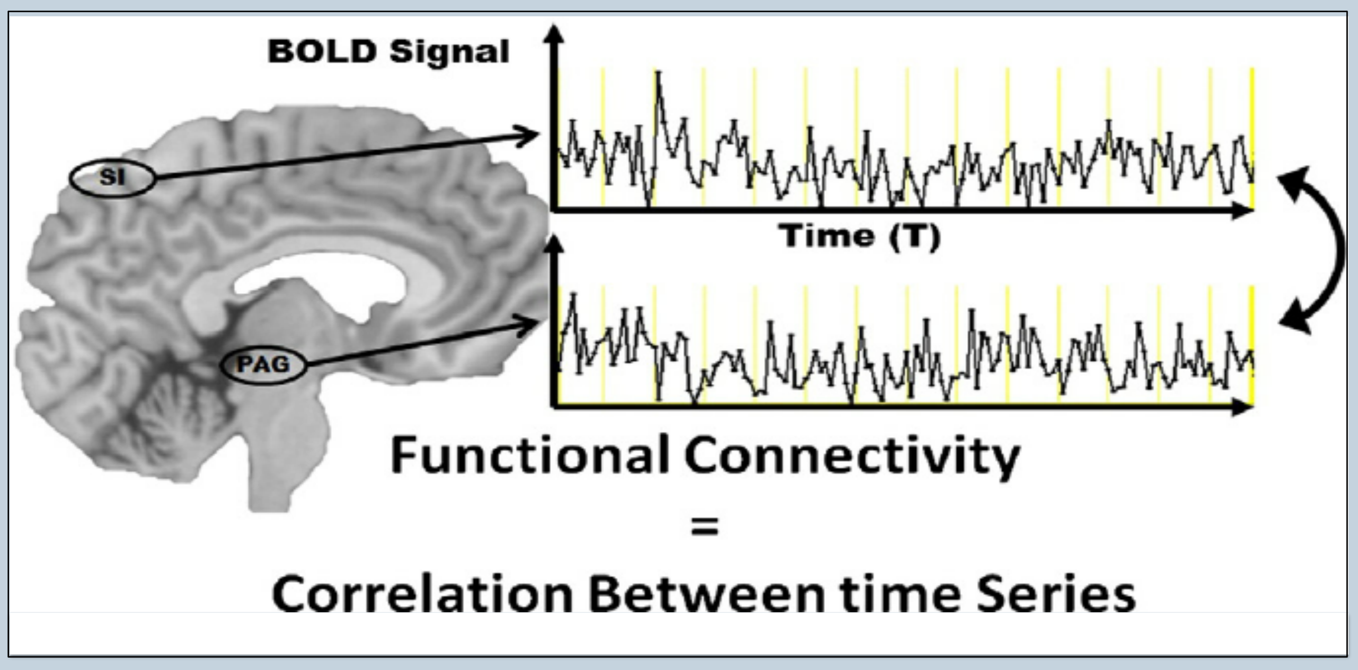

Figure 3. The figure above shows the BOLD signal taken from two different regions of the brain. By comparing these two time series, one can deduce if functional connectivity, or correlation between these time series, changes as one learns a task.

Results

- After processing the data (e.g., my ICA automated approach), we will calculate functional connectivity
  - We implemented an automated ICA approach that automatically removed eye artifacts from EEG data
  - We will be calculating the functional connectivity through Amarel, a "condominium" style computing environment. The benefit of using Amarel is the speed at which the data is processed through MATLAB, saving a tremendous amount of time
- We hypothesize that functional connectivity will change as one learns CPRO2
- We will interpret these findings by considering that functional connectivity can reflect one of three scenarios: (1) one region can directly influence another, (2) influence can be mediated by a third region, and (3) a common stimulus can activate both regions at the same time

Conclusions

- We are expecting to find changes in functional connectivity as one learns a new task
- I learned how to run a complex experiment, operate fMRI and EEG equipment, and process and analyze neural data

References

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