Probing DMN and emotion with naturalistic stimuli: Inter-run and inter-subject analyses

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Background

- Mind wandering associated with default mode network (DMN)
  - Traditionally tied to resting state (Mars et al., 2012)

RESEARCH ARTICLE | BIOLOGICAL SCIENCES

Experience sampling during fMRI reveals default network and executive system contributions to mind wandering

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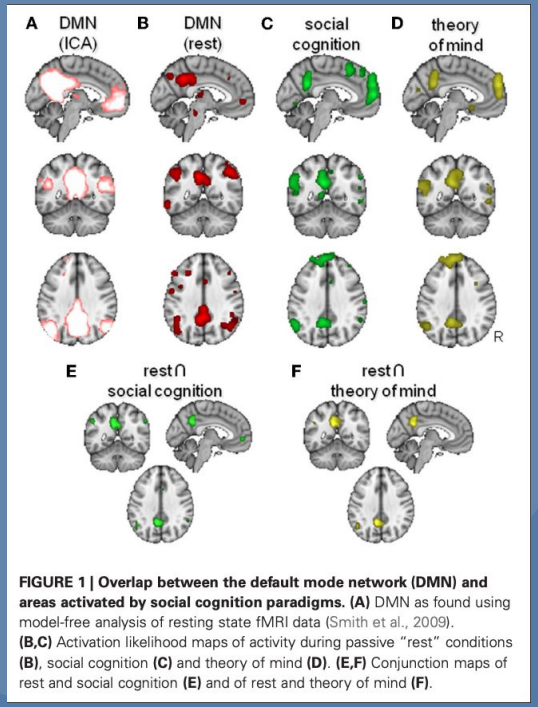


FIGURE 1 | Overlap between the default mode network (DMN) and areas activated by social cognition paradigms. (A) DMN as found using model-free analysis of resting state fMRI data (Smith et al., 2009). **(B,C)** Activation likelihood maps of activity during passive "rest" conditions **(B)**, social cognition **(C)** and theory of mind **(D)**. **(E,F)** Conjunction maps of rest and social cognition **(E)** and of rest and theory of mind **(F)**.

Mars et al., 2012

- Unclear relationship between mind-wandering and emotion

Mind-wandering and negative mood: does one thing really lead to another?

Giulia L Poerio [1], Peter Totterdell, Eleanor Miles

Opinion

The Default Mode Network's Role in Discrete Emotion

Ajay B. Satpute[1,*] and Kristen A. Lindquist[2]

Default mode network deactivation during emotion processing predicts early antidepressant response

M Spies, C Kraus, N Geissberger, B Auer, M Klöbl, M Tik, I-L Stürkat, A Hahn, M Woletz, D M Pfabigan, S Kasper, C Lamm, C Windischberger & R Lanzenberger

Research Questions

Question 1

How do subjects compare to each other within rounds?

- ➔ Do subjects respond similarly to the same stimulus?

Question 2

How do the results compare between the two runs?

- ➔ If different, how do they differ and where do they differ?

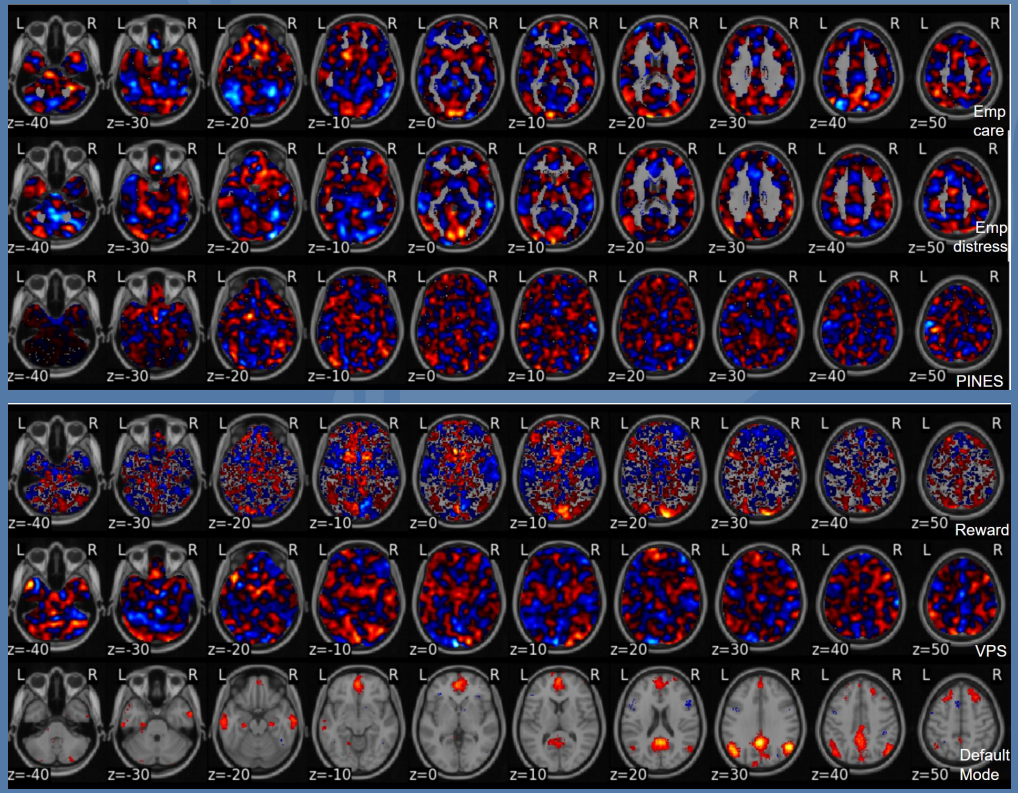
Hypothesis

1) Subjects will respond similarly to each other for emotion, but differently for mind wandering
    a) We anticipate particularly close alignment between subjects for negative affect, distress and vicarious pain
    b) Alignment between empathetic distress and mind wandering
2) Emotional responses will be greater in the first run compared to the second run, but mind wandering will be greater in the second run compared to the first run
    a) Inverse relationship between emotional and mind wandering activity between runs

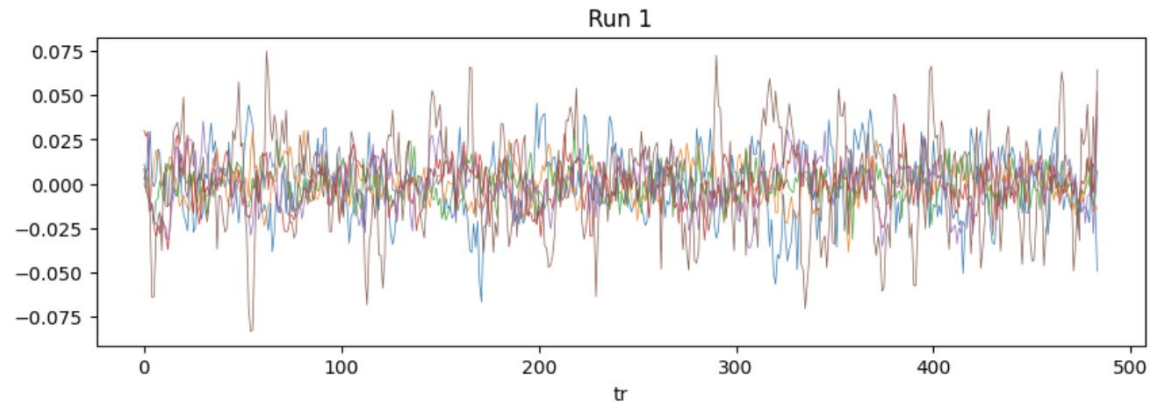
Methods - Masks for emotions and mind wandering

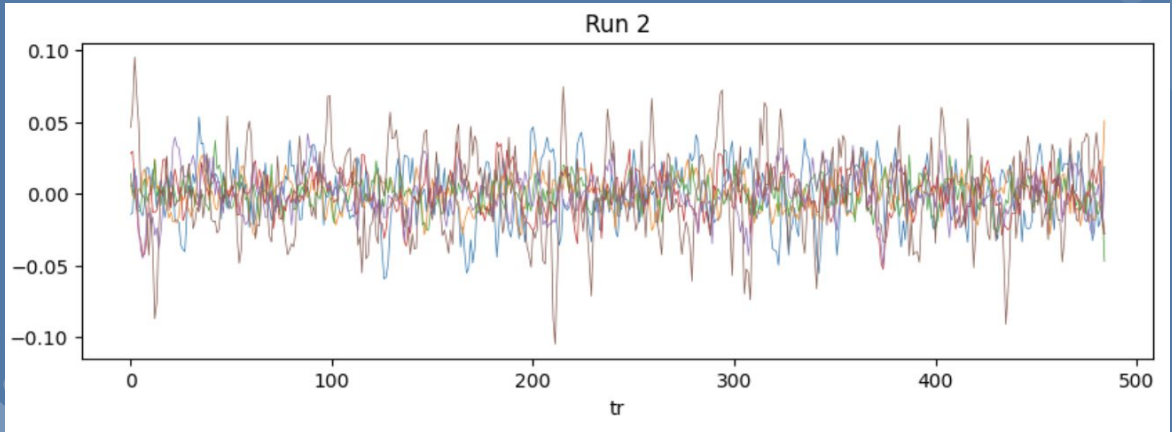
Focused in on 6 masks based on predicted emotions subjects felt during watching

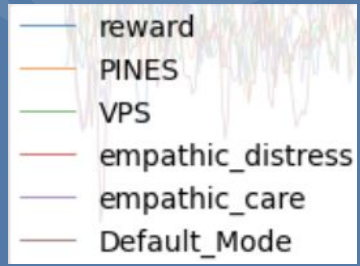
1) Empathetic care
2) Empathetic distress
3) Negative affect (PINES)*
4) Reward
5) Vicarious pain (VPS)
6) Default Mode Network



Methods - Applied Masks







Methods - ISC Within Runs

Purpose (Research Question 1):

1. Analyze synchrony of brain activity
2. Calculate/quantify linear correlation between participants

Method:

- Intersubject correlation (ISC) within each run. Circle shift as permutation method to build null distribution for hypothesis test

Findings:

- Statistically significant + corr in Empathetic Distress, Empathetic Care, Negative Affect (PINES), and Reward for both runs 1 and 2

	Run 1 Stats	Run 1 p-value	Run 2 Stats	Run 2 p-value
VPS	ISC 1: 0.0099	p = 0.491	ISC 2: 0.016	p = 0.264
Default Mode	ISC 1: 0.012	p = 0.514	ISC 2: 0.032	p = 0.07
Empathetic Distress	ISC 1: 0.071	**p = 0.0002**	ISC 2: 0.11	**p = 0.0002**
PINES	ISC 1: 0.037	**p = 0.026**	ISC 2: 0.18	**p = 0.0002**
Empathetic Care	ISC 1: 0.1	**p = 0.0002**	ISC 2: 0.14	**p = 0.0002**
Reward	ISC 1: 0.077	**p = 0.0002**	ISC 2: 0.13	**p = 0.0002**

Methods - ISC Across Runs

Purpose (Research Question 2):

1. Analyze synchrony of brain activity between runs

Method:

- Intersubject correlation (ISC) within each run (using bootstrapping) and then t-test between runs to test for significant differences

Findings:

- Significant differences found between vicarious pain (VPS), Default Mode Network, and Empathetic Distress

	Run 1 v Run 2 test statistic	**P value**
VPS	statistic=-2.2871	**p=0.0222**
Default Mode	statistic=-3.0605	**p=0.0022**
Empathetic Distress	statistic=-2.4717	**p=0.0134**
Empathetic Care	statistic=-1.2984	p=0.1942
Reward	statistic=-0.8515	p=0.3945
PINES	statistic=-1.1758	p=0.2397

Methods - Principal Component Analysis

Purpose (Research Question 1b):

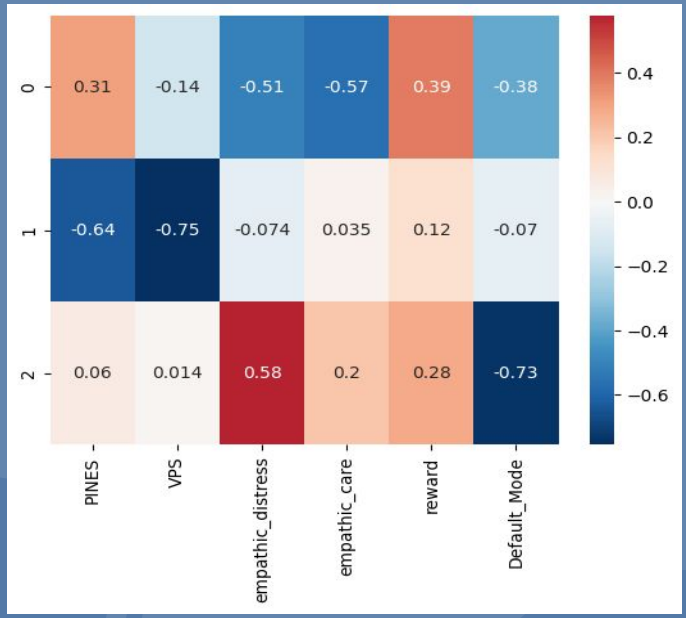
1. Analyze the components in the brain to see if masks align with brain networks from data

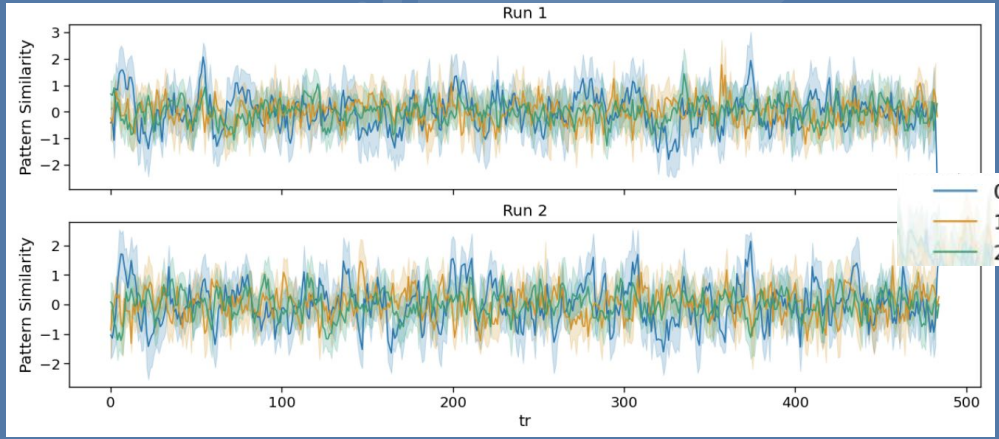
Method:

- Principal Component Analysis (PCA) to isolate the top 3 components
- Found masks with highest degree of correlation

Findings:

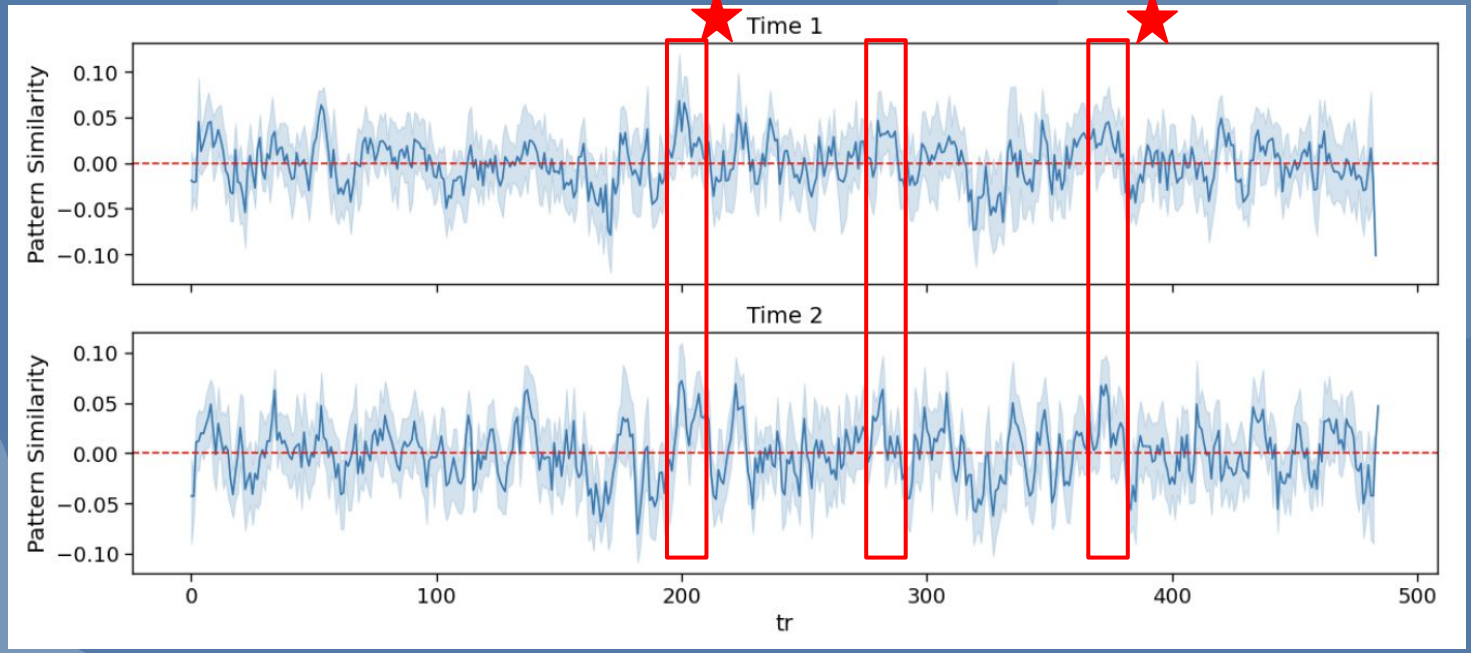
- Correlated masks within each component





Methods - Comparing Mean Activity Across Masks

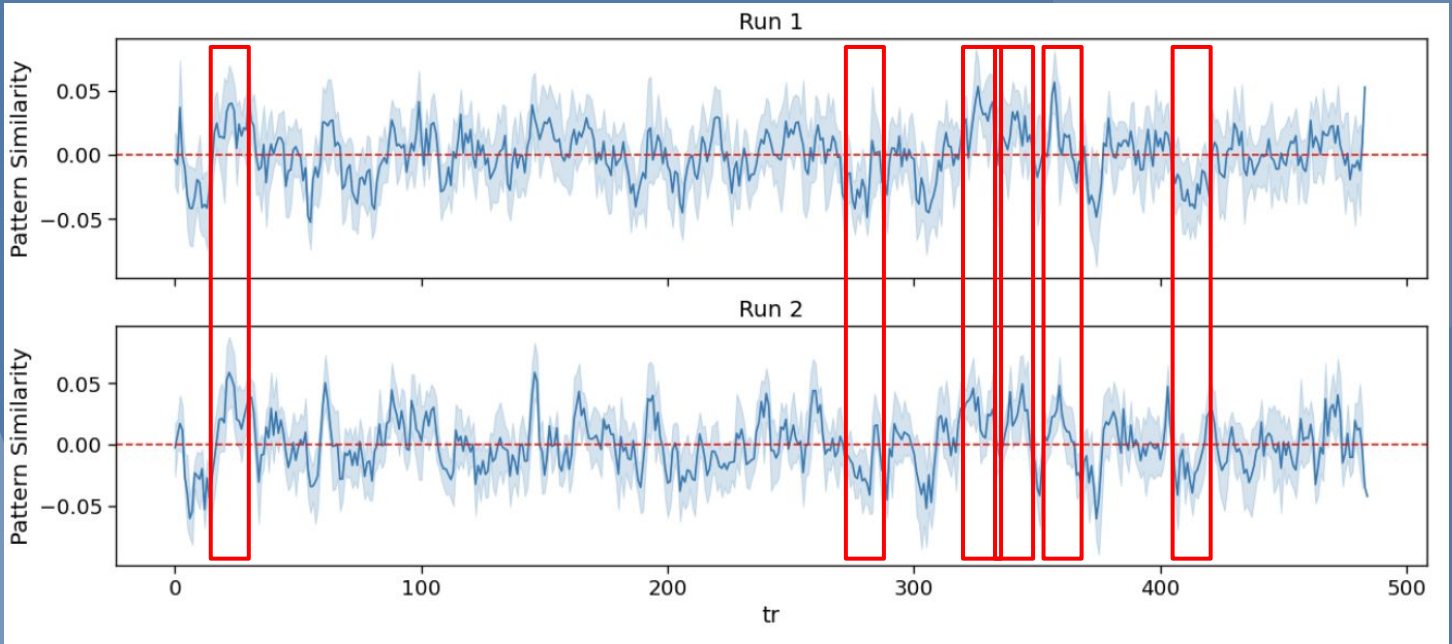
Purpose (Research Question 2b): Reward vs empathetic distress



We'll come back to these tr's in just a bit

Methods - Comparing Mean Activity Across Masks

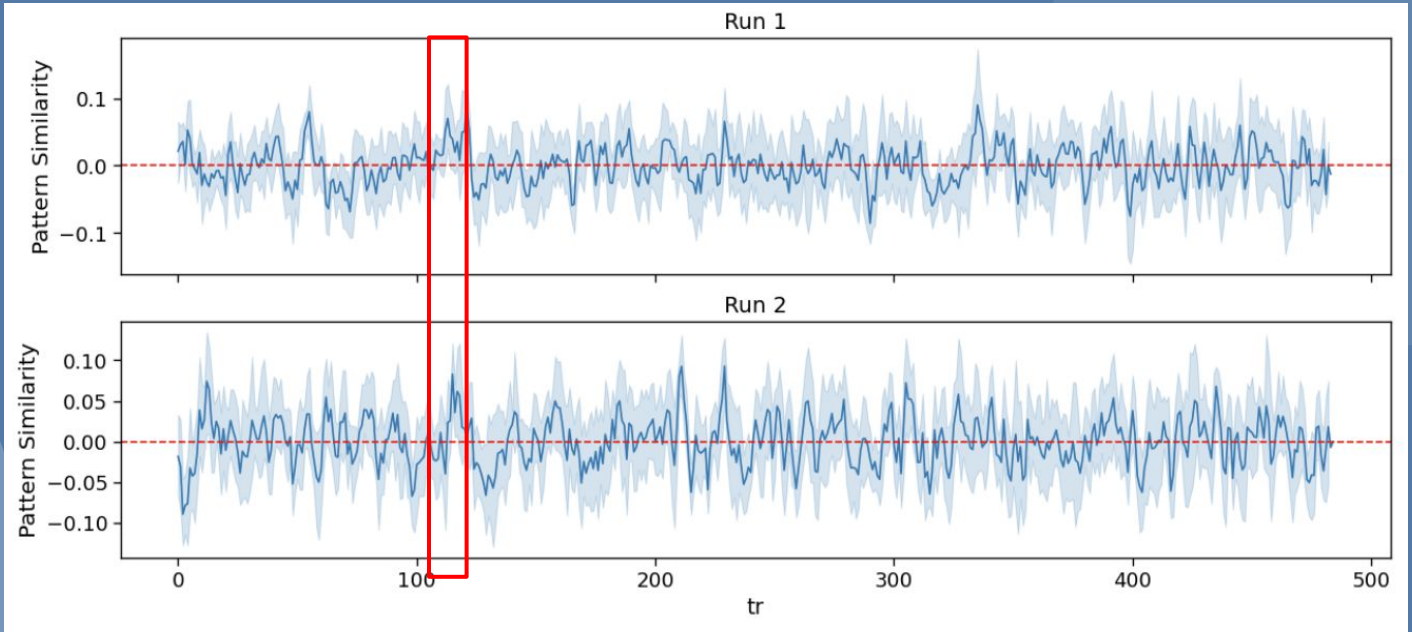
Purpose (Research Question 2b): PINES vs empathetic distress



Many scenes where negative affect and empathetic distress have significant differences.
Not the expected results

Methods - Comparing Mean Activity Across Masks

Purpose (Research Question 2b): Default mode vs empathetic distress



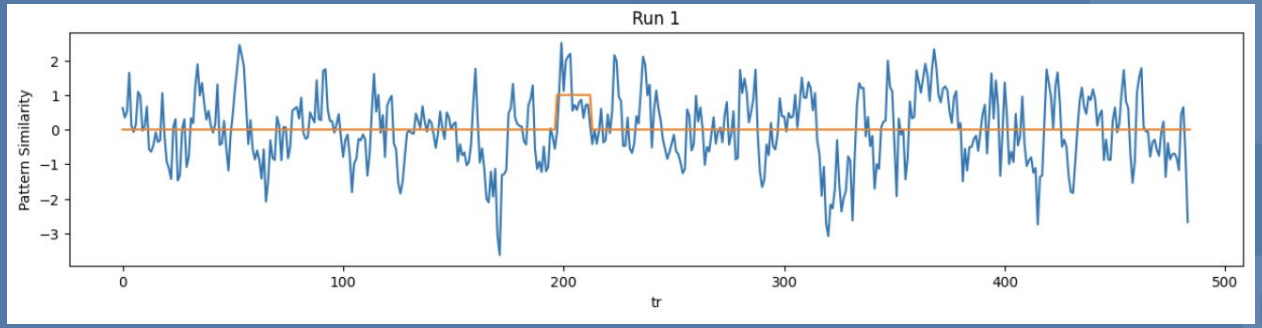
Few significant differences between default mode and empathetic distress data. Supports hypothesis that mind wandering would be correlated with emotional distress

Methods - Investigating Specific Scenes

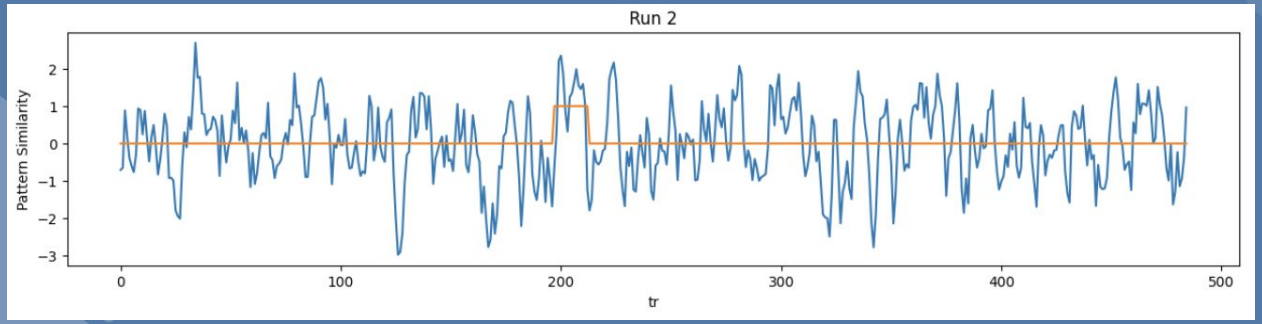
Very large spikes in reward activity compared to other masks
Three scenes of interest were identified (scenes with large appearing spikes):

- Scene 1: 6:40-7:05 (tr: 197-213)
- Scene 2: 10:30 - 10:55 (tr: 315-332)
- Scene 3: 14:35-15:00 (tr: 358-375)

Methods - Scene Analysis for Reward (Scene 1)

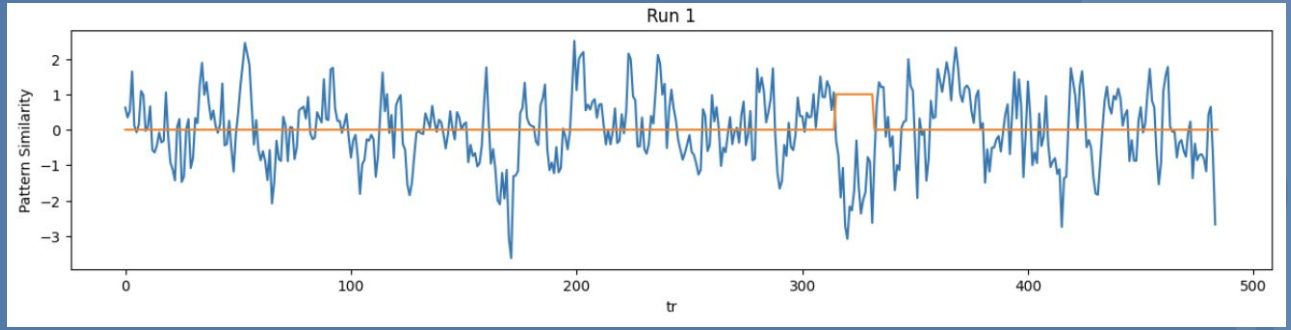


Run 1:
correlation = 0.019
p = 0.061

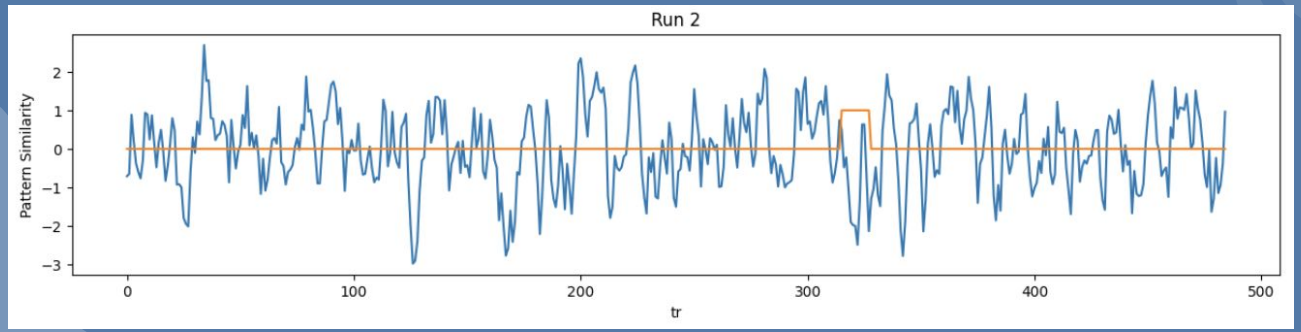


Run 2:
correlation = 0.023
p = 0.0092

Methods - Scene Analysis for Reward (Scene 2)

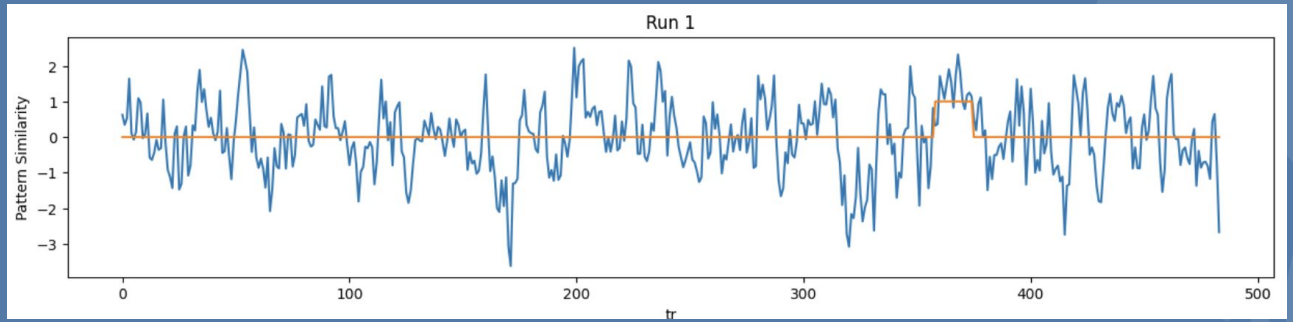


Run 1:
correlation = -0.02
p = 0.014

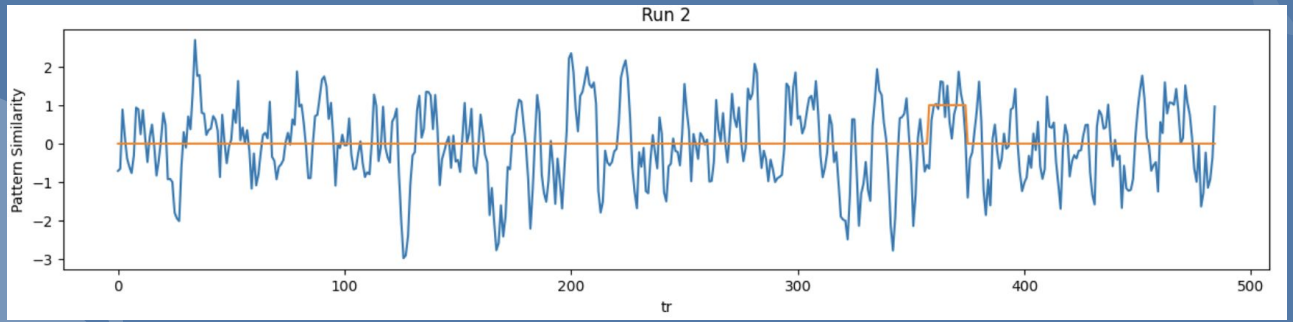


Run 2:
correlation = -0.032
p = 0.0044

Methods - Scene Analysis for Reward (Scene 3)



Run 1:
correlation = 0.024
p = 0.022



Run 2:
correlation = 0.018
p = 0.036

Conclusions - Initial Research Questions

- Subjects positively correlated for mask-related activity for empathetic distress, negative affect, empathetic care, and reward (NOT for DMN/VPS)
  - So as anticipated, there is alignment with emotion for the most part
  - Distinctive DMN-based cognition
- Significant differences between runs 1 and 2 for VPS, DMN, and empathetic distress
  - DMN hypothesized to be different due to familiarity
  - VPS and empathetic distress may be attributed to contextualization within the plot

Conclusions - Additional Investigations

- Results above allowed us to perform additional analysis using mean brain activity across subjects within each run for masks with significant ISC results.
  - Reward and empathetic distress significantly differed at 3 time points (2 of which align with our selected scenes of interest)
  - PINES and empathetic distress significantly differed at 5 time points, suggesting that negative affect and empathetic distress activity were not very correlated
  - Default mode network and empathetic distress significantly differed at 1 time point, indicating that their activity is well correlated compared to others
- Analysis of reward activity during specific scenes resulted significant spikes in activity for all three scenes
  - Scene 1: only run 2 had a significant positive spike
  - Scene 2: both runs had a significant negative spike
  - Scene 3: both runs had a significant positive spike

Limitations

Subjects -

- No accounting for psychological traits/states across subjects at the time of scan
- No accounting for any neurodivergence
- Knowing the experiment ahead of time; unusual degree of subject awareness → also common background training in fMRI/PSYC analyses
- Dartmouth is not a representative sample of the United States or the human population

Paradigm -

- Small sample size
- Hardware malfunction during scanning
- Middle video in 3-video paradigm may result in varied neural activity compared to 2-video paradigm
- Limited by accuracy of the masks we're using
- Movie results may not generalize to real-world social interactions

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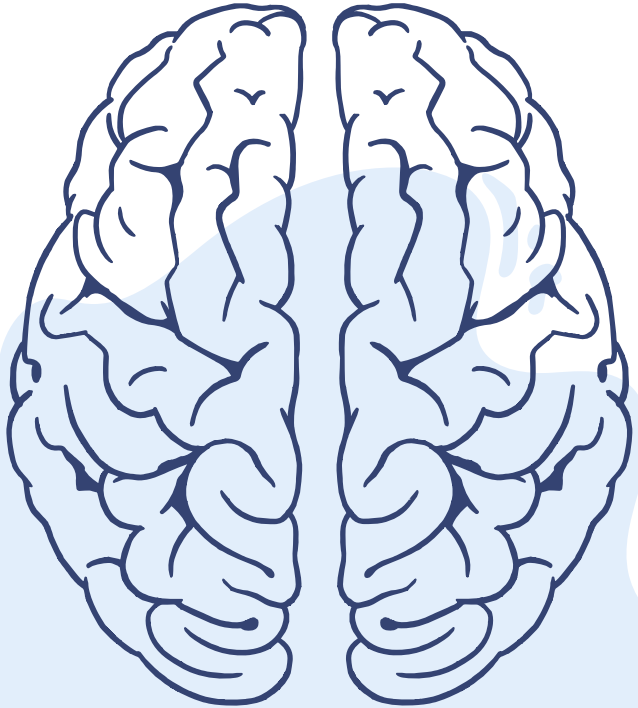

Questions?