INFORMATION PROCESSING IN THE DEFAULT MODE NETWORK

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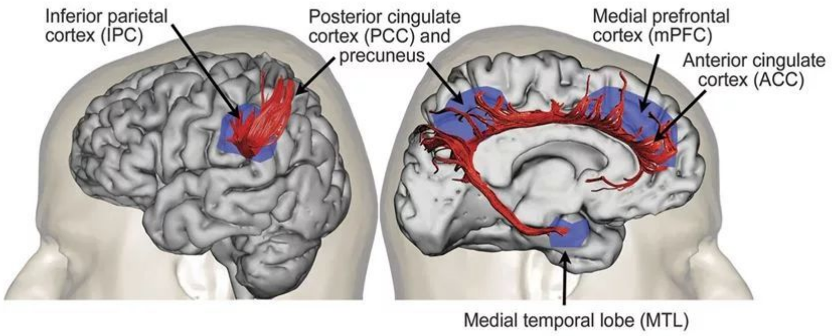
PSYC60 Chang 22F

Research Question

How do we process naturalistic stimuli differently with prior knowledge in the Default Mode Network (DMN)?

DMN Background

default mode network ● regions in the brain that show increase in activity during mind wandering, perspective shifting, long-time scale naturalistic processing of real-life events, and when guiding *external stimuli processing by creating and updating previously constructed mental representations of that stimuli*



Midline DMN (PCC, mPFC) maintains mental representations that can guide behavior, facilitate task performance, integrate new information as it comes in.

It has been theorized that the way we integrate our internal models with new external stimuli is through *event models.*

Event Models

event model *multimodal representations of events that bring together information about people, objects, sequences of actions + their consequences in a spatiotemporal framework*

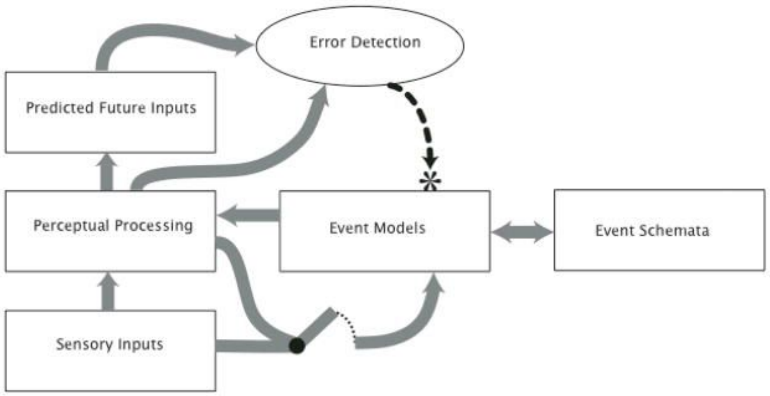
In everyday life, we use event models to anticipate what is about to happen and to conceptualize a task at hand (similar to a schema?) and we “update” event models when we transition from one event to the next

In naturalistic stimuli studies, at these *event boundaries* we see widespread shifts in cortical activity patterns, particularly in the PCC (part of the DMN)

Thus, DMN and in particular the PCC seems to integrate recent experiences for better episodic encoding of experiences (note that activity

Event Segmentation Theory

- We *segment* our continuous information streams to create event models that predict upcoming events
    - Unconscious process - fMRI with movie and segmentation afterwards (Zacks et al., 2001a)
- Violations of predictions update our event model & coincide with *event boundaries*
- Coarse vs fine-grained unitization
    - Fine-grained unitization is more resource-demanding (Newtson, 1976)
    - Predictable activity → coarser-grain
    - Surprising or confusing → finer grain
- Features (Zacks et al. 2009)
    - Perceptual (movement, color, sound)
    - Conceptual (characters in a story, their goals)



Hypotheses

H_0: There is no difference in event segmentation between run 1 vs run 2.

H_1: There is a difference in event segmentation between run 1 vs run 2.

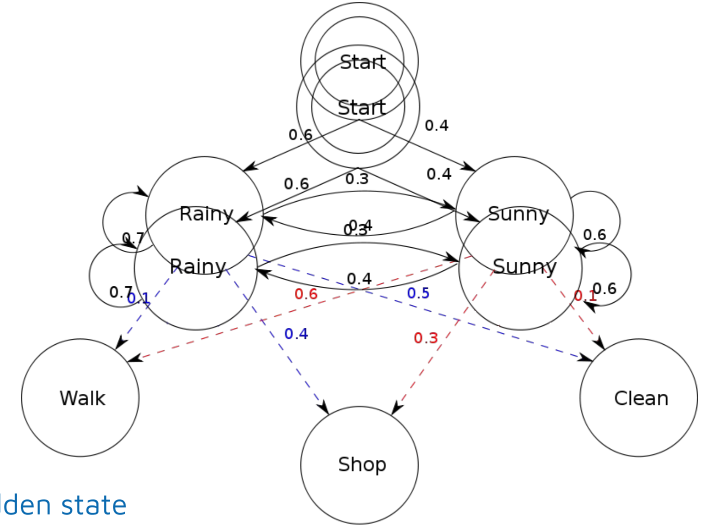
Subjects and Stimuli

- Subjects
  - College students, ranging from 20-22 years old (3 M, 6 F)
  - N = 9 but scanner issues with one subject (effectively N = 8)
- Stimuli
  - "Jibaro" episode from *Love Death Robots* (14 min)
- Experiment
  - Using fMRI machine, scan each subject twice (ie 2 runs) with the same stimulus video
  - Subjects were told to press a button if they wanted to tell someone anything (issues with button-presses, not all data was saved)

Data Processing & Analysis – Hidden Markov Models

Markov Models

- Transition probabilities depend on current state



HIDDEN Markov Models

- Observations depend on “hidden” states
  - Hidden states are governed by a Markov Model
  - Maybe there’s some dependence between the hidden state and the observation? (ex: hidden state should “look like” observations in some way, or be a kind of common denominator)

Why on Earth Would I Tell You About That?

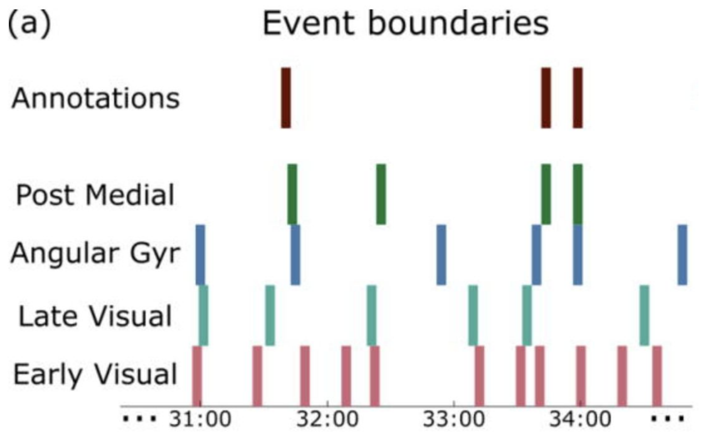
Setting aside the obvious moral objections

Brain instantiation

- Tons of difficult-to-interpret but clearly cohered brain activity
  - Since we can understand sequences from stories, it seems pretty obvious that our brains do *some* temporal grouping
  - Think of the brain as transitioning through a bunch of hidden states
    - WHO KNOWS what the hidden states actually respond to
    - There should be some reliance on what happened previously (hence the Markov part)
    - Observations = fMRI data

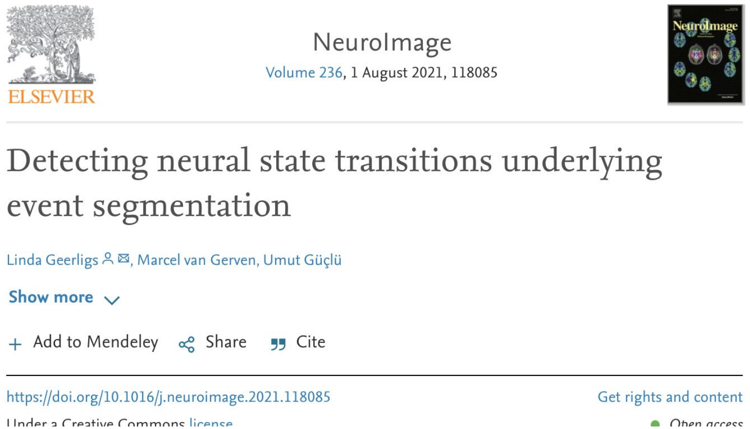
What are we trying to get?

Something sort of like that



Baldassano et al. (2018), *Neuron*

Implementation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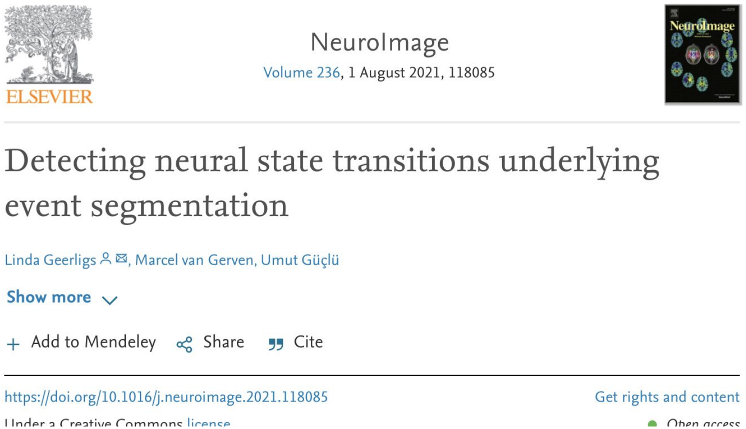
Did you know:

- This was harder than it needed to be
  - The size of our data was greater than anything we've used before
    - Shoutout to Professor Chang for reducing our data
    - RIP to all the kernels we lost along the way
  - We originally wanted to use a newer method with fewer assumptions
    - For one, it would allow us to make event transitions that aren't fully sequential
    - Other cool feature: it would find its own optimal number of states
    - Other feature: it takes about 1 hour to process 1 subject's data for 1 run for 1 ROI
  - This older method is sort of a pain to install
  - Sometimes everyone agrees on one thing and then you do the exact opposite on accident

Implementation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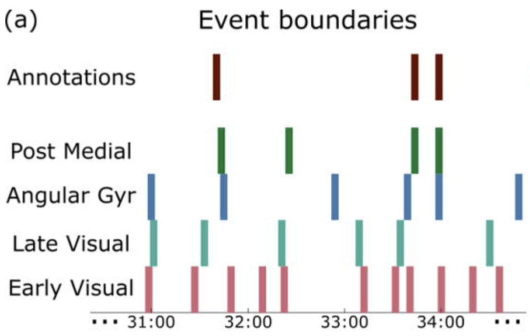
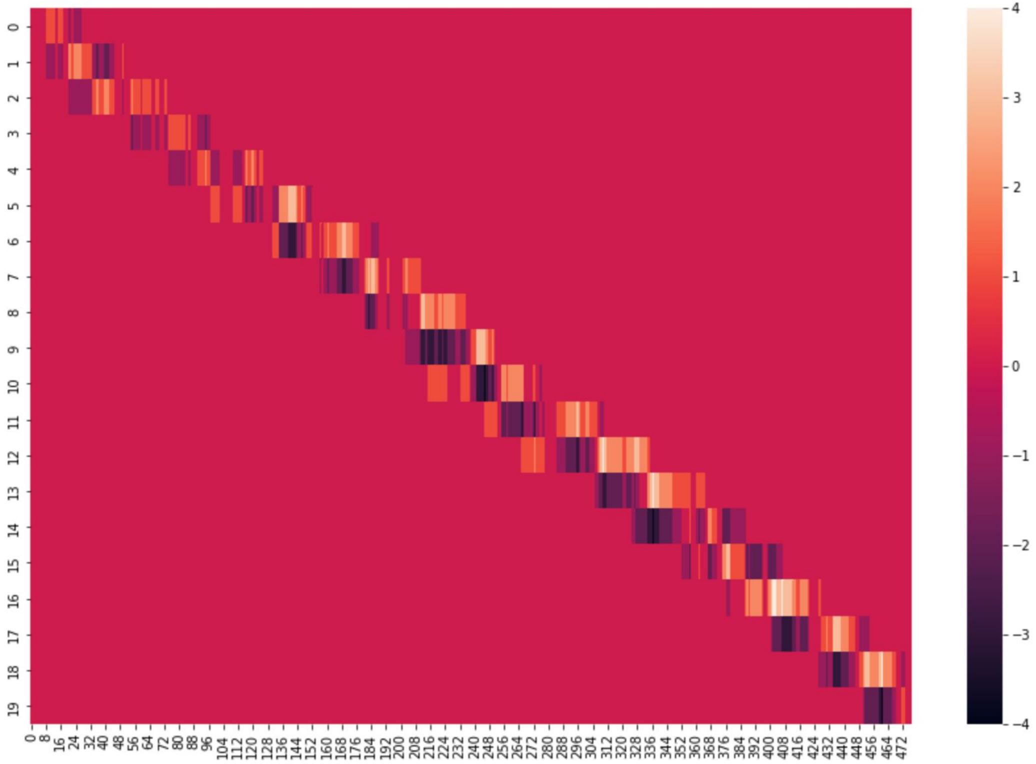
Did you know:

- This was easier than it needed to be
    - Once we cut our losses, the Brainiak package was decently well-behaved
    - WAY faster, took around 20 minutes to process *all* our data
        - This is in part due to two assumptions it makes that aren't great
            - Complete linearity with event transitions
            - Number of events is hard-coded

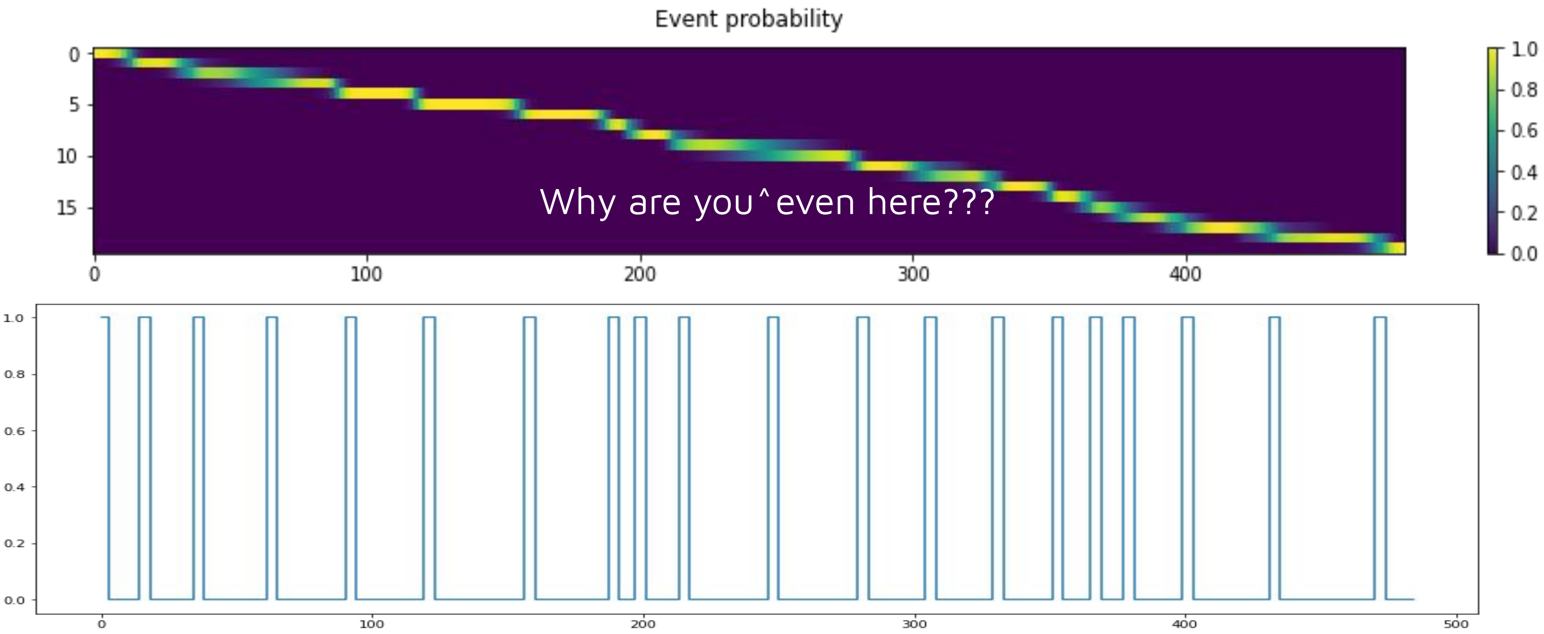
Results

What did you do? What happened to my sweet, easily interpretable darling???





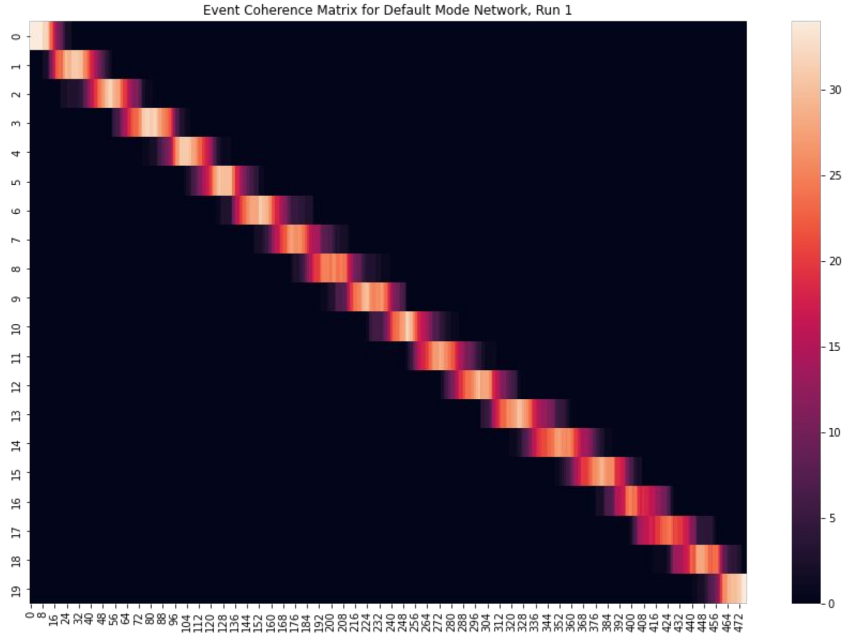
Results


Event probability
Why are you^even here???
0
5
10
15
0
100
200
300
400
1.0
0.8
0.6
0.4
0.2
0.0
1.0
0.8
0.6
0.4
0.2
0.0
0
100
200
300
400
500

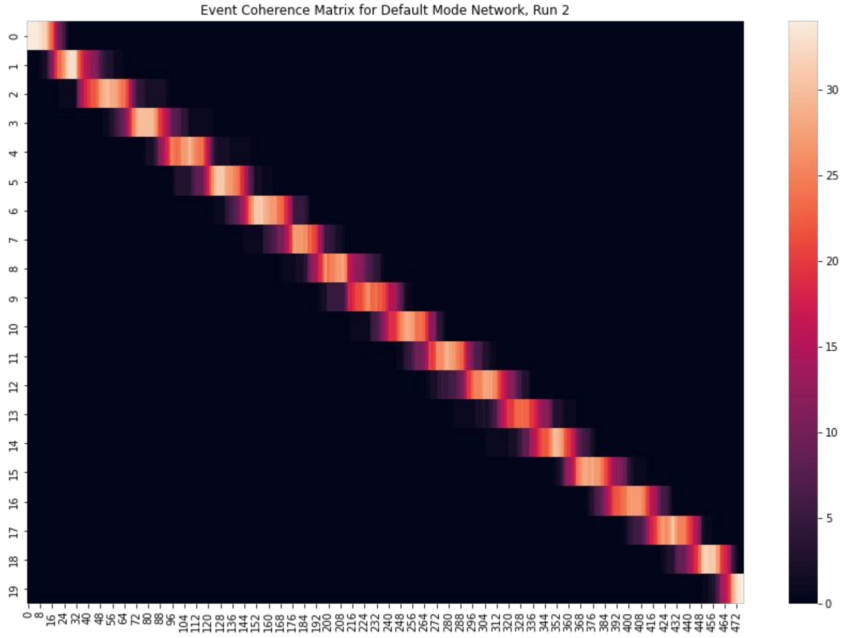
DMN Coherence

ROIs:
(1) PCC/precuneus
(2) vmPFC
(3) DMPFC
(4) TPJ anterior supra marginal gyrus/Parietal operculum
(5) TPJ posterior supra marginal/angular gyrus + bilateral inferior parietal lobule (IPL)

events

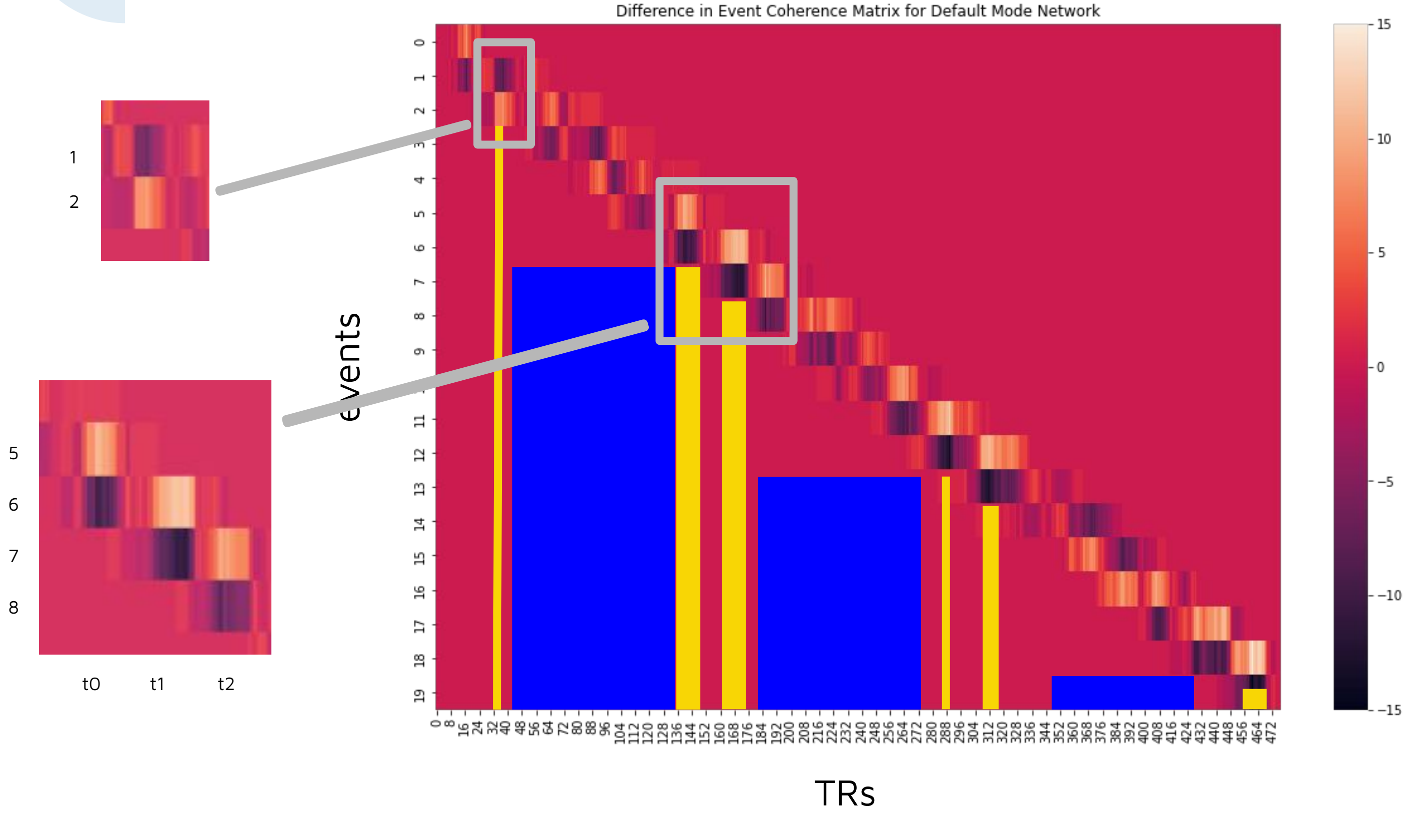


TRs

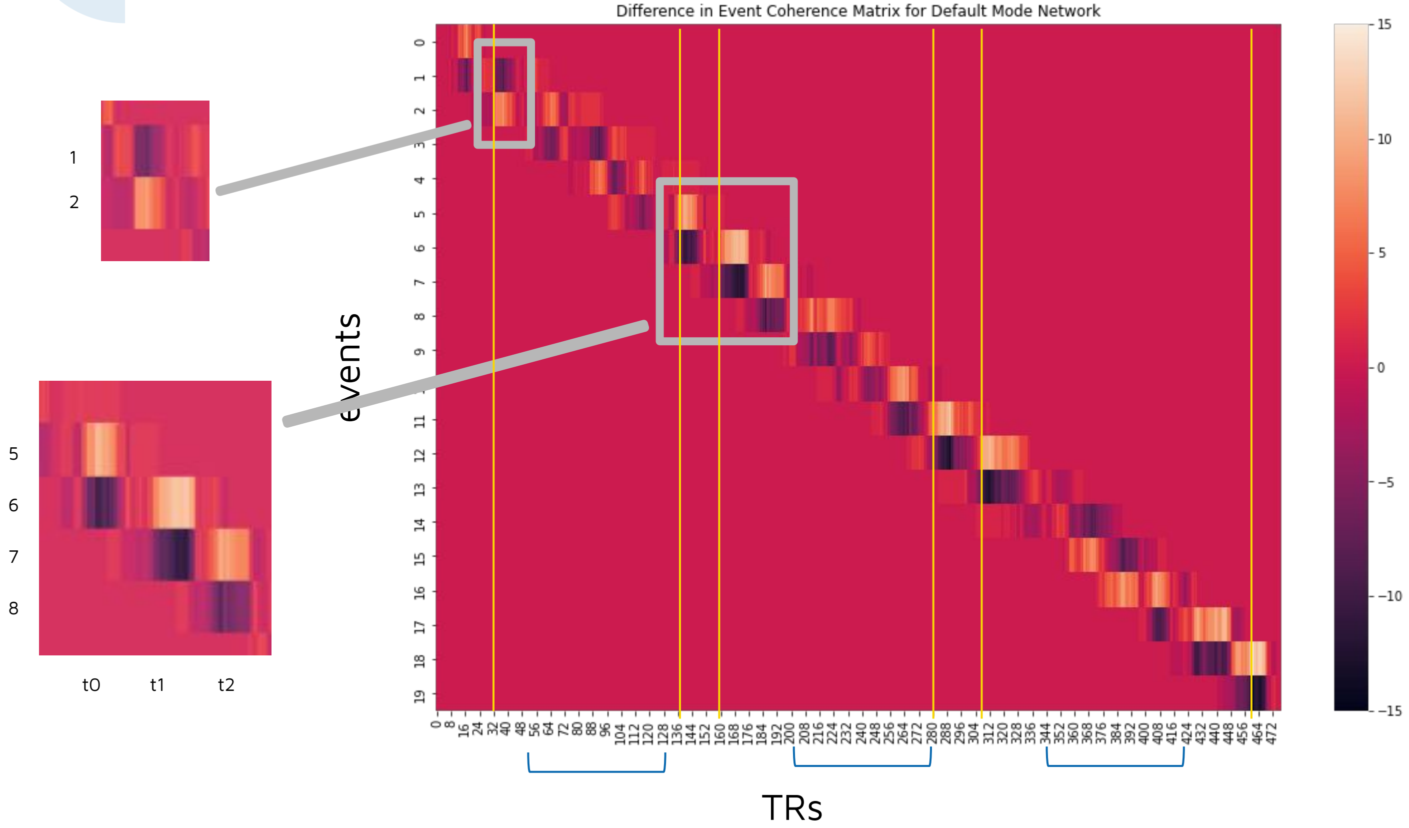


TRs

DMN Differences Between Runs



DMN Differences Between Runs



Similar Event Segmentation Across Subjects in DMN

1:52 - 4:16 (TR = 56-128)

6:40 - 9:20 (TR = 200-280)

11:28 - 14:00 (TR = 344-420)

All ~2.5 min in length

Siren attacking soldiers

Siren + sleeping soldier ⟶ kissing in the river

Blood rushes into the river but before she pulls him into the water

Different Event Segmentation Across Subjects in DMN

1:04 (TR = 32) - P

4:32 (TR = 136) - C

5:20 (TR = 160) - C

9:20 (TR = 280) - P

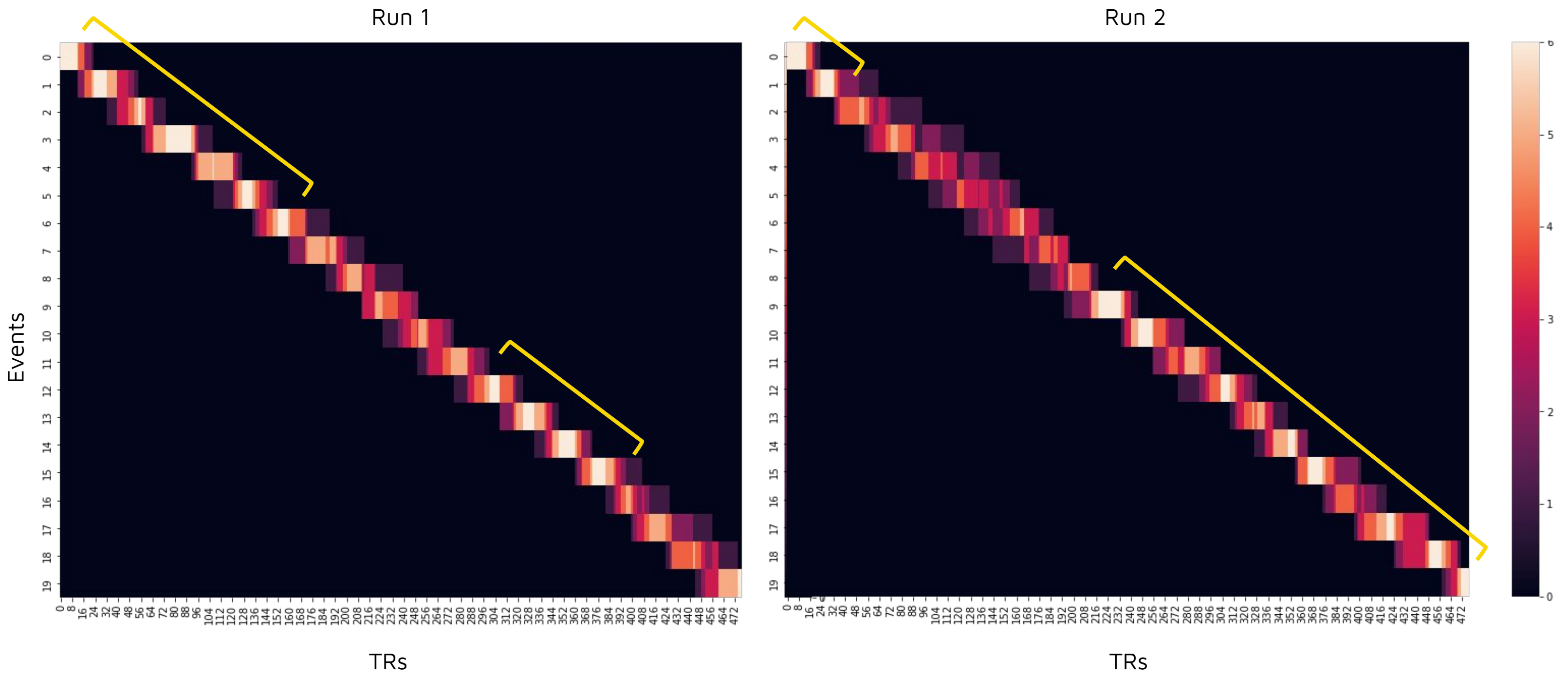
10:12 (TR = 306) - P

15:20 (TR = 360) - P/C

P = Perceptual Feature

C = Conceptual Feature

Posterior Cingulate Cortex (PCC) / Precuneus



Run 2 Event Segmentation in PCC/Precuneus

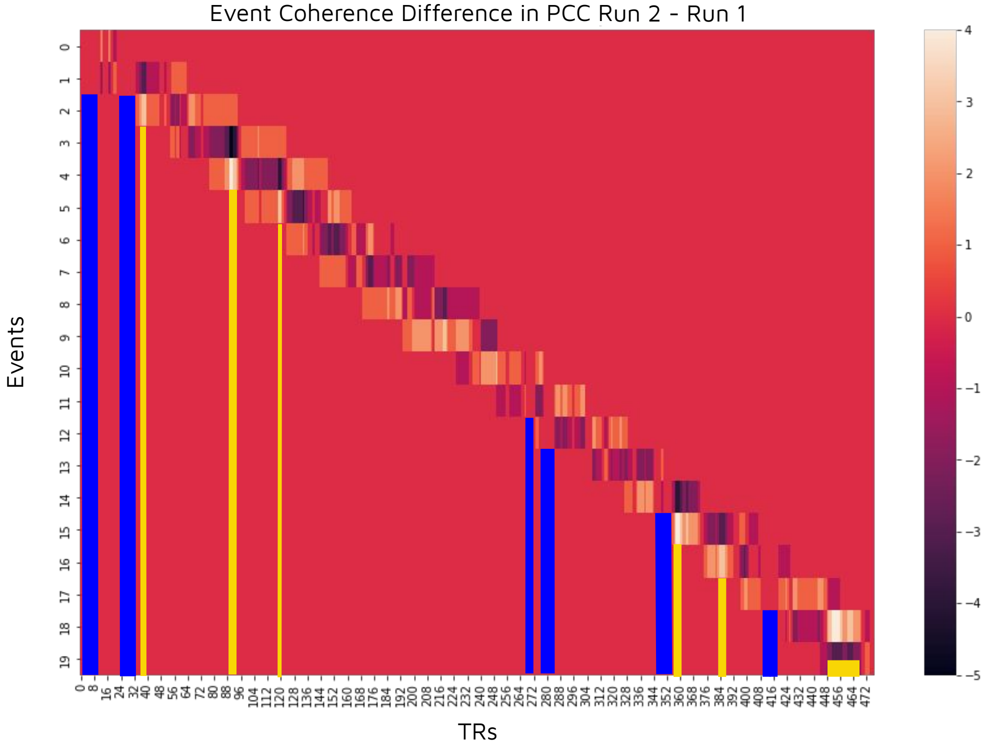
5:20 (TR = 160) - awaken

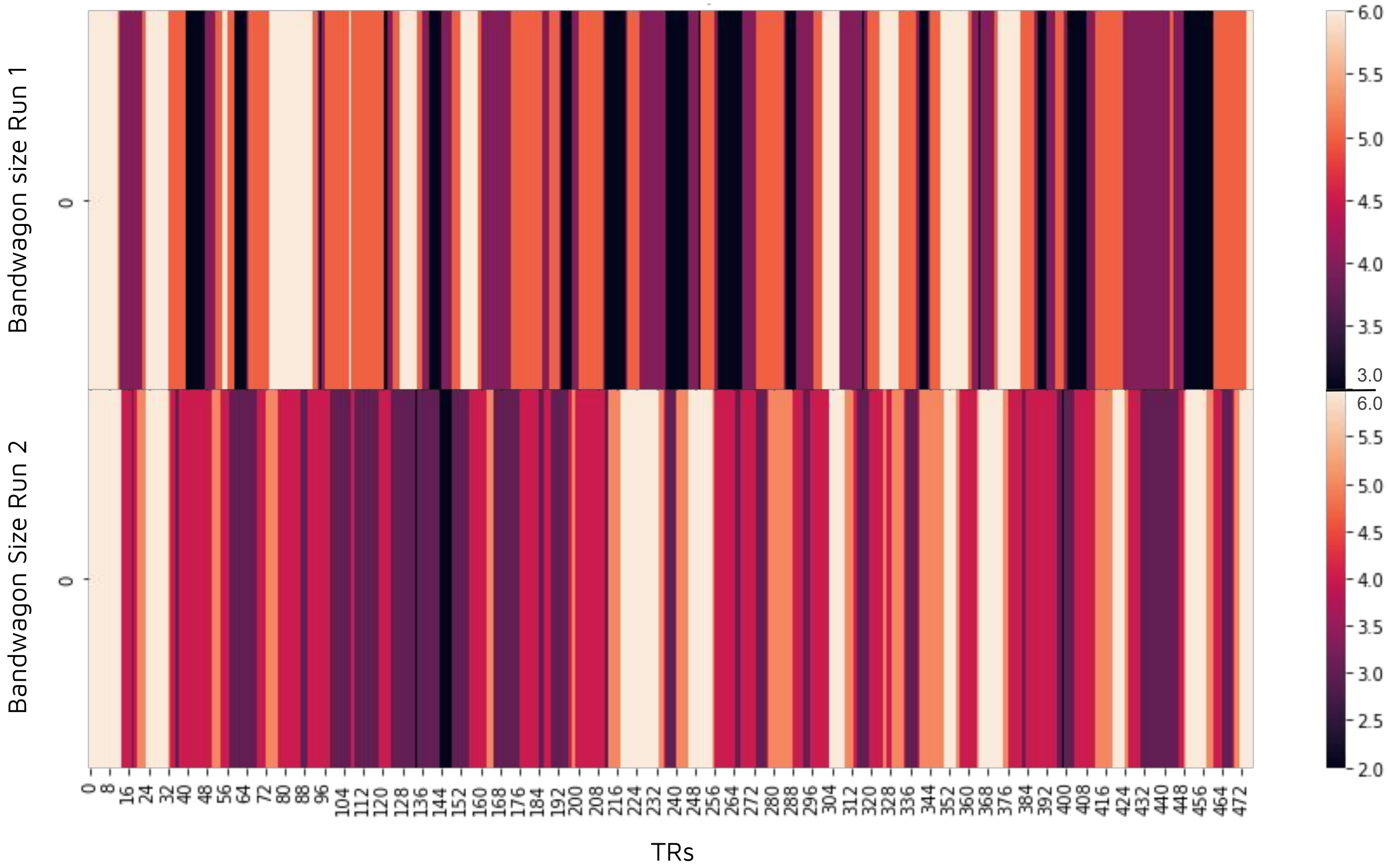
8:45 (TR = 260) - the chase

10:12 (TR = 306) - bloody face

12:45 (TR = 380) - hearing

PCC/Precuneus Differences Between Runs




Bandwagon size Run 1
Bandwagon Size Run 2
TRs
0
8
16
24
32
40
48
56
64
72
80
88
96
104
112
120
128
136
144
152
160
168
176
184
192
200
208
216
224
232
240
248
256
264
272
280
288
296
304
312
320
328
336
344
352
360
368
376
384
392
400
408
416
424
432
440
448
456
464
472
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0

DISCUSSION

what does this tell us about the DMN?

BASICALLY this network does a lot and so it's kinda hard to say.

But if we were to make a stab at it:

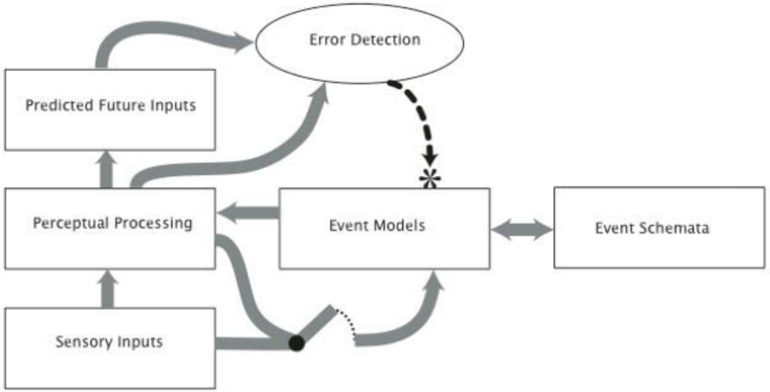
The DMN is important to event modelling and helping our brain respond to unexpected situations by incorporating an incoming stimulus into our existing knowledge in highly nuanced ways.

Most likely uses different kinds of event segmentation for different kinds of stimuli, incorporates knowledge from other areas in the brain

DISCUSSION

what does this tell us about how we process naturalistic events?

- Updating event models to minimize error – longer stretches of stable event models in run 2 with relatively less surprise/confusion
- General shift from fine-grained unitization of events → coarse-grained as familiarity increases
- Both perceptual and conceptual features present for event boundaries



LIMITATIONS & FUTURE ENDEAVOURS

Limitations

- Previous experience with the stimuli would impact response in Run 1
- Running with the GSBS algorithm to not hardcode the number of events
- Experimental design: more participants :(
  but always a limiting factor with fMRI studies

What about other ROIs within the DMN?

- Does each region have a specialized role in event segmentation?
- What about connectivity — how does the DMN modulate activity with the hippocampus for memory or the nucleus accumbens for reward?
- What about other regions in the brain? Would we see identical patterns elsewhere?

What does this say about how we're actually segmenting real life experiences? What about how we segment things differently — what do the regions where we're not synchronized mean?

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