GPS Recalibrated: Exploring Navigation Strategy Shifts under Real-time fMRI Neurofeedback

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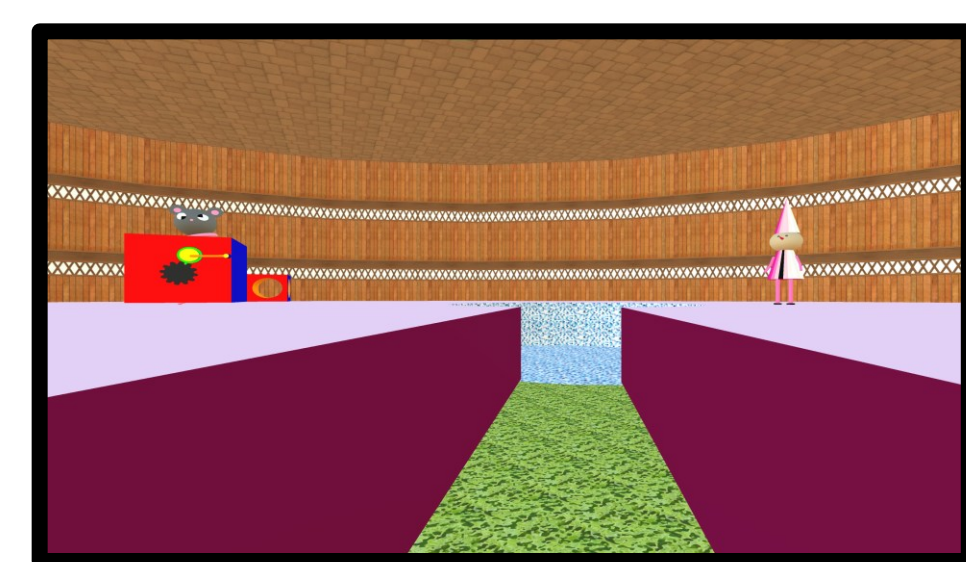
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1. Introduction

- Navigation strategies are supported by distinct brain regions[1,2,3,6]
  - Response strategies (e.g., **familiar routes**) - Caudate nucleus
  - Place strategies (e.g., **shortcuts**) – Hippocampus
- Older adults prefer response strategies[4], related to hippocampal atrophy
- Real-time fMRI (rt-fMRI) neurofeedback enables volitional upregulation of the hippocampus, resulting in improved episodic memory[5]
- Here, we apply rt-fMRI to see whether upregulation of the hippocampus shifts navigation strategy from response to place strategies.

Hypothesis 1: *Real-time fMRI neurofeedback promoting upregulation of the hippocampus will shift navigation strategies from response-based to place-based.*
Hypothesis 2: *Behavior-only group will show preference for response strategies.*
Hypothesis 3: *fMRI results will show increased activation of the hippocampus over time, particular for individuals who shift from response to place strategies.*

2. Method

Virtual Y-maze[4]

Learning (video, 5x)

Probe "find the goal"

- Landmark
- **S** Start
- **G** Goal
- **P** Probe
- Learning
- Place
- Response

At center, same turn or based on objects?

- 20 environments with varied textures, colors, unique objects
- 5 environments per session, 4 sessions over separate days
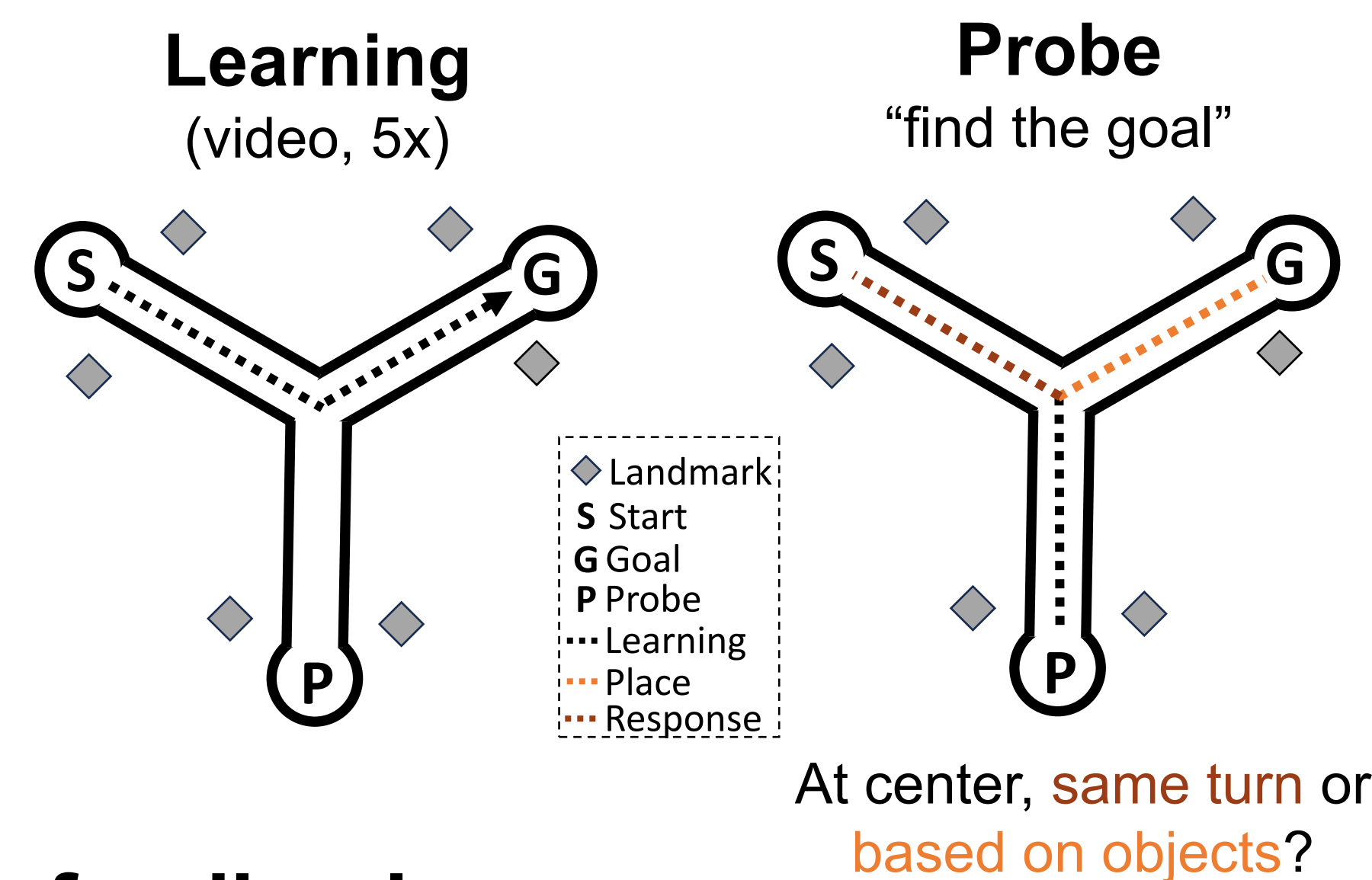
Real-time fMRI Neurofeedback

- During learning, "**make the wall greener**"
- Learning videos (20 SECONDS) interleaved with baseline trials (fixation)
- Processed hippocampal activation compared to baseline (using anatomical hippocampal mask) with Open-NFT (opennft.org)
- Wall color became greener based on **learning > baseline** contrast
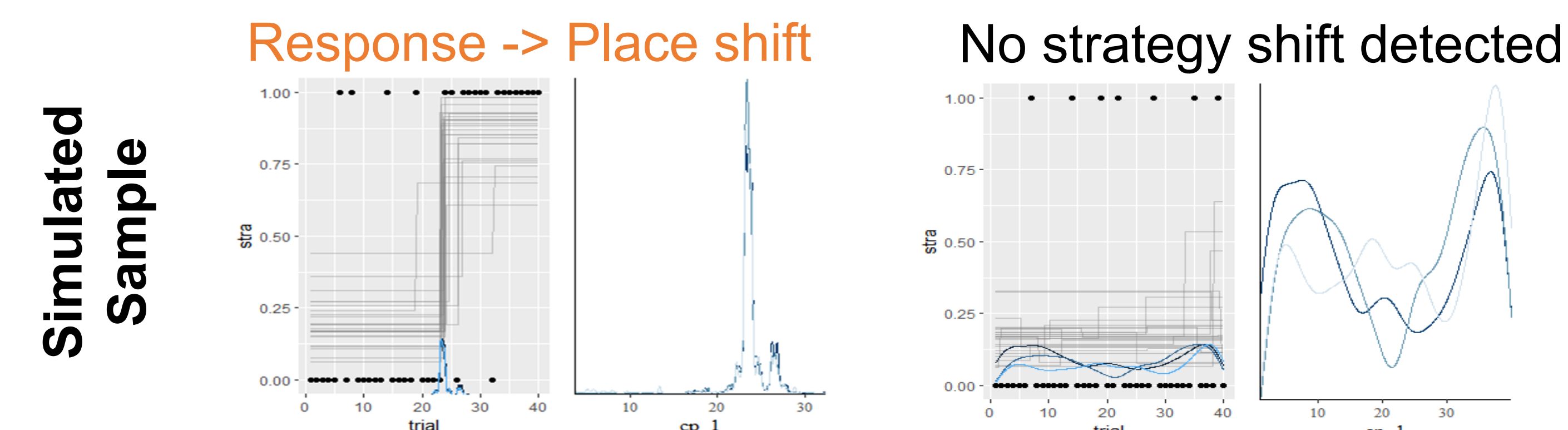
Participants

- Rt-fMRI Neurofeedback
  - 2 younger adults (2 female)
  - 3 older adults (2 female)
  - > 80% response strategy on dual solution paradigm (DSP)[1]
- Behavioral only
  - 13 younger adults (6 female)
  - 11 older adults (2 female)
  - DSP data not analyzed yet

Analyses

**fMRI data**: Univariate analysis (**learning > baseline**)
Y-maze data (Pre-registered):
- Detect individual strategy shift: **Change-point detection (CPD)**[7]
- Aggregate and compare shift distribution between NF and the control group

Simulated Sample

Response -> Place shift

No strategy shift detected

3. Results: Behavior

Change Point detection in rf-fMRI NF:
Two participants shifted from response to place strategy

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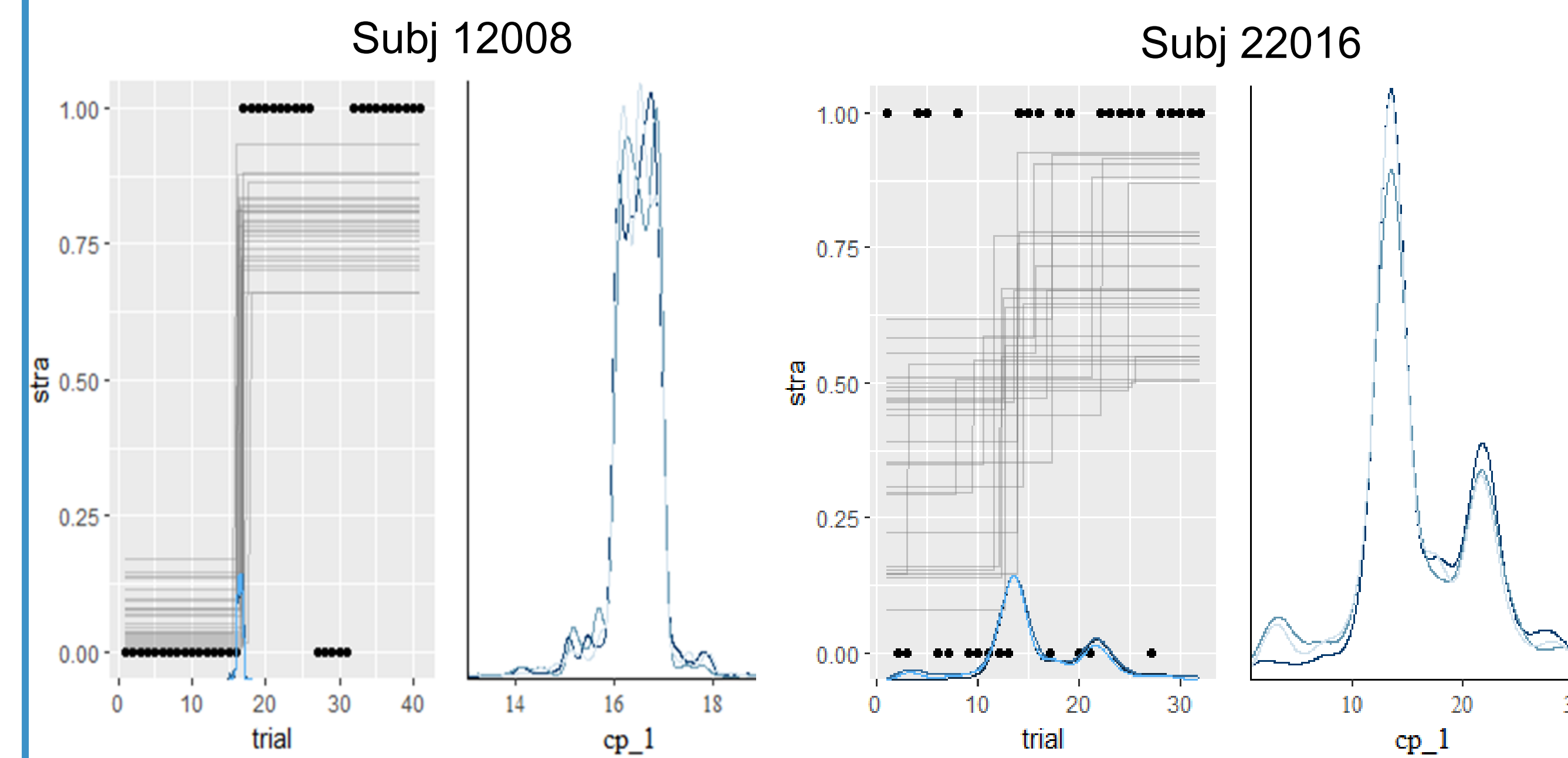
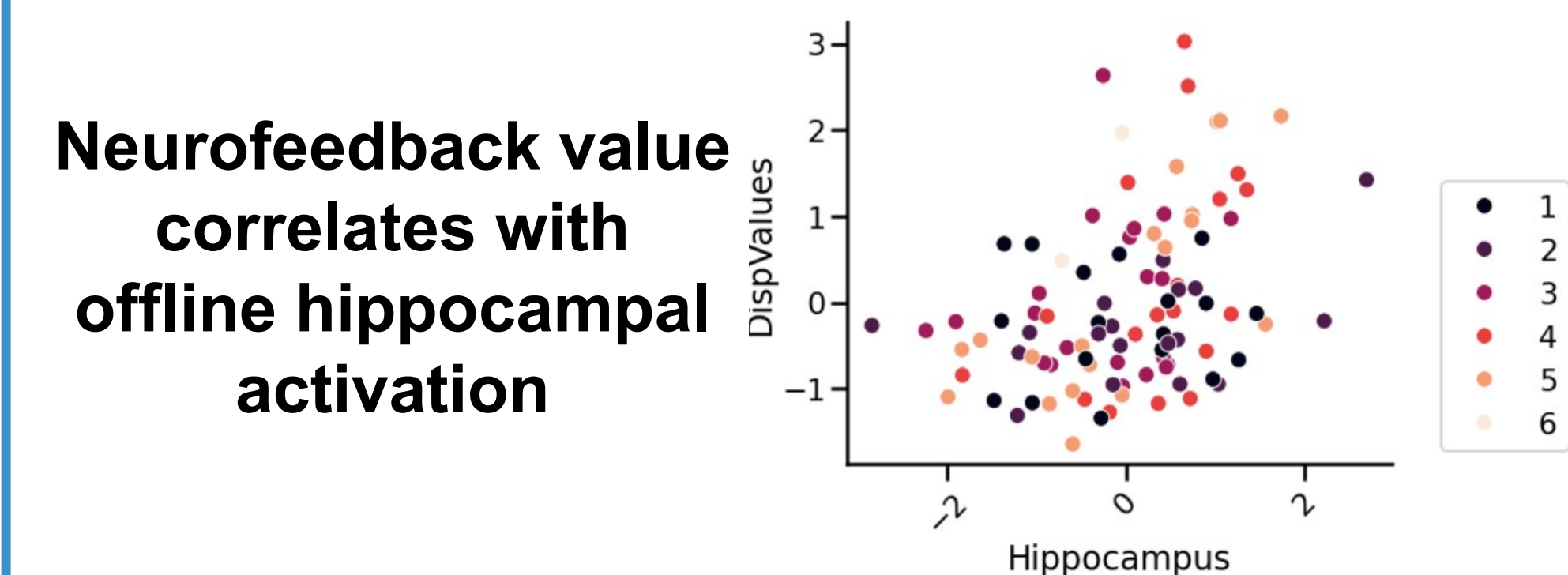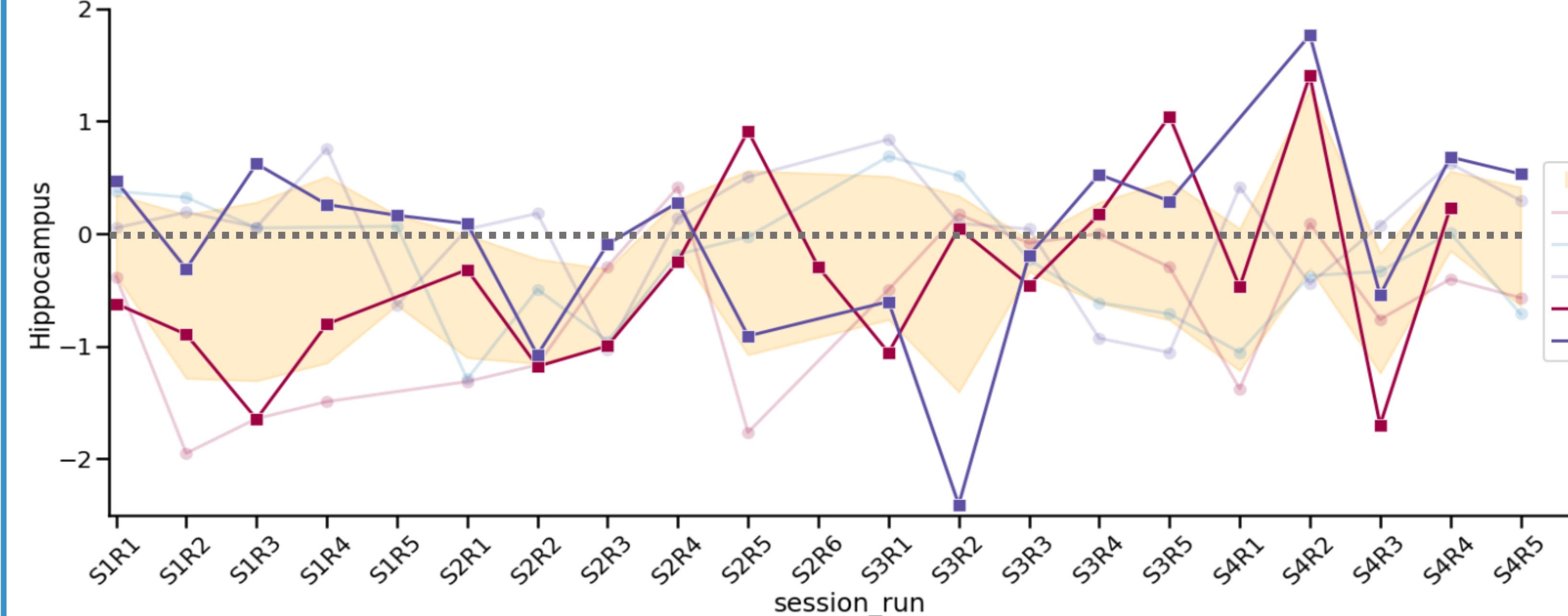| Treatment	Age Group	Shifted R to P	Shifted P to R	Consistent P	Consistent R
NF	YA	1	0	1	0
	OA	1	0	2	0
Control	YA	0	0	13	0
	OA	3	0	7	1
Total		**5**	**0**	**27**	**1**

Note. YA = Younger Adults; OA = Older Adults; R = Response-based Strategy; P = Place-based Strategy

Change Point detection in behavior-only group:
- Three OAs shifted from response to place strategy. No place to response shift.
- One persistent response-based strategy.
- Contrast to Rodgers et al. (2012), OAs were not significantly preferring response strategy, suggesting a ceiling effect that skewed strategy preference, which undermines NF effectiveness. To be confirmed with further analysis on their DSP data.

4. Results: fMRI

Individual bilateral hippocampal activity across sessions

- Average
- 12006
- 21008
- 22014
- 12008
- 22016

Hippocampus activity from two "shifted" participants

- Response
- Place

subID = 12008

subID = 22016

Neurofeedback value correlates with offline hippocampal activation

Univariate analyses:
- Participants did not upregulate hippocampus over time
- Upregulation did not correlate with place learning
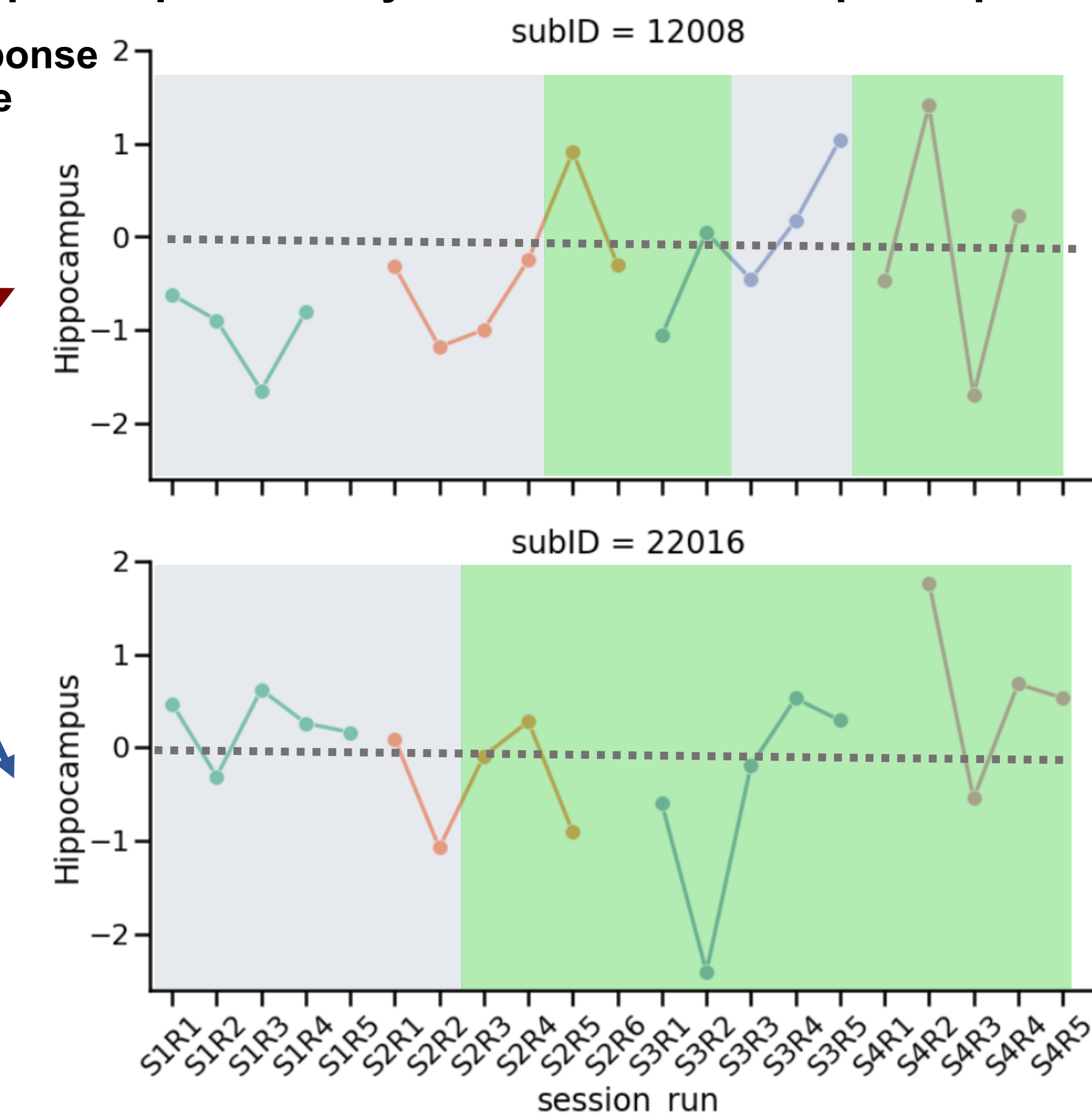
5. Conclusions

- **Behavioral evidence of Navigation strategy shift**
  - Despite response strategy use on a separate task, the NF group either used a place strategy or switched from response to a place strategy – both evidence of NF effectiveness.
  - However, the behavior-only group also showed a place preference overall.
  - Behavioral-only group does not show older adult Y-maze preference for response strategies.
  - Future analyses will determine relation between Y-maze and DSP strategy preferences.
- **fMRI evidence of Navigation strategy shift**
  - Correlation between online and offline hippocampal activation verifies rt-fMRI NF target.
  - Lack of fMRI evidence might result from narrow ROI.
  - Future searchlight analysis would reveal potential change of neural activation in other regions.

6. References

1. Marchette, ..., Shelton. (2011).
2. Voermans, …, Fernández. (2004)
3. Rondi-Reig, …, Berthoz. (2006).
4. Rodgers, .., Moffat. (2012).
5. Sherwood, …, Parker. (2016)
6. Stringer,…, Skinner, (2005)
7. Lindeløv. (2020).

7. Acknowledgement