Synchronization of brain activity in the vmPFC during naturalistic stimulation
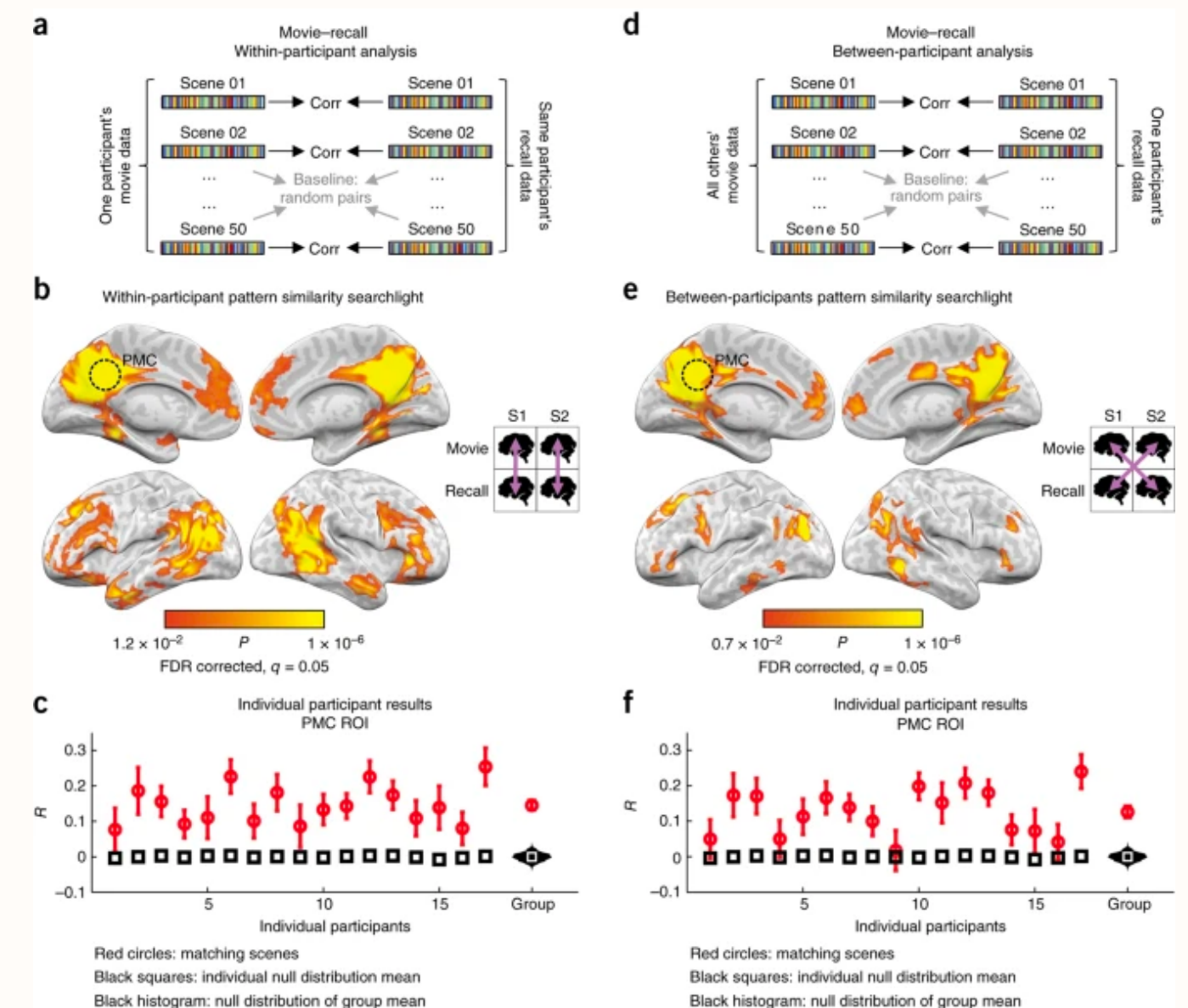
PSYC-60 FINAL PRESENTATION BY JEFF

INTRODUCTION

Background study

Shared memories reveal shared structure in neural activity across individuals

Chen et al. , 2021

- The study was aimed ay exploring the differences in the underlying neural representation when participants shared an experience and later were asked to recall it.
- Participants viewed a 50-min movie, then verbally described the events during functional MRI, producing unguided detailed descriptions lasting up to 40 min.
- The data showed that individual event patterns were both highly discriminable from one another and similar among people, suggesting consistent spatial organization.
- Th results reveal the existence of a common spatial organization for memories in high-level cortical areas, where encoded information is largely abstracted beyond sensory constraints

INTRODUCTION

Background study

Endogenous variation in ventromedial prefrontal cortex state dynamics during naturalistic viewing reflects affective experience

Chang et al. , 2021
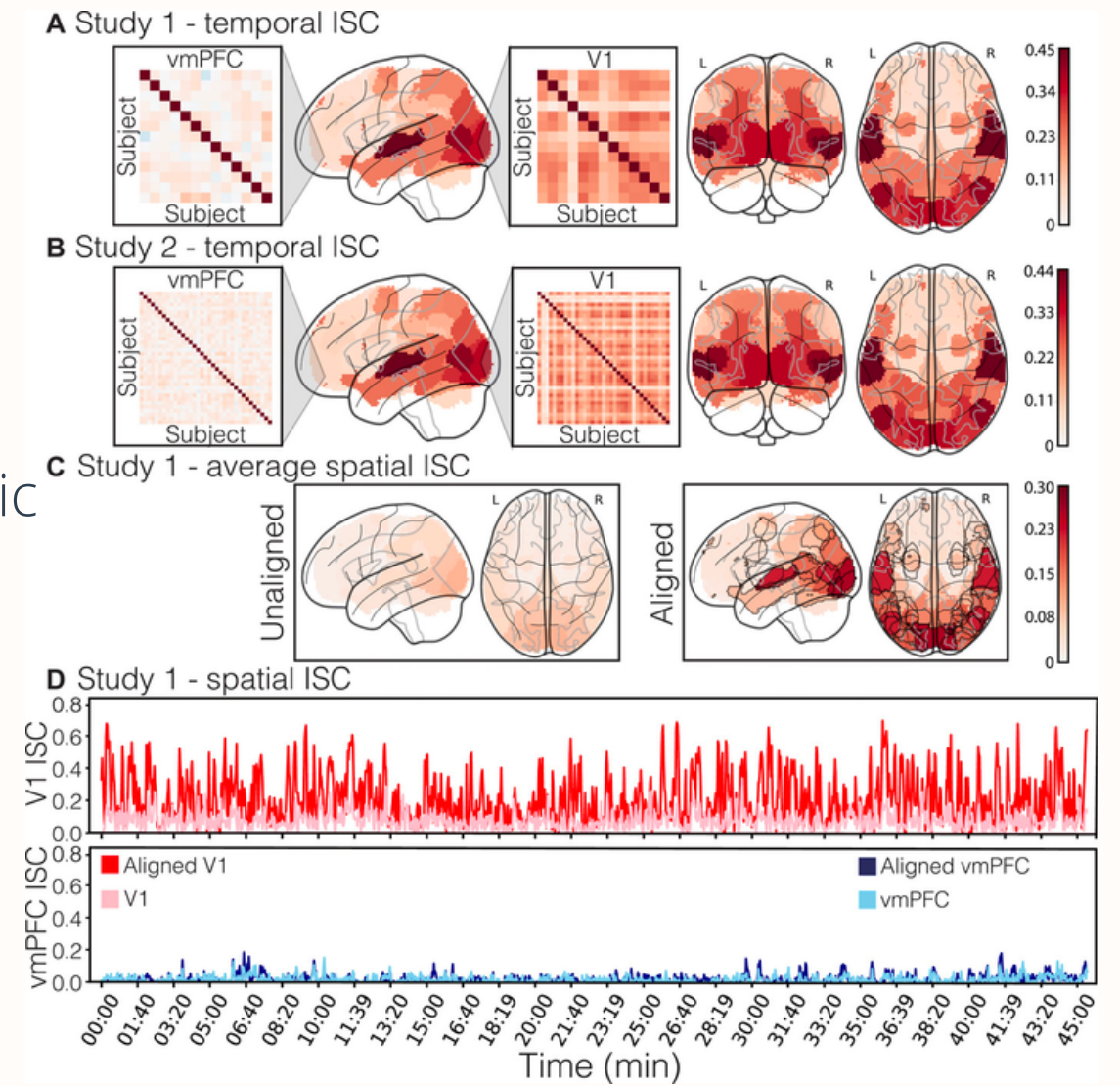
- The study was aimed ay elucidating the role of the ventral Medial Prefrontal Cortex in in processing our ongoing experiences
- The hypothesis was that the vmPFC plays a critical role in processing endogenous information by integrating information from the external world with internal states, past experiences, and future goals and as such will have little across participant consistencyduring natural viewing
- The study involved 13 participants who viewed a 45 minute televisiond drama
- The data suggest that the vmPFC slowly transitions through a series of discretized states that broadly map onto affective experiences.
- Participants exhibited a marked increase in state alignment during high affectively valenced events in the show.
- The study suggested that the vmPFC ascribes affective meaning to our ongoing experiences

INTRODUCTION

## Inter-Subject Phase Synchrony

- **ISPS** is in practice a form of functional connectivity.
- **ISPS** is a measure quantifying the correlation of a time series obtained from the same brain region across different participants.
- It is data-driven, measuring the voxel-wise synchronization at each time point
- **ISPS** approach estimates the group-wise synchrony of phase time series rather than the original subject-level BOLD signals, thus revealing unique insights into task-driven brain activity that are not revealed by ICA alone
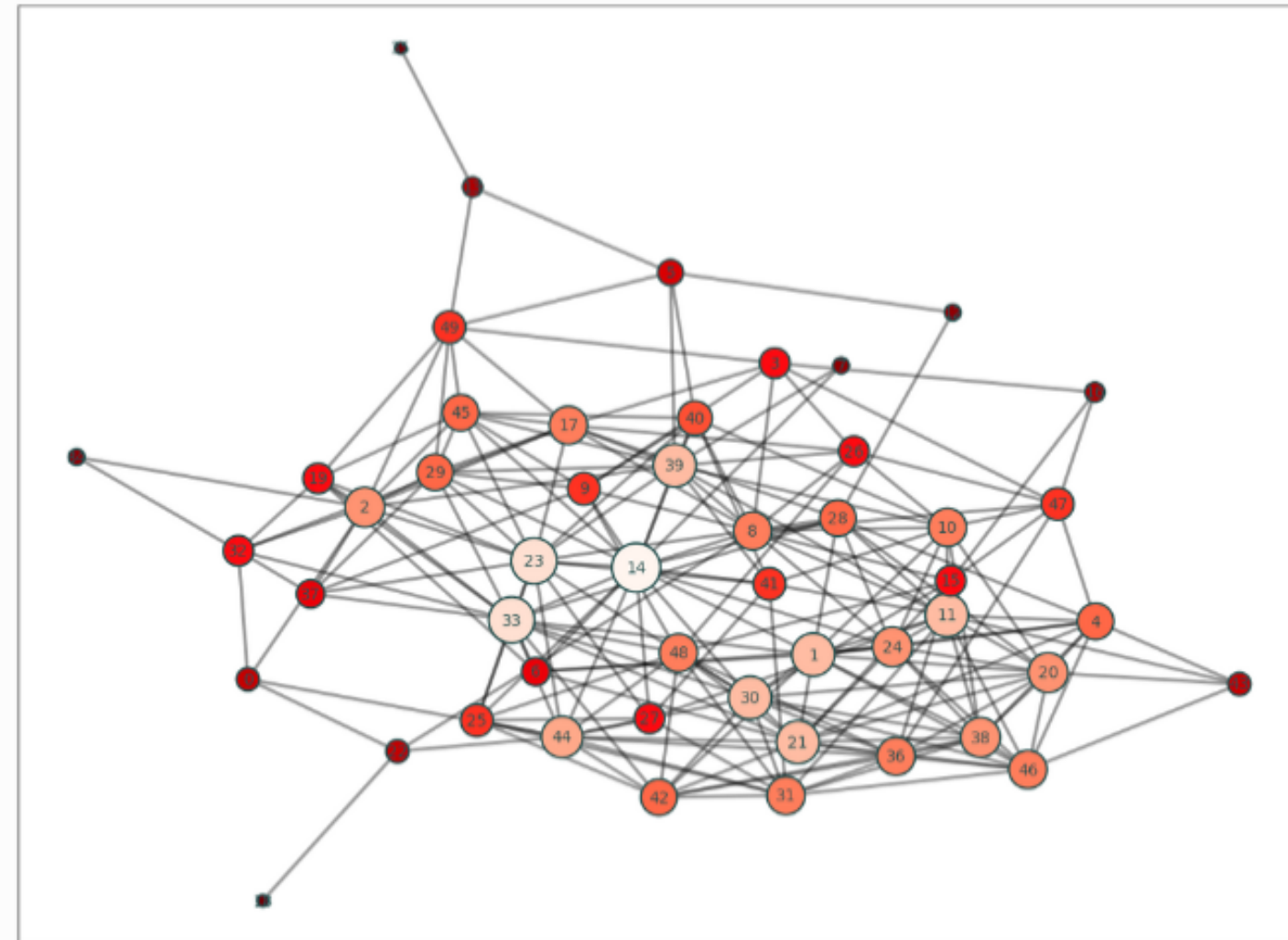
INTRODUCTION

Memory representaion

Workin memory is a multicomponent system that manipulates information storage for greater and more complex cognitive utility (Baddeley and Hitch, 1974; Baddeley, 1996, 2000b). The three subcomponents involved are phonological loop (or the verbal working memory), visuospatial sketchpad (the visual-spatial working memory), and the central executive which involves the attentional control system
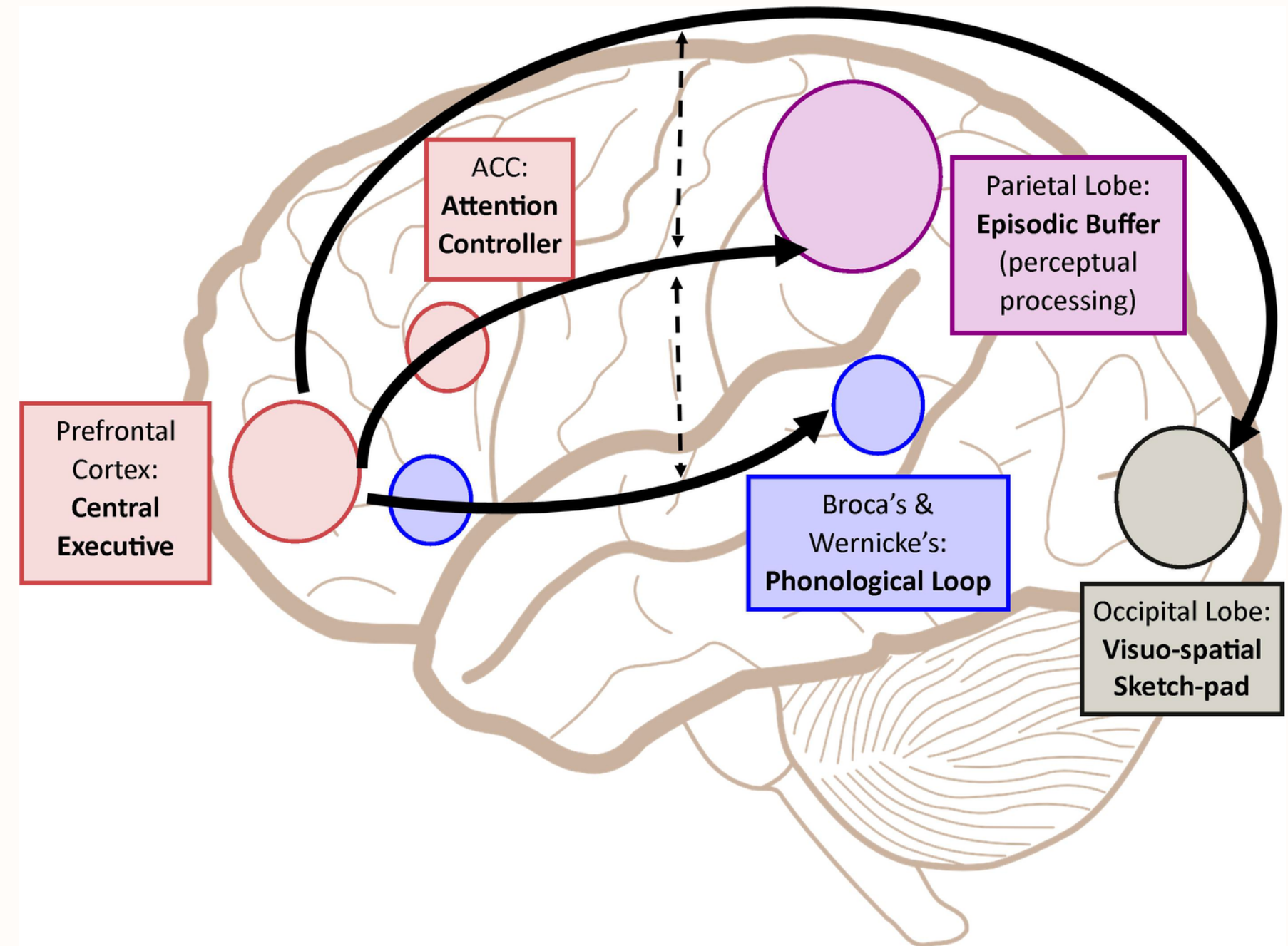
INTRODUCTION

Hypothesis and questions
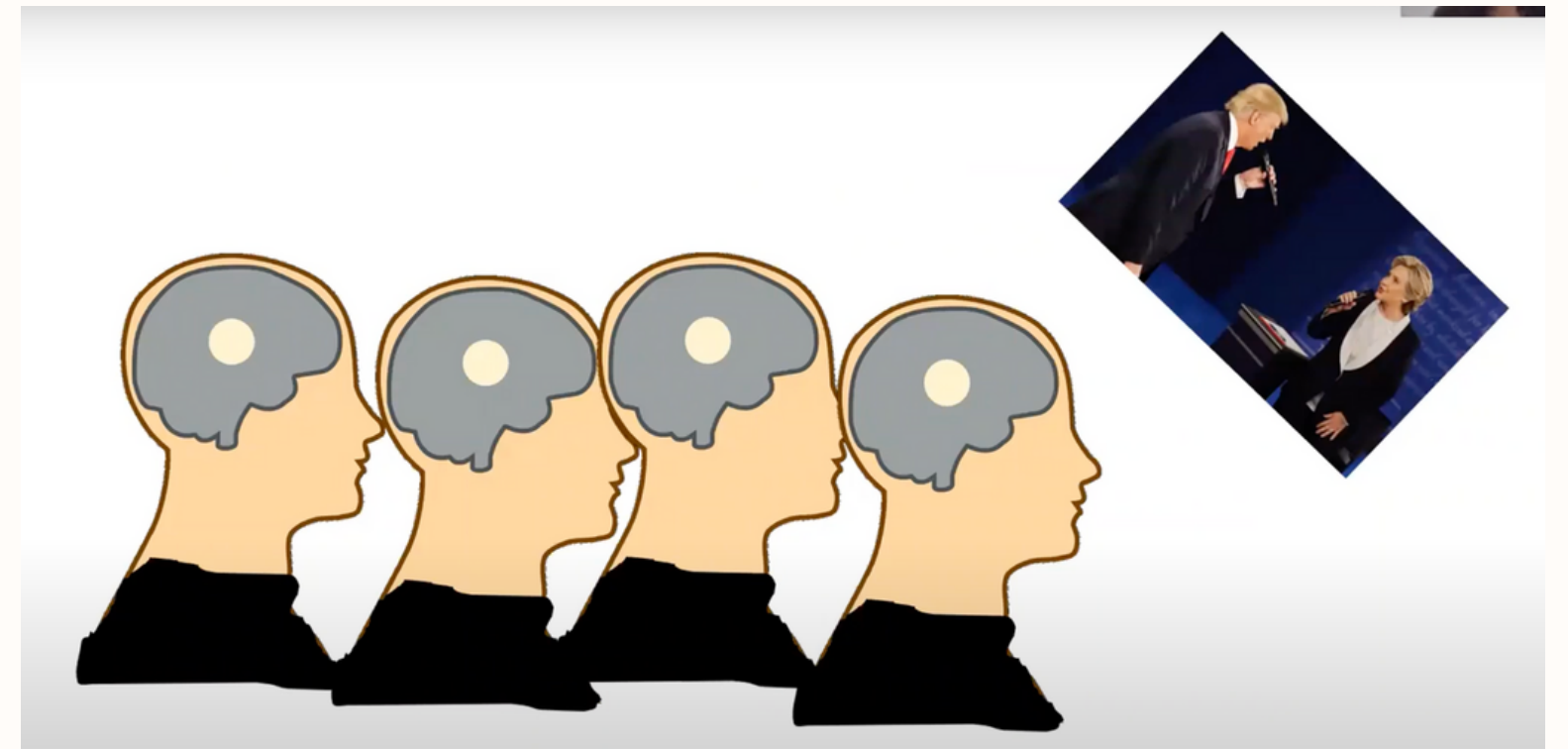
1. To what extent does memory representation in the vmPFC synchronize during naturalistic viewing of emotionally provoking events across different participants
2. How does synchronization in the vmPFC compare to sensory regions that directly process exogenous information such as V1 and the primary Auditory cortex
3. What regions covary with the vmPFC during the viewing task

METHODS

Subjects and stimuli

The study consisted of four participants (n=5) who viewed a 4 minute video on the Insurrection on the U.S. Capitol from a first person perspective.

The participants were then asked to recall what memories they had of the experience for 30 seconds.

The fMRI data of the participants was collected during the naturalistic viewing and the recall task

METHODS

Data processing and analysis

- The fMRI data was preprocessed using fMRI prep and later denoised
- I ran first level GLM model for further processing to remove the noise and other covariates to obtain the residual data
- I looped over the 50 ROIs using whole brain meta-analytic parcellation of the neurosynth database and analyzed each mask for the different regions
- I computed Inter-subject Phase Synchrony at different frequency bands thresholding at $p < 0.05$.
- I computed the ISPS time series for the vmPFC, V1 and primary auditory cortex for comparison for the viewing task at a frequency of .04 - .07 hertz
- I used the ISPS function to view timepoints that are statistically significant for the vmPFC time series to carry out reverse correlation
- To calculate functional connectivity, I computed the pairwise temporal similarity of each ROIs ISPS time series and thresholded these correlations with an arbitrary threshold to create a sparse adjacency matrix
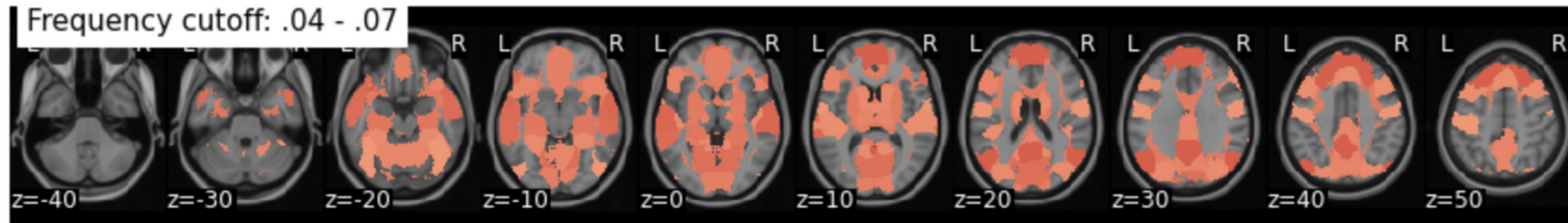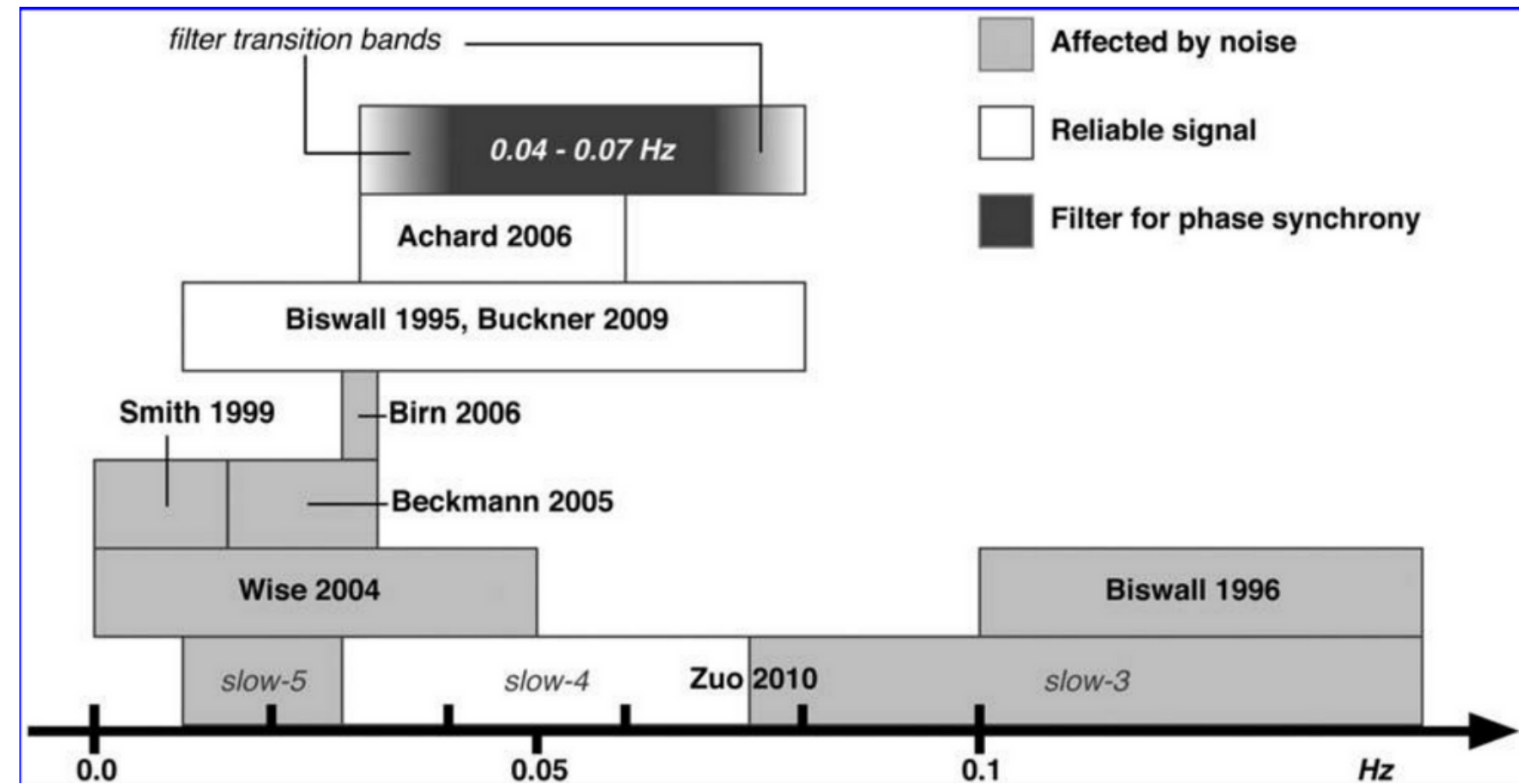
RESULTS
Variable frequency Analysis

- There is less consistency at the very fast frequencies (.073 -.2)
- There is stronger ISPS in primary sesnsory regions such as the early visual and primary auditory cortex at slower frequencies
- There is stronger ISPS in other brain regions at lower frequency in more areas of the cortex
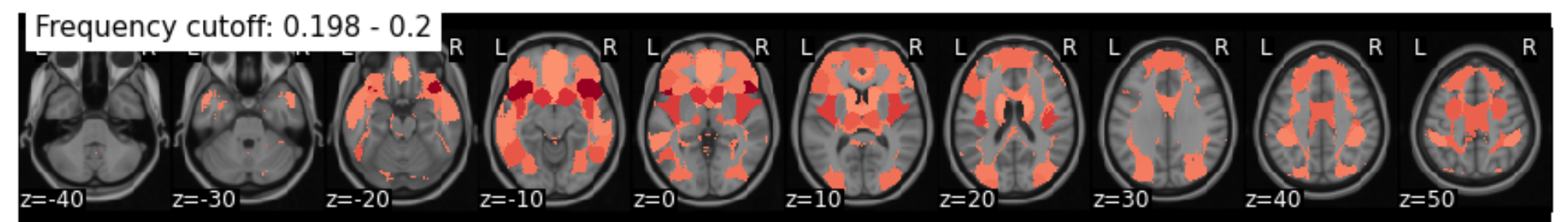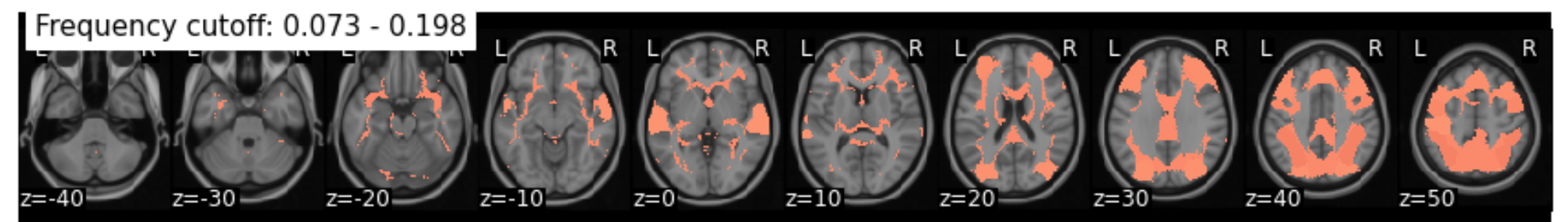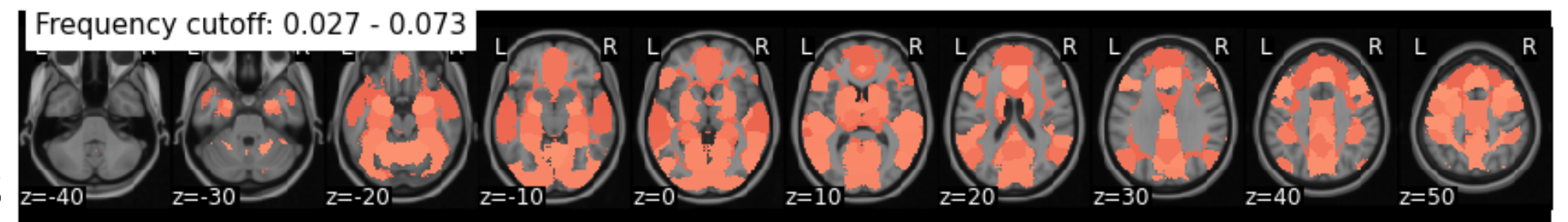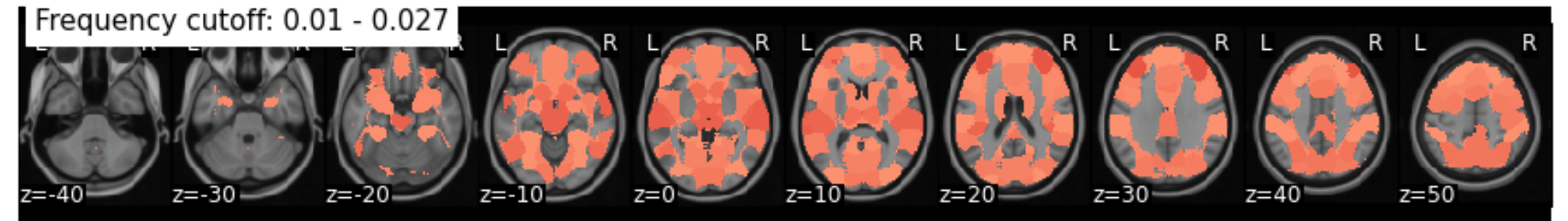
RESULTS
Variable frequency Analysis

- Our fMRI data was collected with time to repetition (TR) in the order of 2 sec (0.25 Hz Nyquist frequency)
- The subsequent analysis used the lower bound cutoff frequency of 0.04Hz and an upper bound of 0.07Hz as recommended by (Glerean et al., 2012).
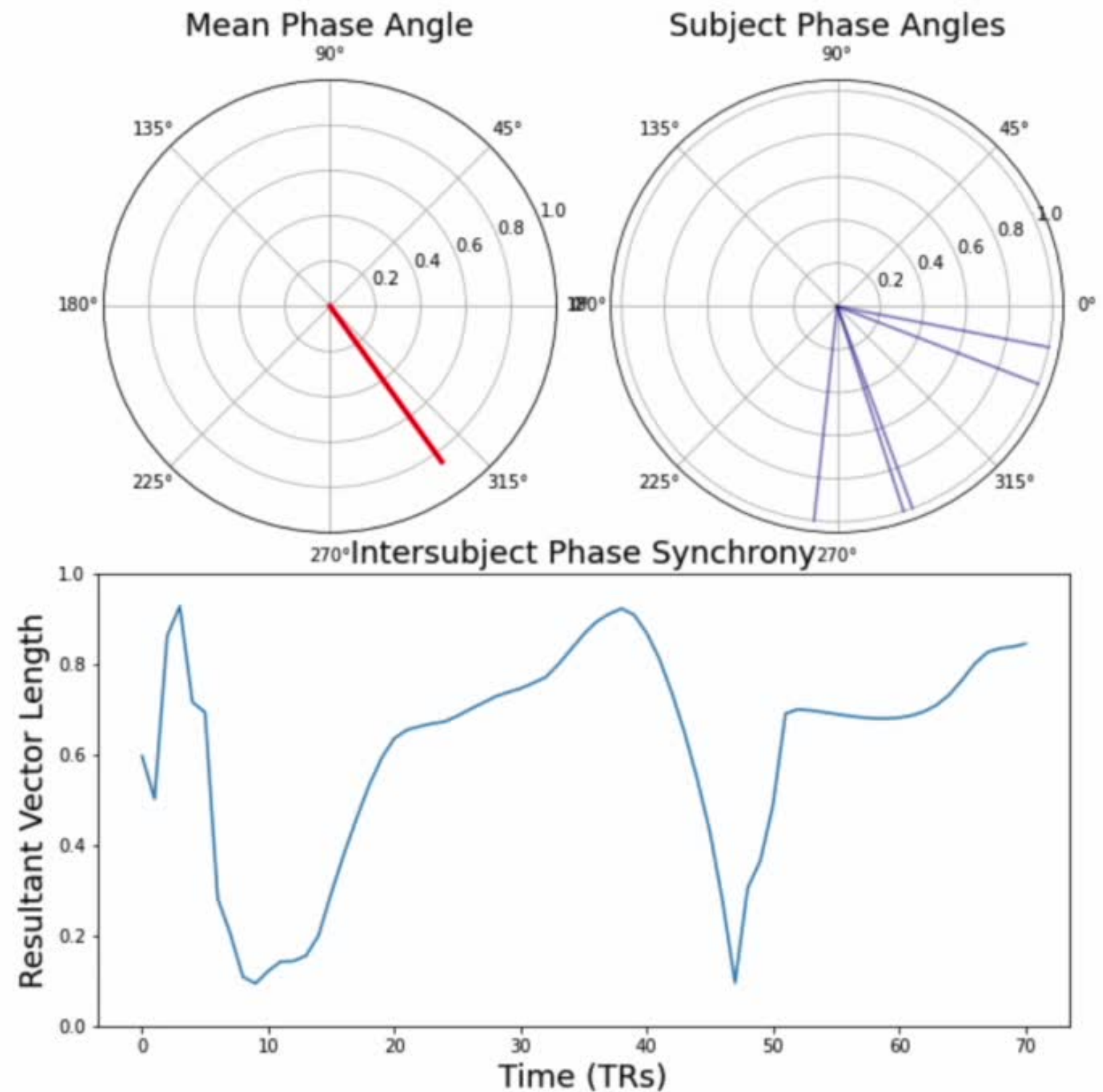
RESULTS

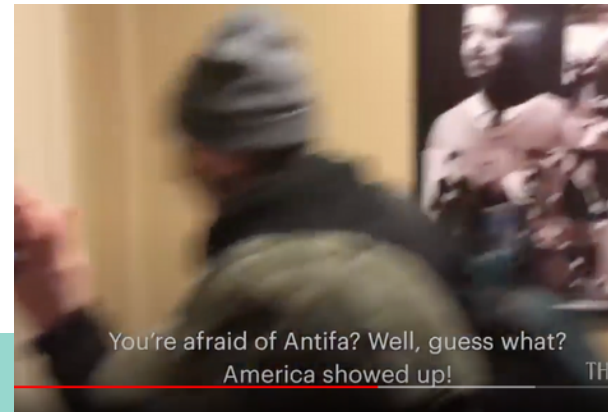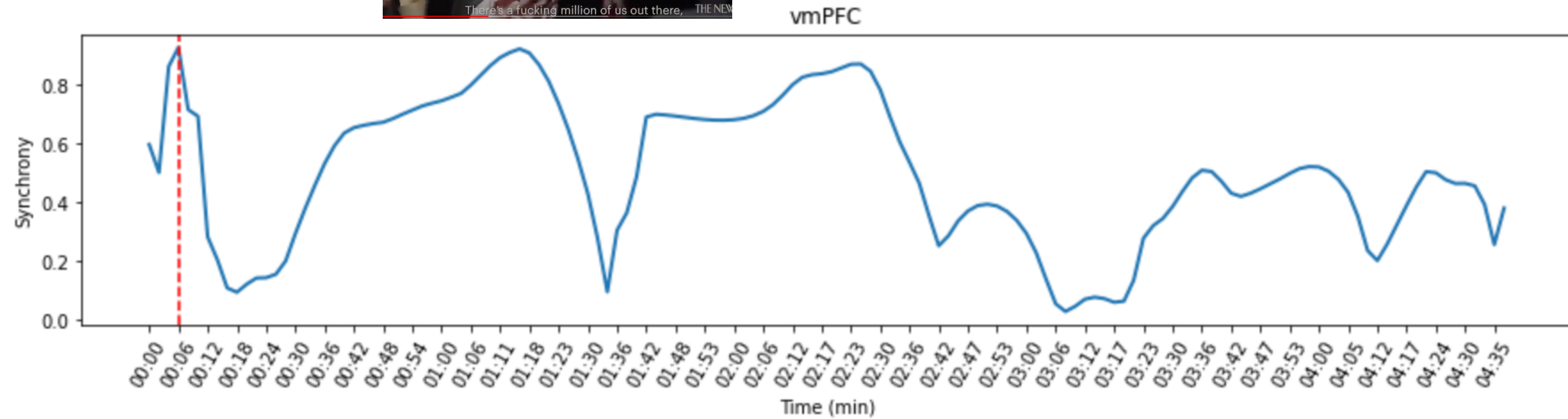## vmPFC Phase synchrony over time - viewing task

The resultant vector length is our metric of inter-subject phase clustering, or the degree to which participants are in phase with each other at a given time point.

We are able to see the synchrony across subjects in the vmPFC during the video viewing task.

RESULTS
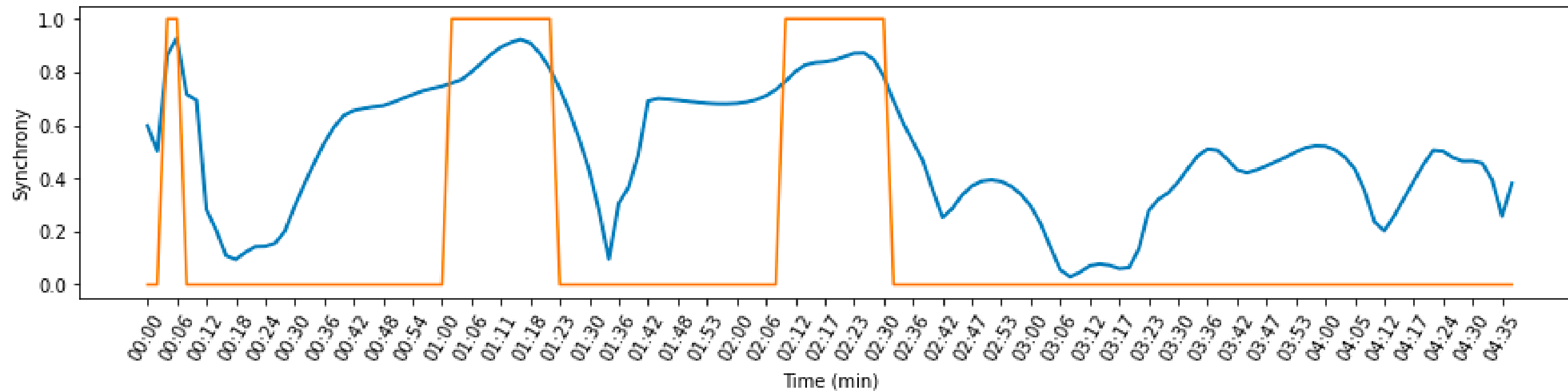## ISPS timeseries for the vmPFC during the viewing task

RESULTS
ISPS timeseries for the vmPFC during the viewing task

Using the ISPS function to view timepoints that are statistically significant for the vmPFC ISPS time series

RESULTS

vmPFC Phase synchrony
at different timepoints

The follwoing timepoints showed the highest ISPS across participants in the vmPFC

average synchrony of .95 for the
timepoints 0:00 - 0:06

RESULTS

vmPFC Phase synchrony
at different timepoints

The follwoing timepoints showed the highest ISPS across participants in the vmPFC

average synchrony of .9 for the
timepoints 1:06 - 1:18

RESULTS

vmPFC Phase synchrony at different timepoints

The follwoing timepoints showed the highest ISPS across participants in the vmPFC

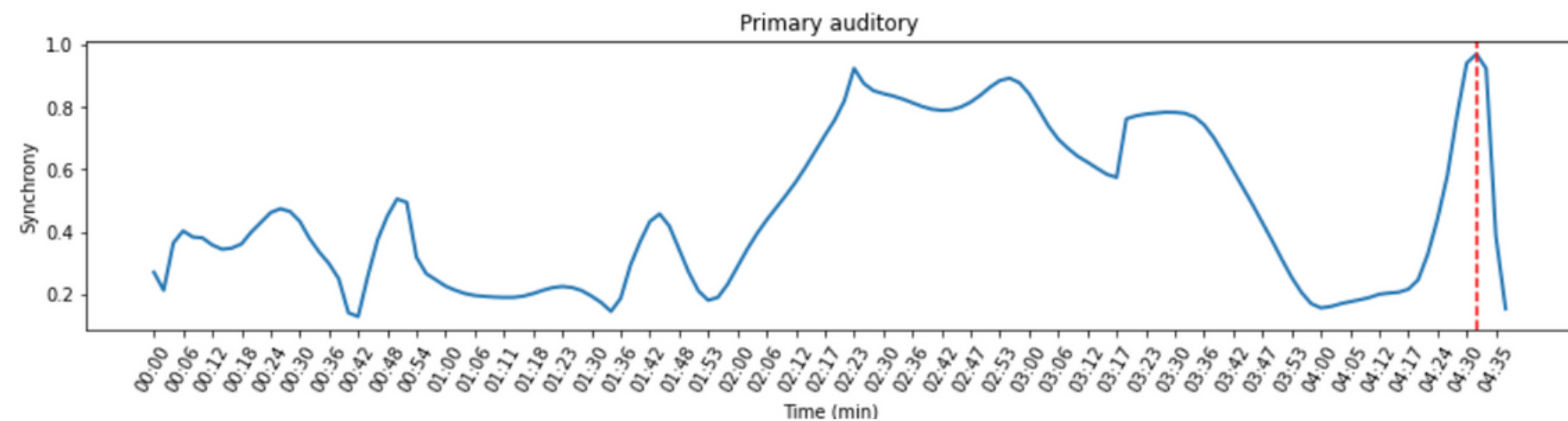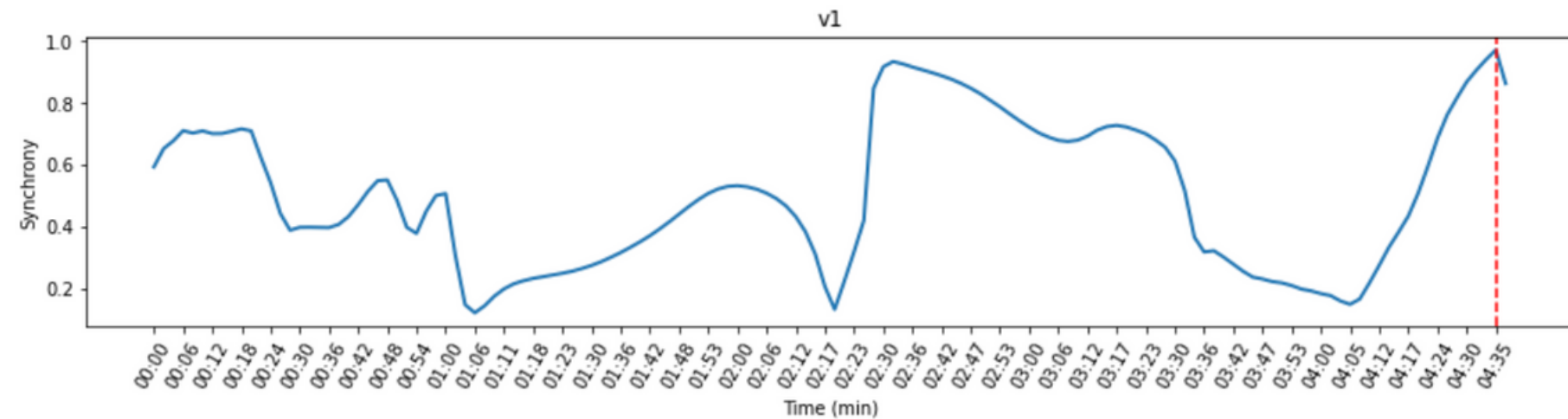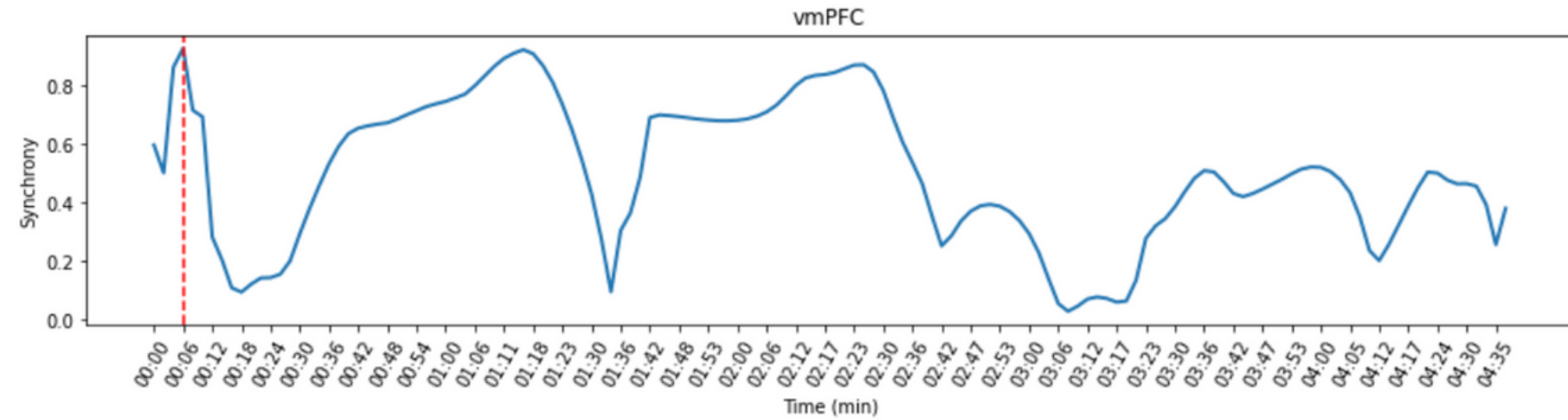average synchrony of .8 for the timepoints 2:12 - 2:28

RESULTS

ISPS timeseries comparison during the viewing task

vmPFC MEAN = 0.5056925 STDEV 0.24167338

V1 MEAN = 0.503411 STDEV 0.23389234

**Primary auditory** MEAN = 0.46802658 STDEV 0.2503037

The vmPFC showed a slightly higher mean across participant synchronization compared to the V1 and the primary auditory regions

RESULTS

Functional Connectivity- viewing task

There was high functional connectivity between the vmPFC and the DMPFC and the DLPFC

ISPS Functional Connectivity Matrix

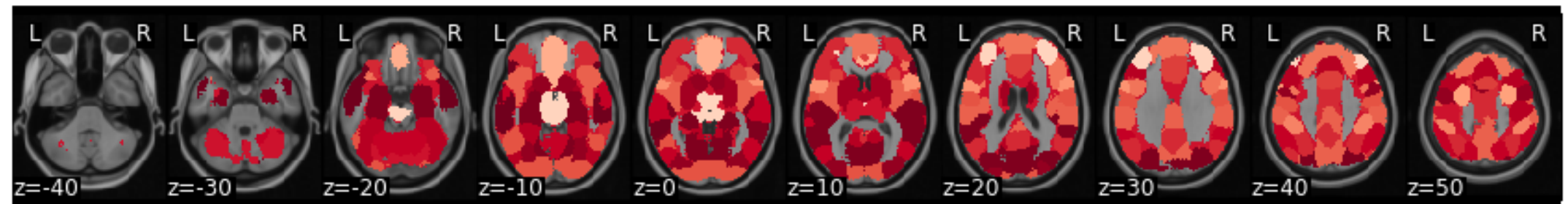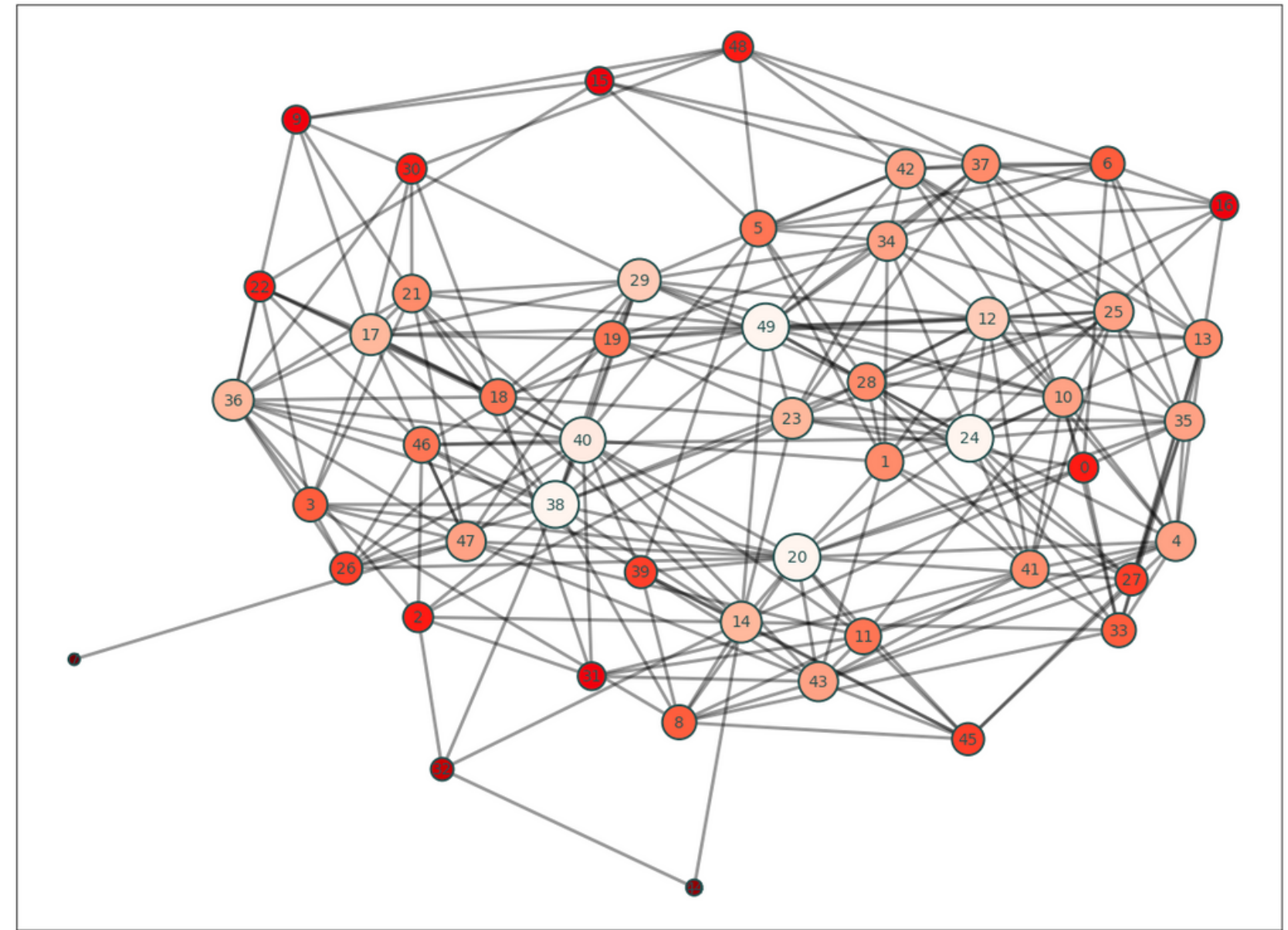Thresholded ISPS Functional Connectivity Matrix
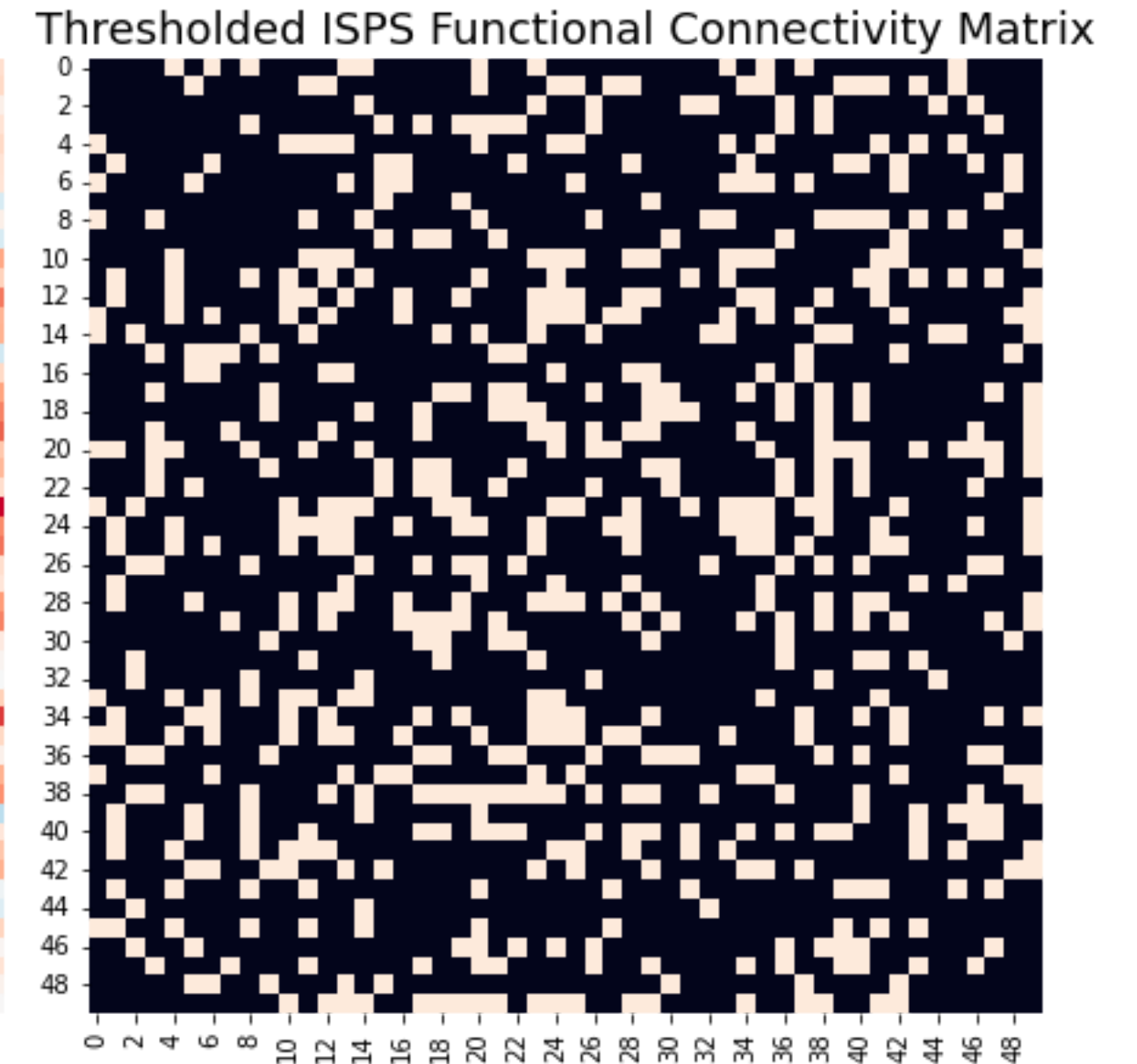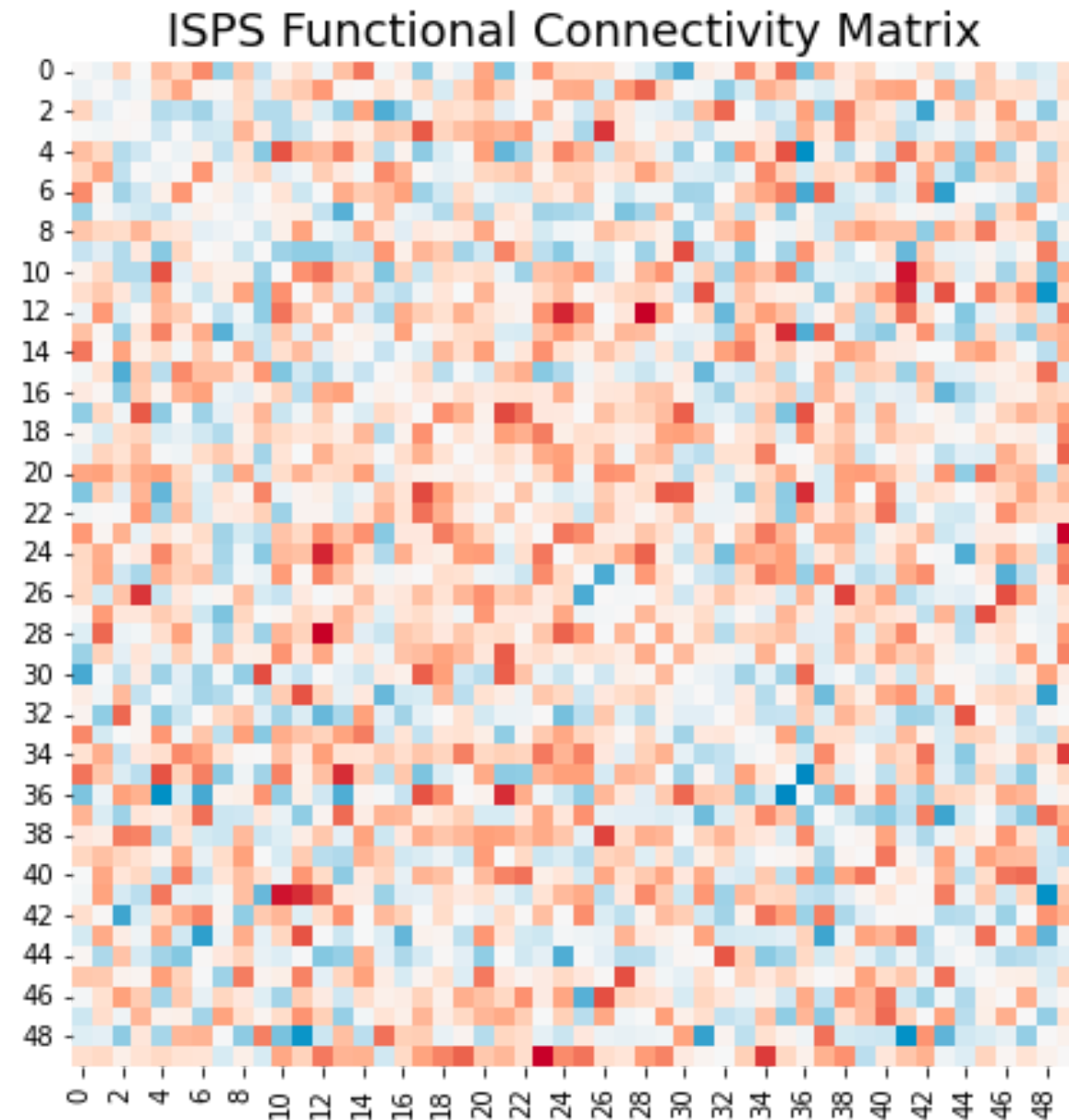
RESULTS

Functional Connectivity - viewing task

DMPFC (ROI = 2) acts as a conduit between cognitive control areas and affect-triggering regions

DLPFC (ROI = 44) has been implicated in higher cognitive functions, such as switching attention and working memory.
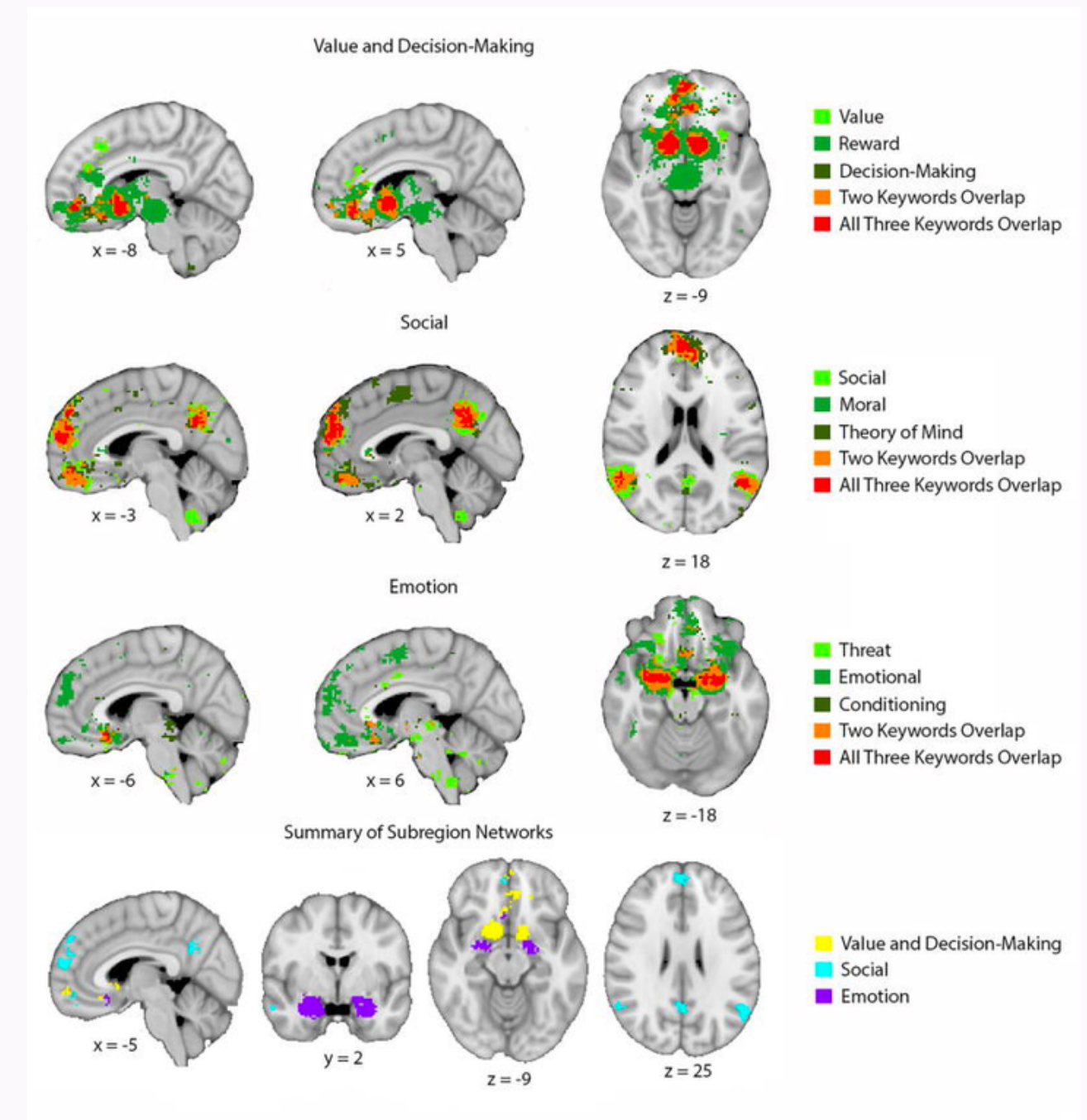
DISCUSSION

The role of the vmPFC in emotional processing of affective experiences

The vmPFC is implicated in a variety of social, cognitive and affective functions .

Anatomically, the vmPFC projects directly to regions involved in affect such as the hypothalamus and amygdala as well as cognitive systems involved in conceptual processing such as the dorsal and medial prefrontal cortex.

The vmPFC is thought to be instrumental in affective and conceptual processing.
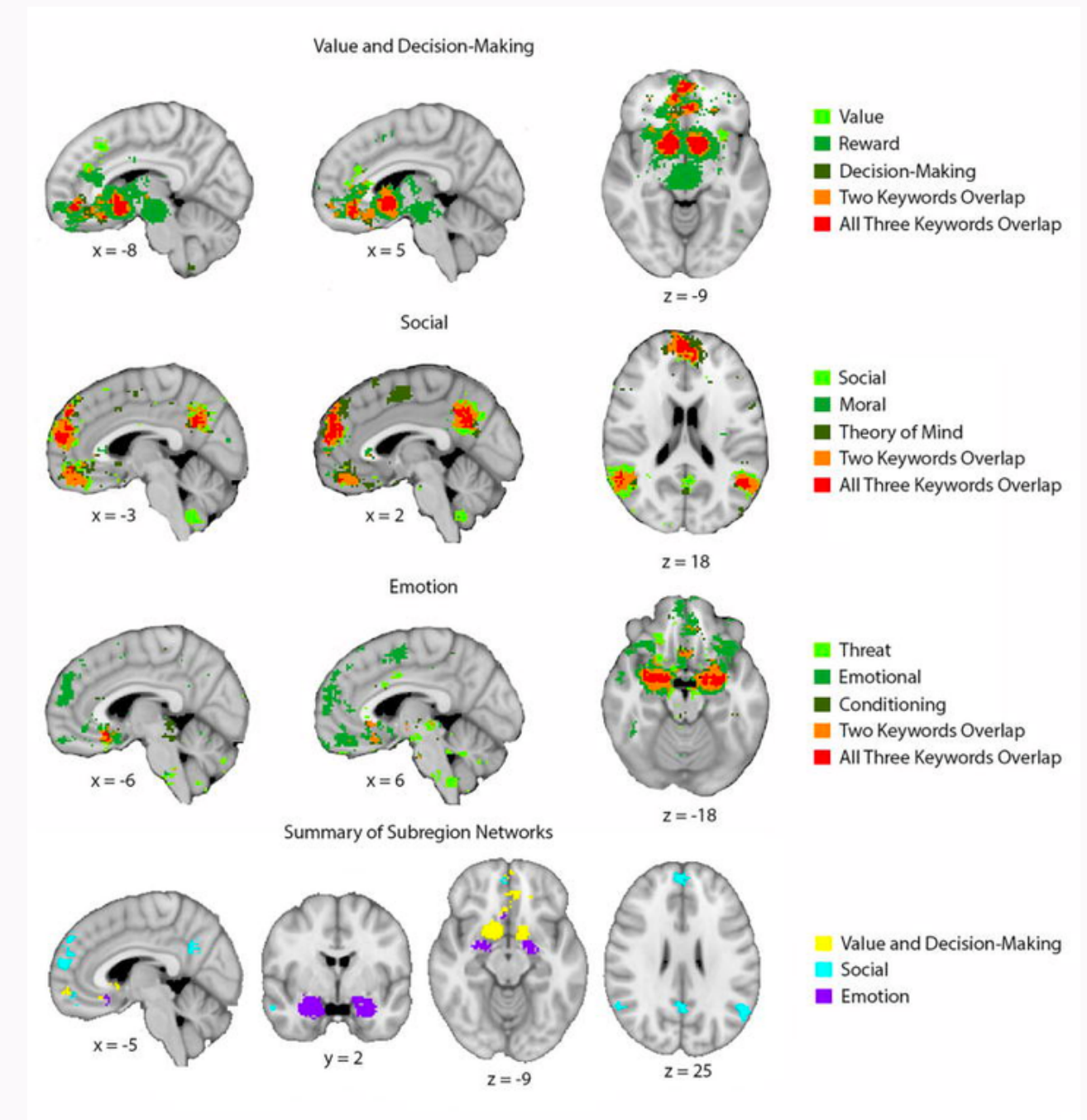
DISCUSSION

The role of the vmPFC in emotional processing of affective experiences

Due to its involvement in highly affective processing, the vmPFC was integral in processing the participants past experiences regarding the insurrection with the naturalistic stimuli.

There was strong alignment in the subjects brain responses when viewing events in the video that evoked intense emotion.

The vmPFC exhitbted higher levels of synchronization compared to V1 and the primary auditory system

DISCUSSION

The role of the vmPFC in emotional processing of affective experiences

The results from the ISPS showed that the memory in the vmPFC was not idiosyncratic but showed strong responses evoked across individuals that was synchronized at different timepoints.

However, the stimuli in the video was highly affective and thus could imply that the state alignment observed in the vmPFC is as a result of the intensity of the events in the video.
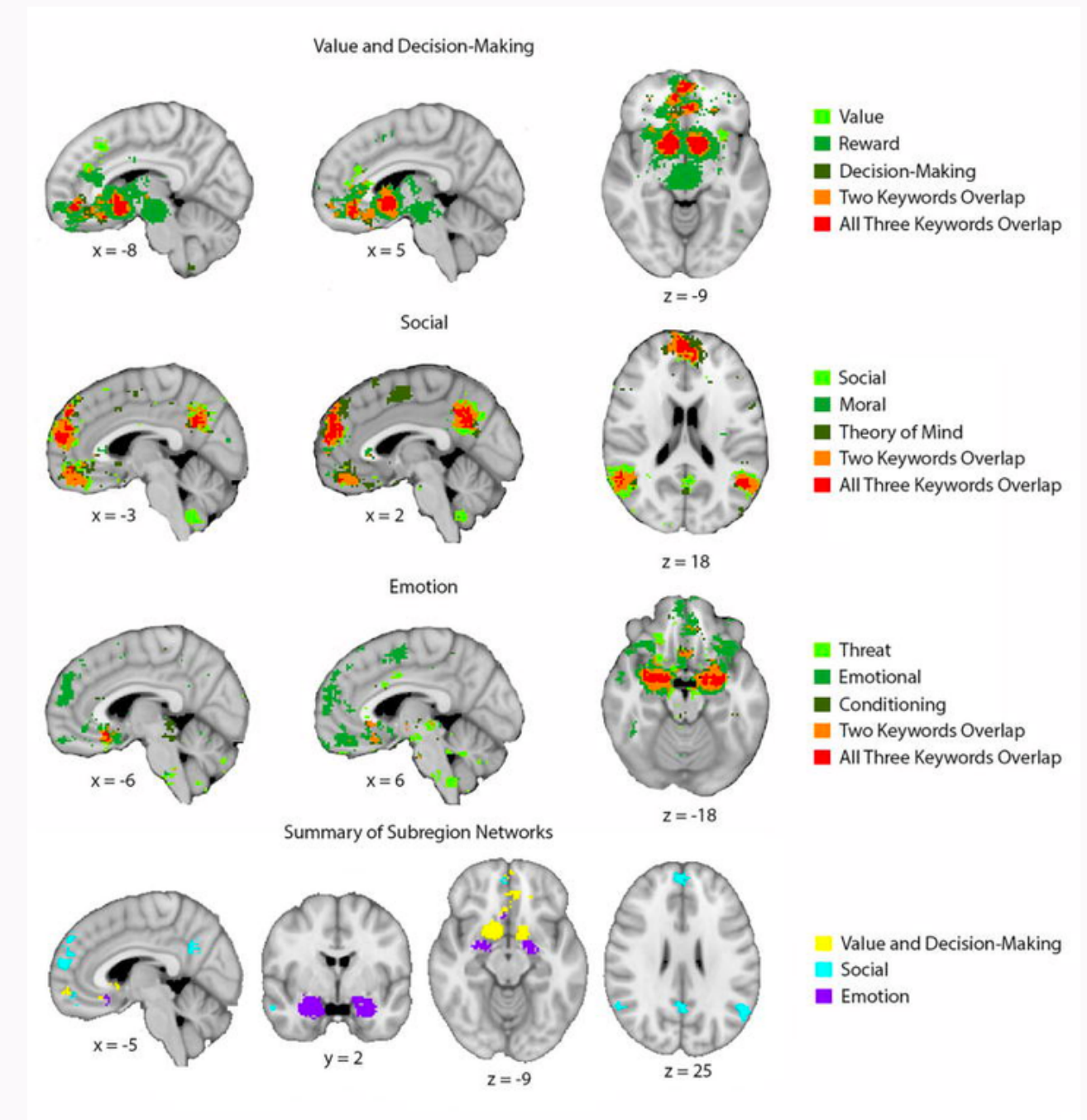
CONCLUSION

Limitations

- The study had a small group of subjects (n=4)
- The stimuli was highly affective and there was no control stimuli. The participants had also viewed emotion evoking images on the subject matter prior to viewing the video
- There is no clear understanding or analysis as to what extent does memory representation resemble the original event.
- There is the possibility of alteration occurring between perceptual experience and later recollection
- The participant group was biased in terms of their view on the socio-political events of the task and the prior knowledge of the task and these could have contributed to the results of the study

CONCLUSION

Future experiments

- Future experiments should be conducted with a larger number of participants and focus on both highly and less affective stimuli
- It would be interesting to see the differences between synchrony in experiments that are carried out repeatedly for the same viewing task and the correlation between the two tasks
- Further experiments should be conducted to compare the role of the vmPFC when it comes to recalling highly affective experience between different individuals
- The stimuli should be such that it might evoke different responses in different groups of individuals i.e. there should be variation in personal bias when selecting the partcipant group