The Role of Brain Oscillations in Deep Predictive Learning: Behavioral Approaches

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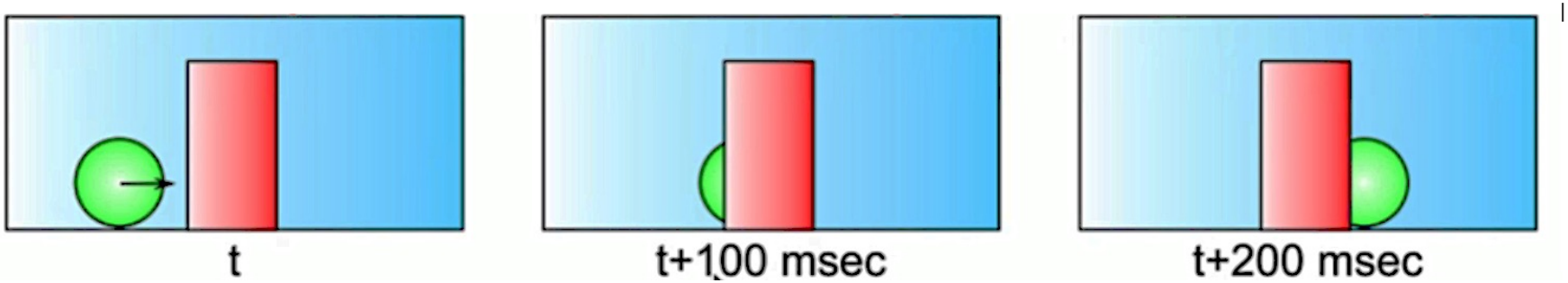
Outline

Introduction

Predictive Learning



Key Points

- We are constantly predicting our future
- Learning signals (i.e., the prediction error) driven by the difference between the brain's top-down prediction and bottom-up real world information
- **Hypothesis**: Predictive learning occurs based on a temporal organization (alpha cycle, 100ms).

Current Research

Current Research

What would be a good experimental paradigm to test predictive learning?

Experimental Design

Experimental Design

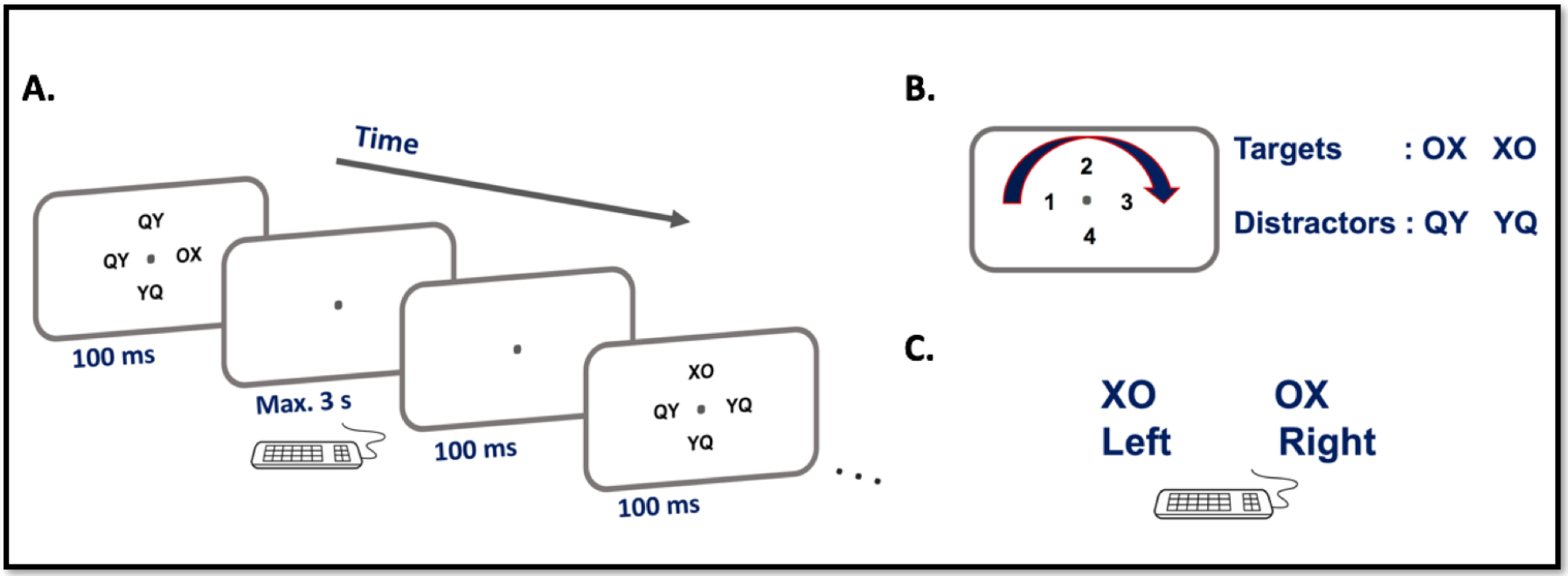
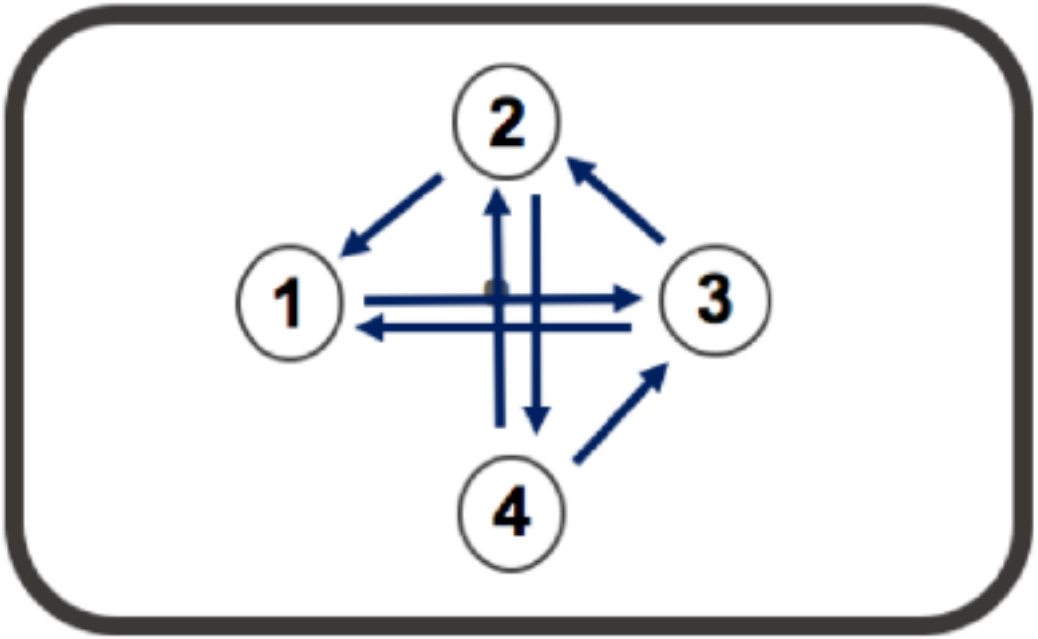


Figure: *N. Deroost et. al, "Spatial processing and perceptual sequence learning in SRT tasks" (2006).*

- **Statistical-sequence learning**
- **Pure perceptual learning**

Experimental Design



S1: 42132431

S2: 13423124

- **Implicit Learning**

Experiment 1

Procedure

Goal:

- Replicate the sequence learning without including any motor related learning

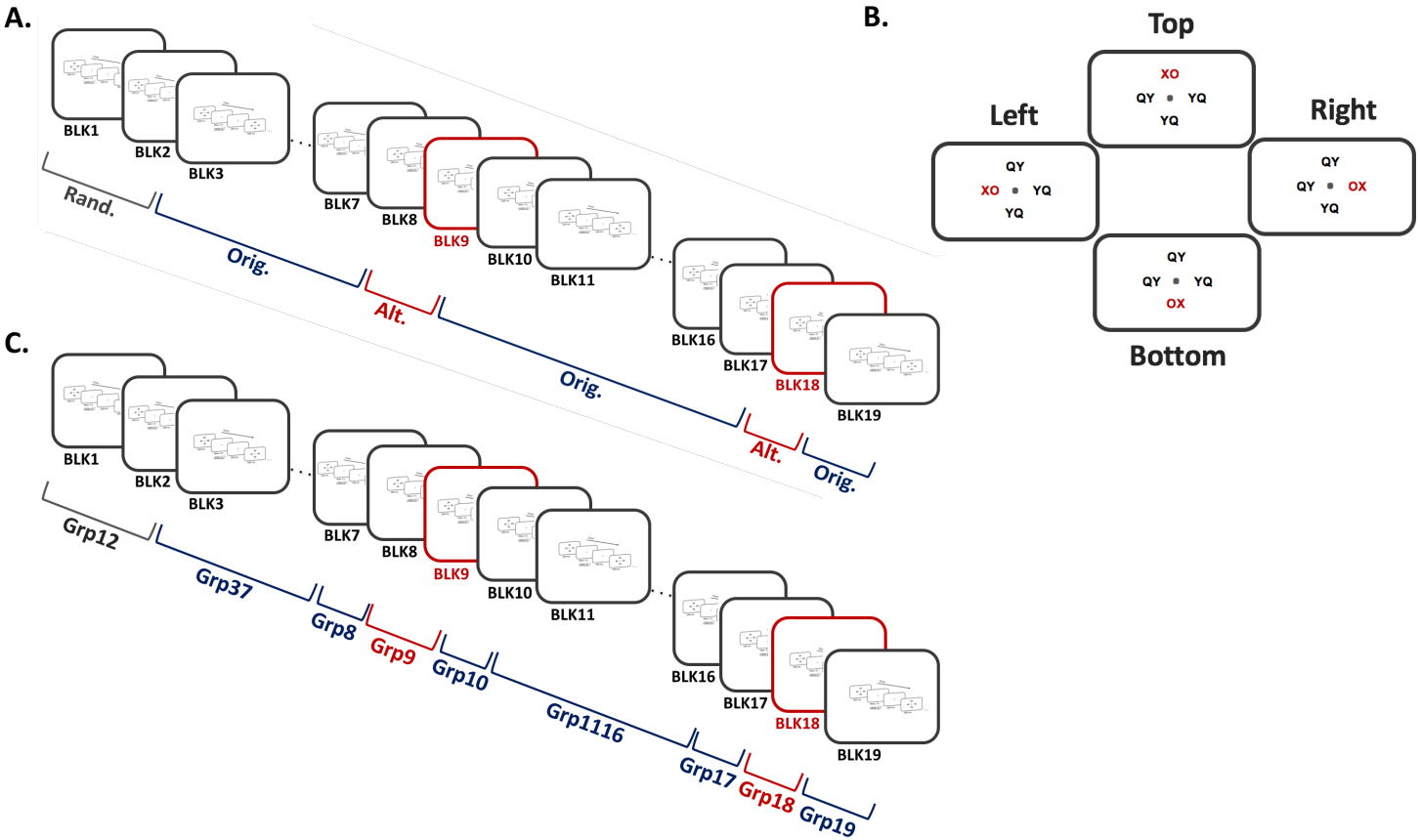
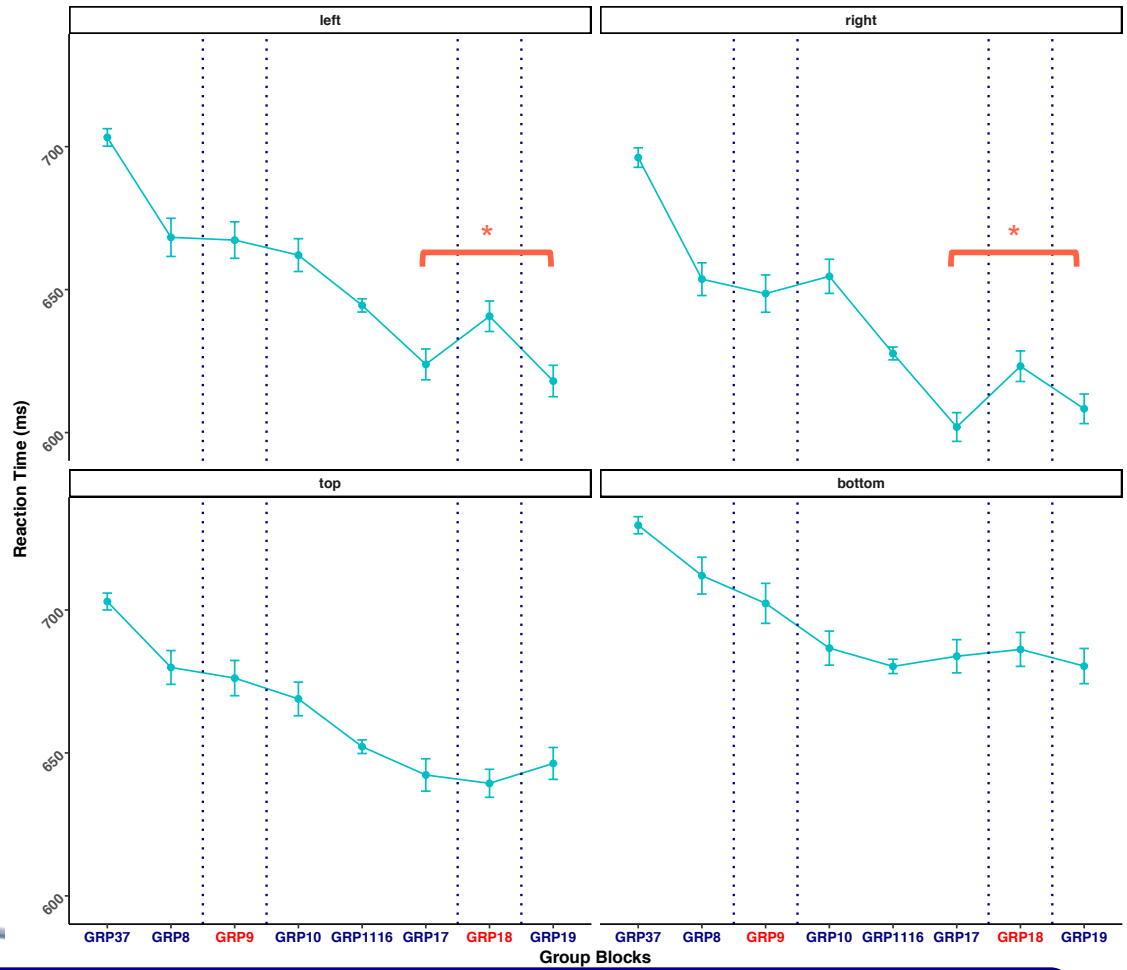


Figure: Illustration of the experimental procedure and groups

Behavioral Results

- **Seq. learning in left and right**
- **Loc. right fastest**
- **Loc. bottom slowest**



Key Question:

- Did our experimental paradigm show predictive learning behaviorally and without the confound of motor learning component?

Summary

Key Findings:

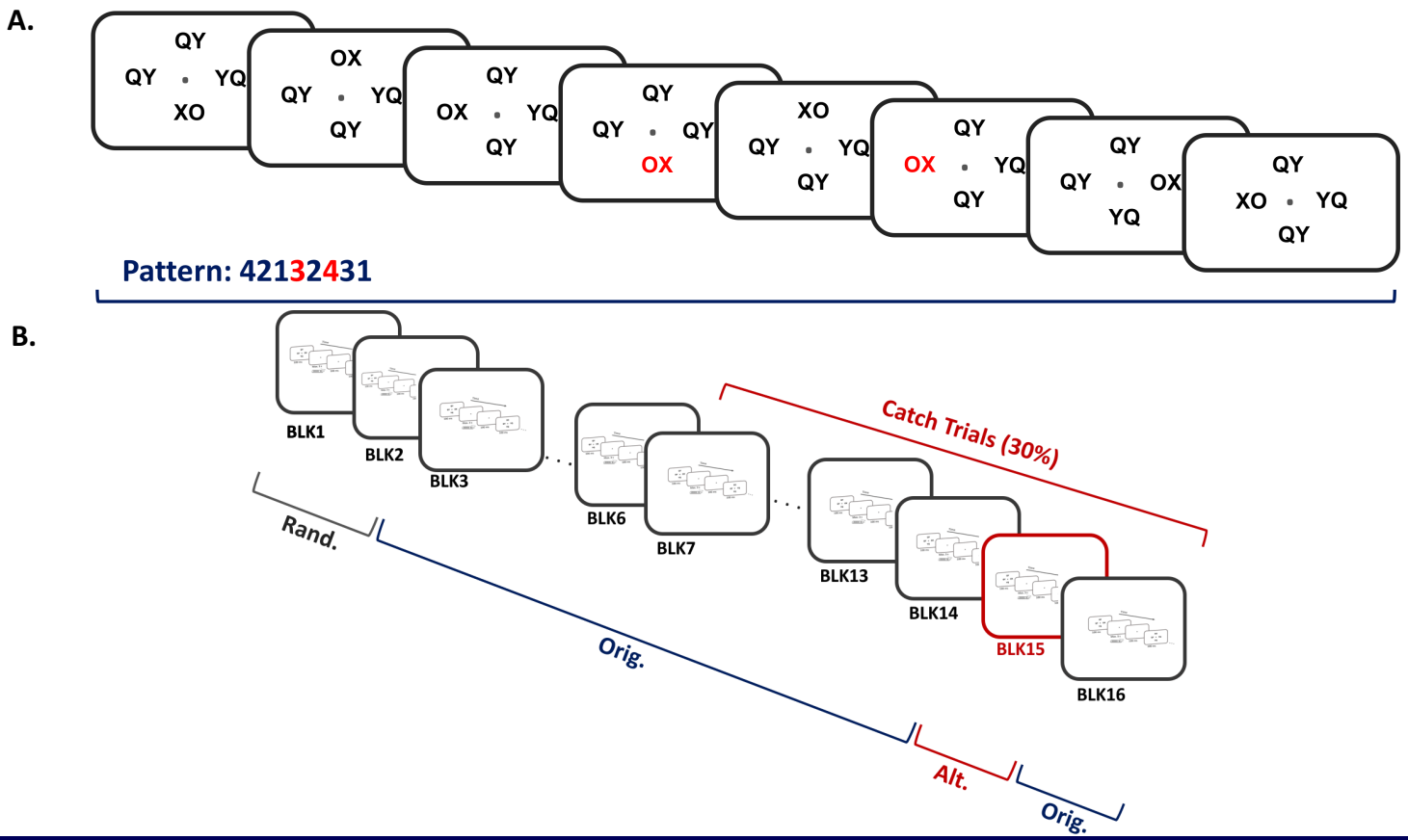
- **General learning;** Faster responses over time.
- Fastest RTs in loc. right.
- Slowest RTs in loc. top.
- **Sequence-specific learning;** Quadratic trend over transition blocks in loc. **left**. and **right**. item

Experiment 2

Procedure

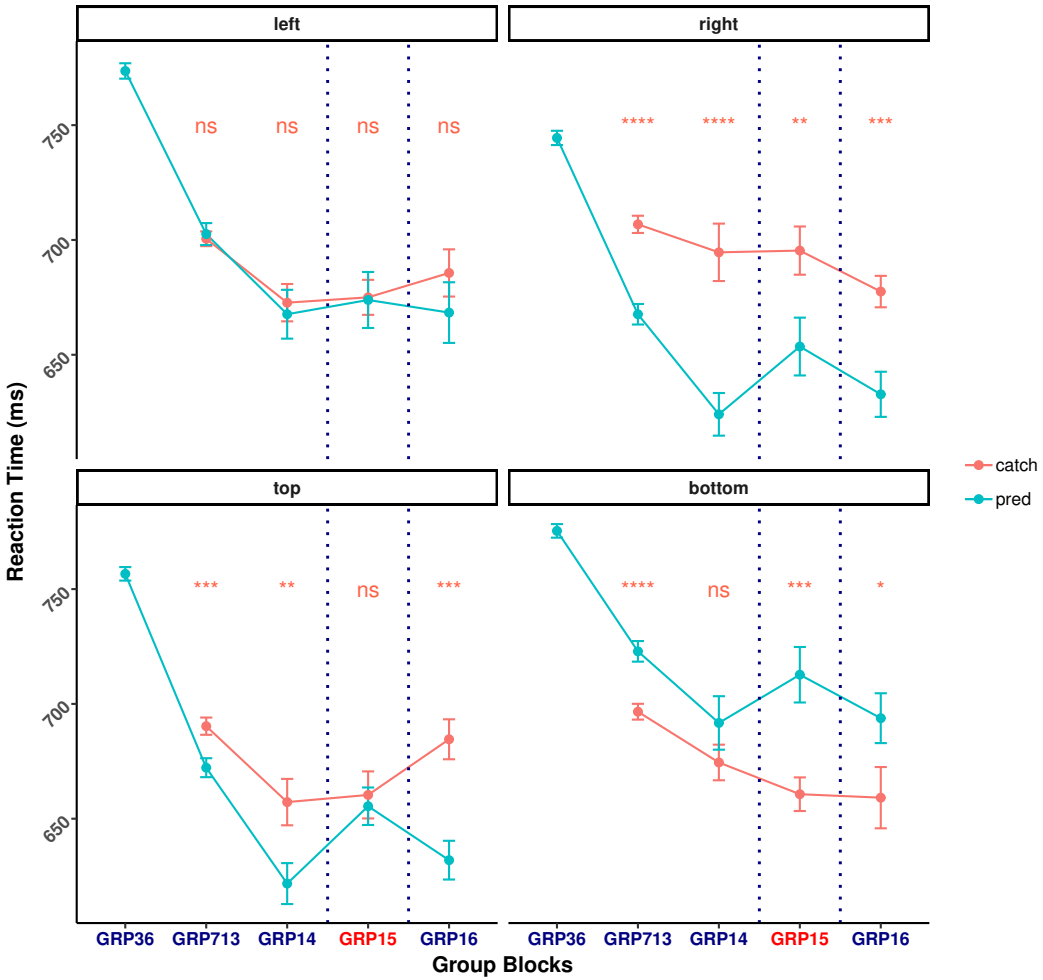
Goal

- Add **catch** trials to the experiment
  - Measuring a **trial-by-trial** predictive learning
  - Measure **prediction error** after recording EEG



Behavioral Results

- **Seq. learning in loc. right**
- **Loc. right fastest**
- **Loc. bottom slowest**



Key Question:

- Predictive learning behaviorally and without the confound of motor learning component?

Summary

Key Findings:

- **General learning;** Faster responses over time.
- Fastest RTs in loc. right.
- Slowest RTs in loc. top.
- **Sequence-specific learning;** Quadratic trend; only in location **right** and **not left**.

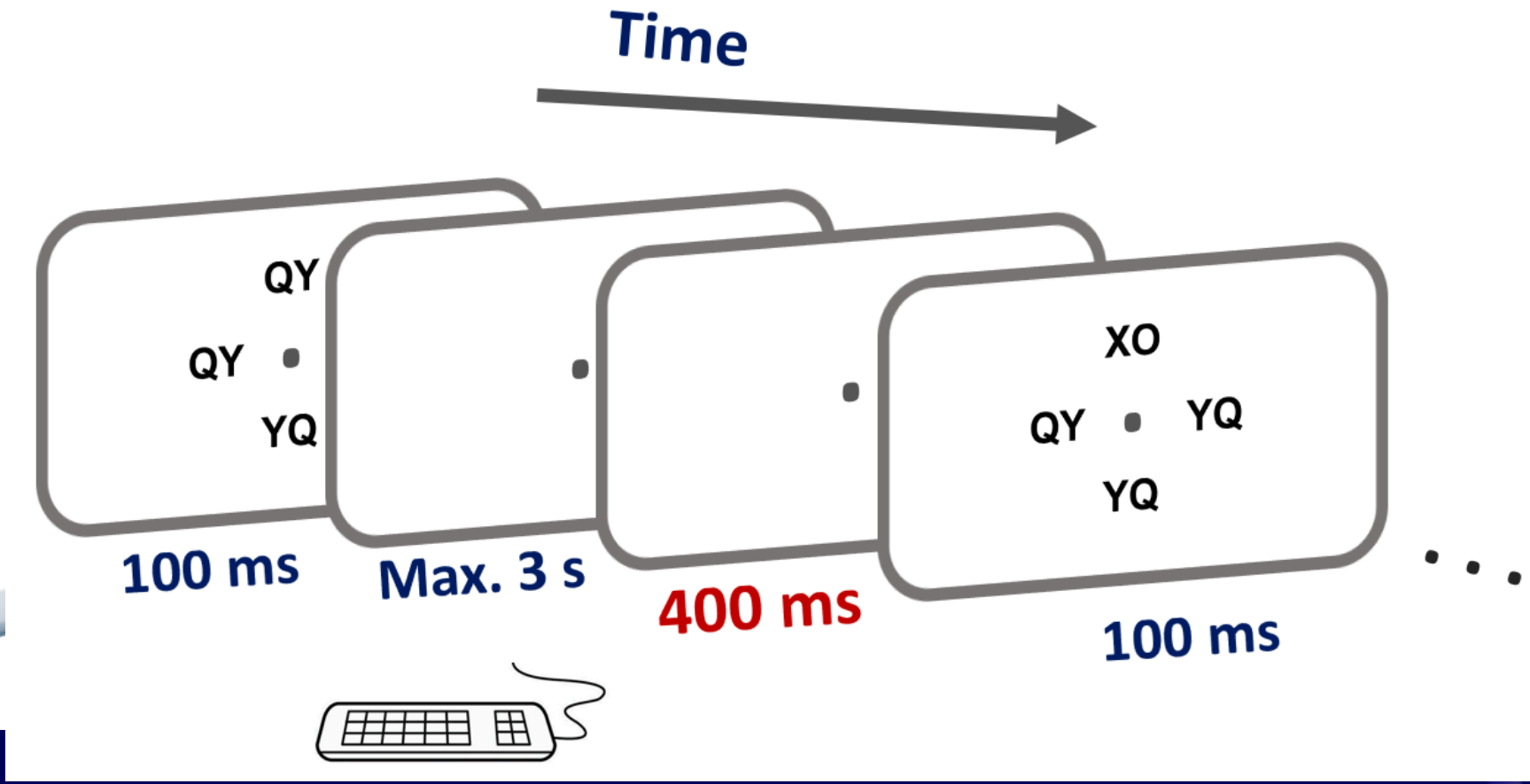
Next step:

- After observing promising behavioral results, we recorded EEG.

Summary

Next step:

- Increasing baseline.

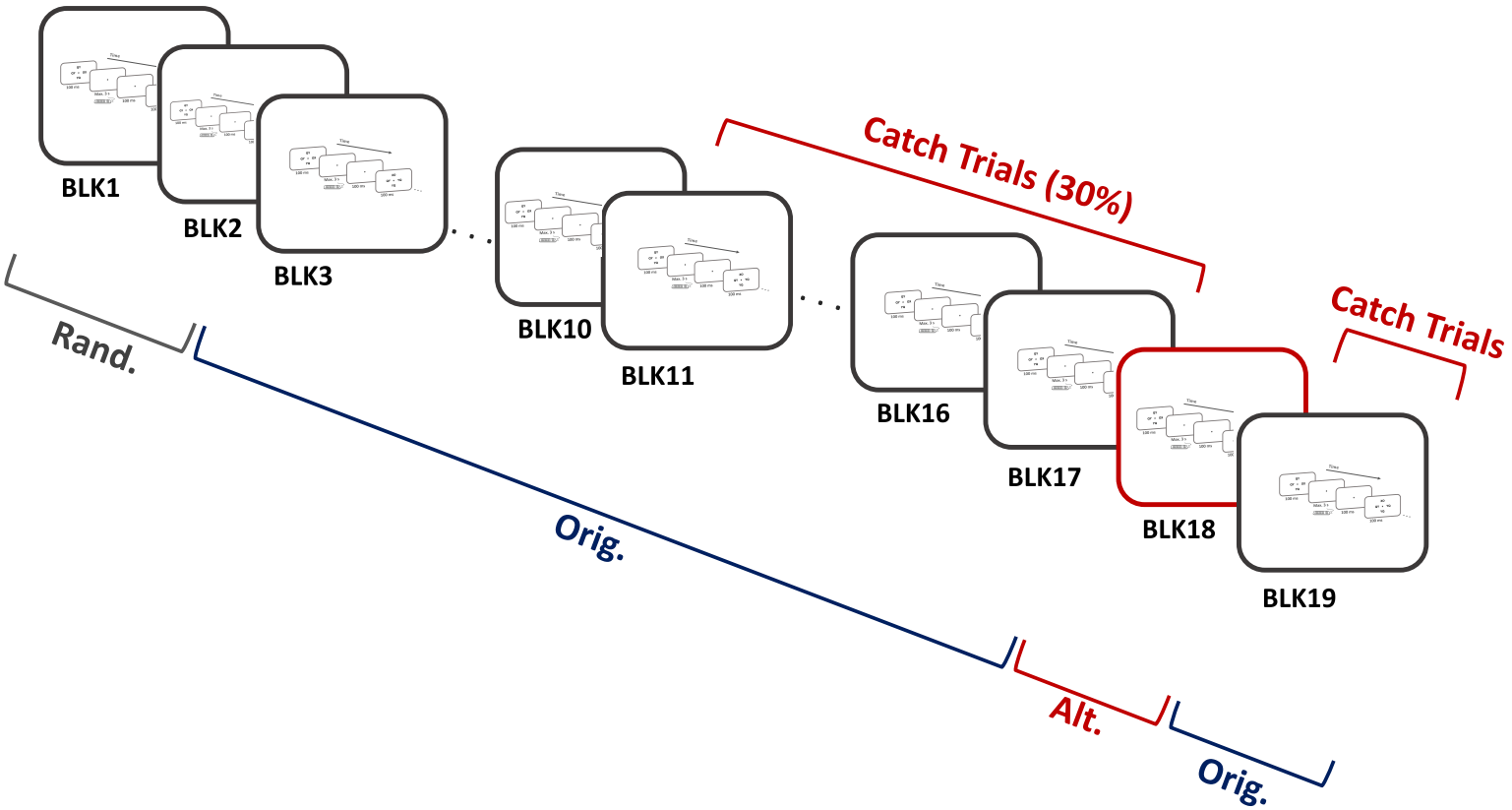


Experiment 3

Procedure

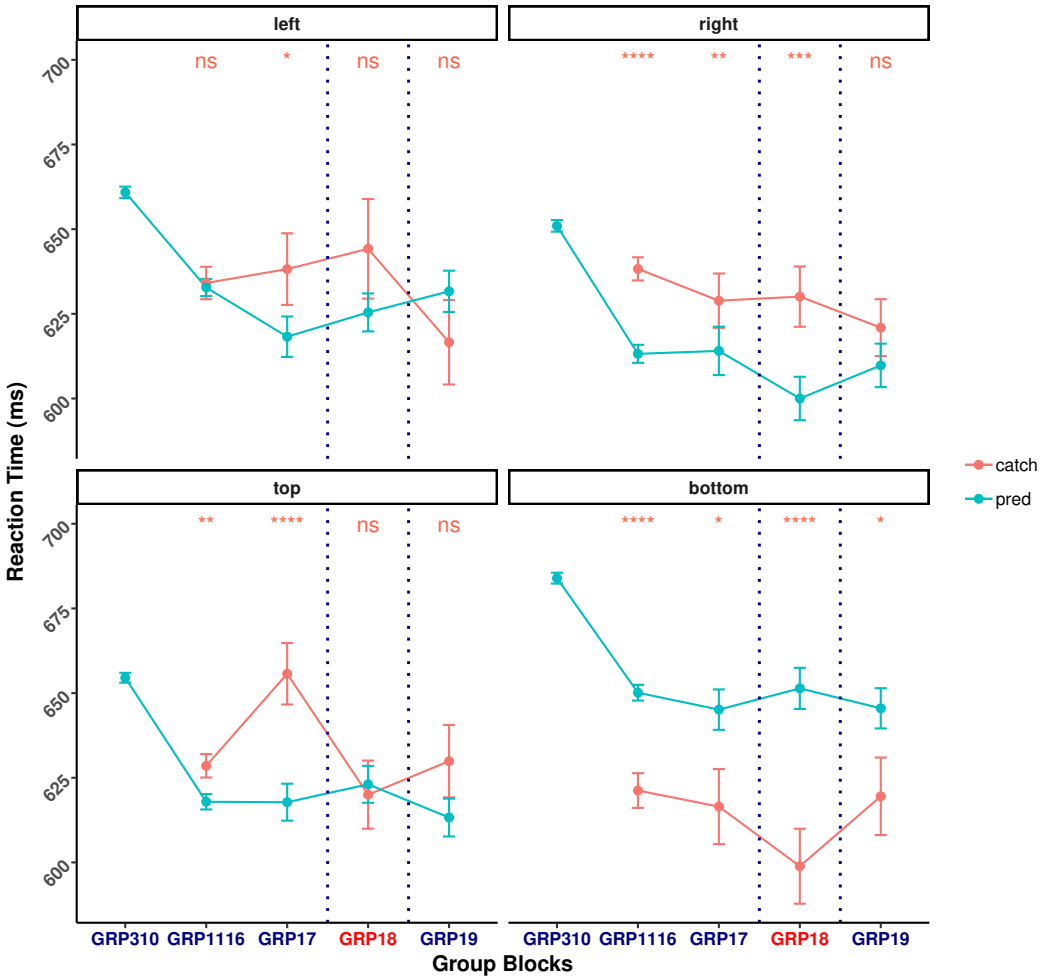
Goal:

- Replicate the previous findings after increasing the ISI.



Behavioral Results

- **Seq. learning in loc. right**
- **Loc. right fastest**
- **Loc. bottom slowest**



Summary

Key Findings:

- **General learning;** Faster responses over time.
- Fastest RTs in loc. right.
- Slowest RTs in loc. top.
- **Sequence-specific learning;** NO significant quadratic trend over transition blocks.

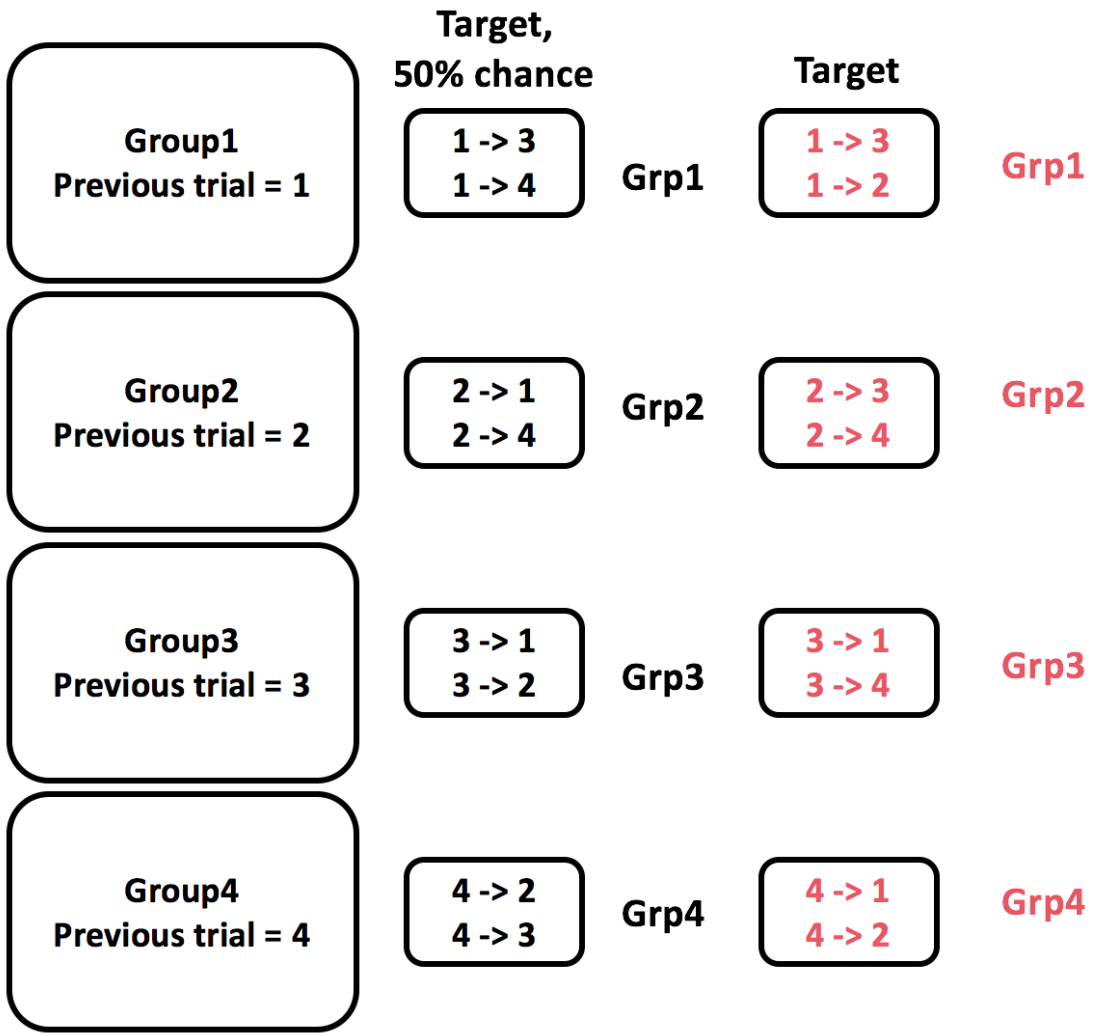
EEG Analysis

Second-order feature

2 1 -> 3
3 1 -> 4

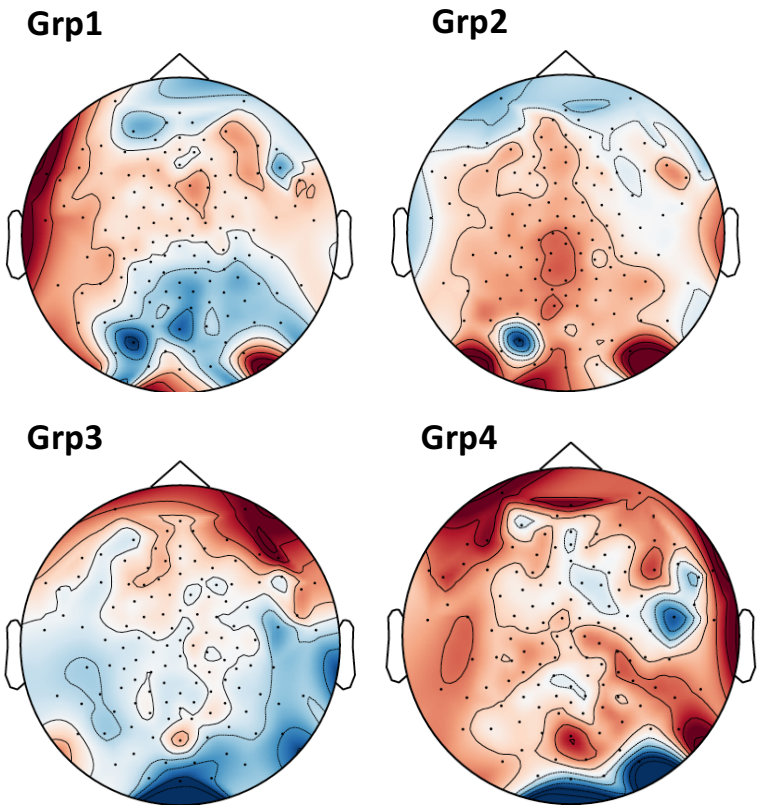
Pattern S1: 4213 2431

Pattern S2: 1342 3124

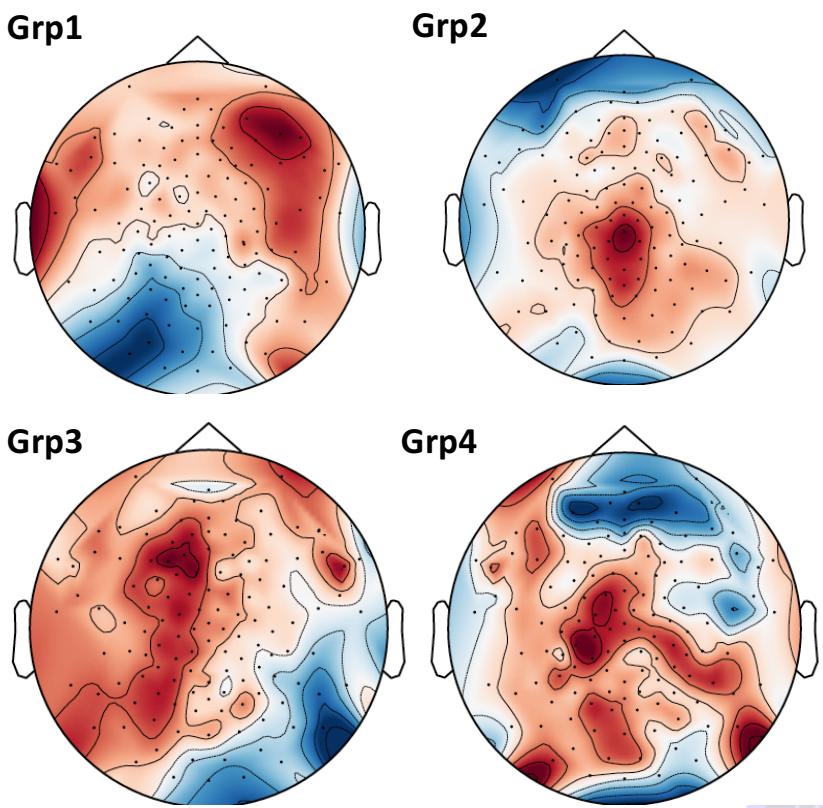


Topographical maps

Pre-stimulus Block 3-6, P1

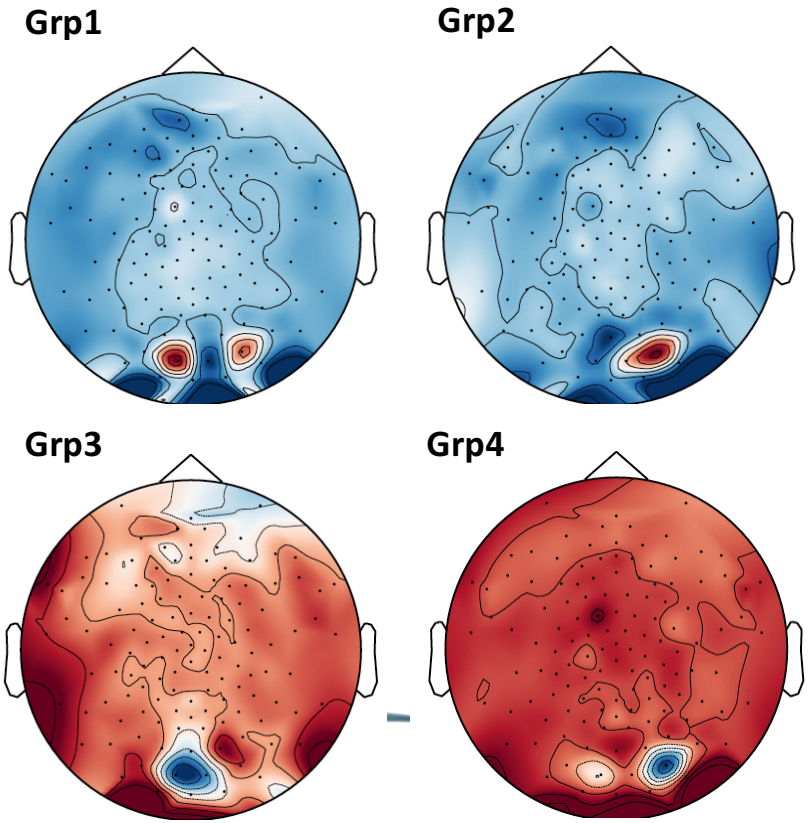


Post-stimulus Block 3-6, P1

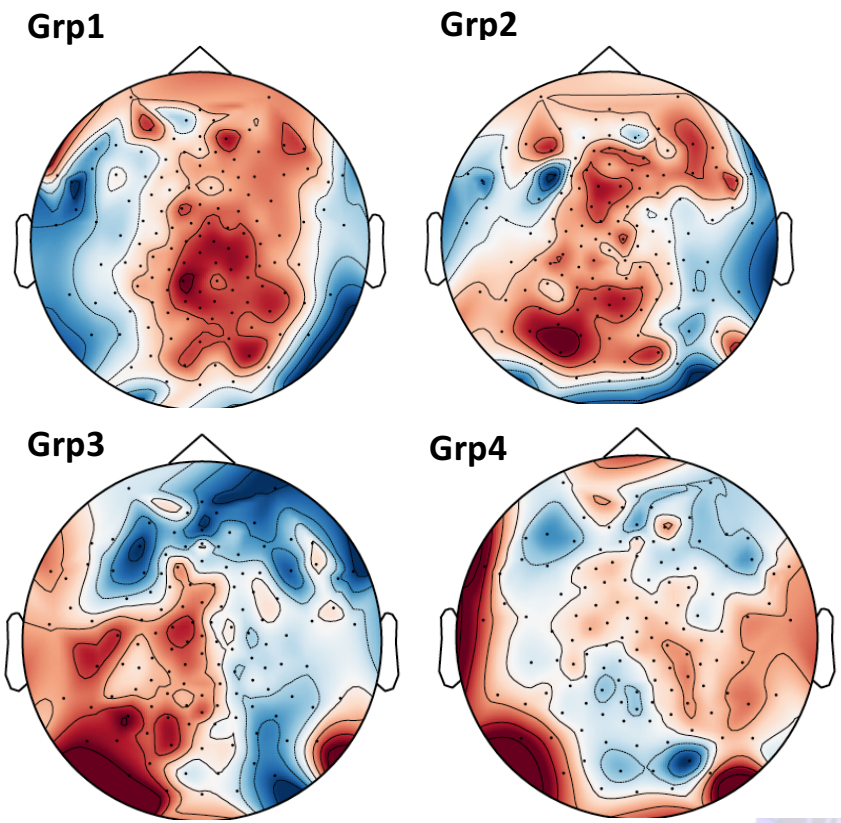


Topographical maps

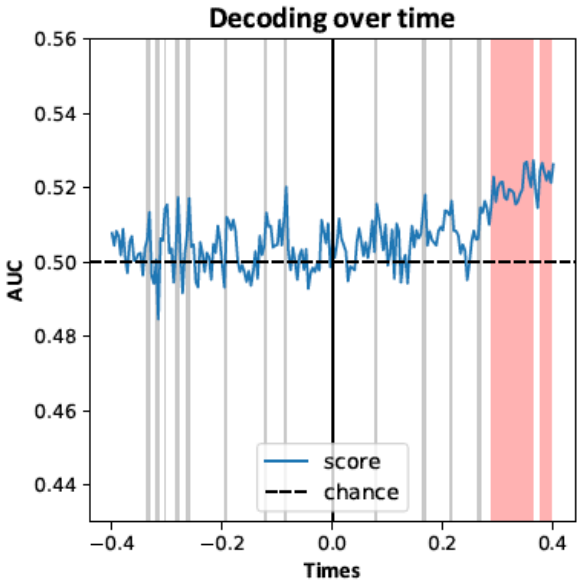
Pre-stimulus Block 3-6, P2

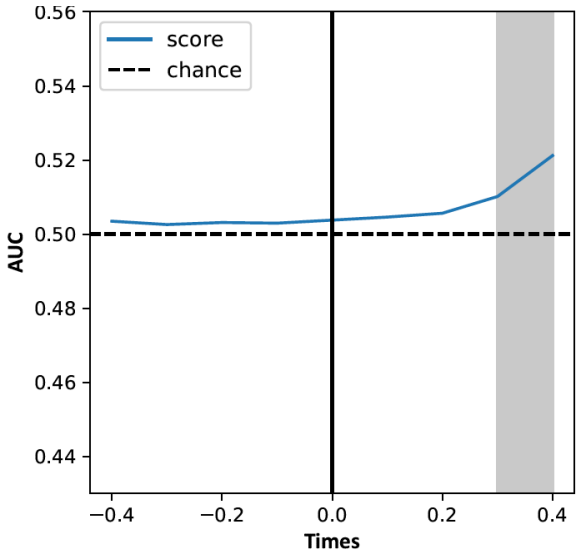


Post-stimulus Block 3-6, P2

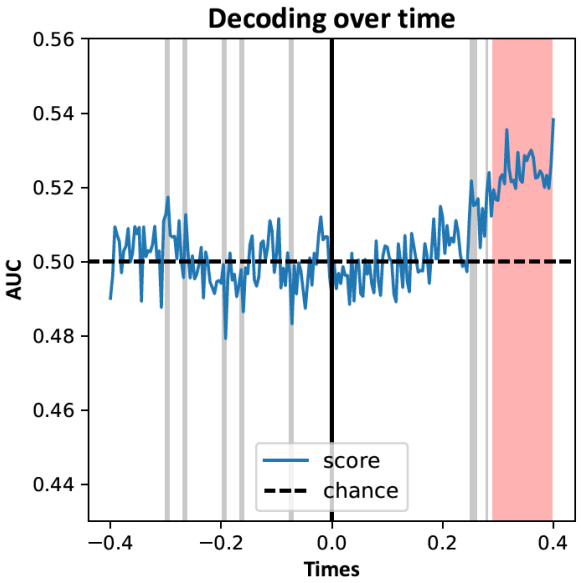


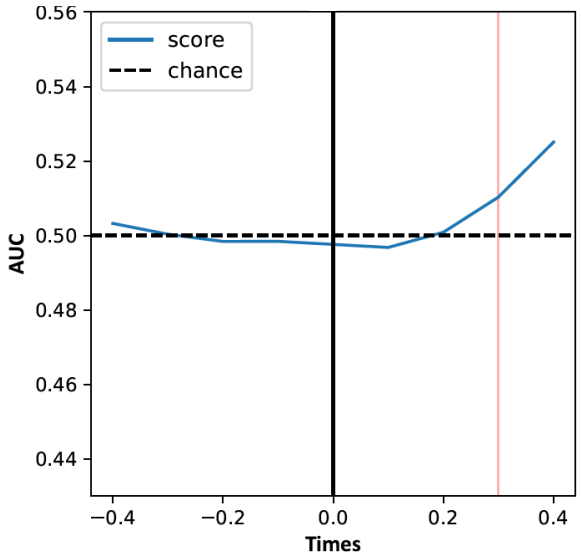
Block 3-6





Block 7-10





Temporal Generalization

- Decoding performance as a function of time that specifies when a certain piece of information becomes explicitly encoded in brain activity.
- Blind to dynamics of brain activity
- The next question we may ask is: **how does the underlying neural code evolve in time?**
- Generalization across time reveals how mental representations are dynamically transformed

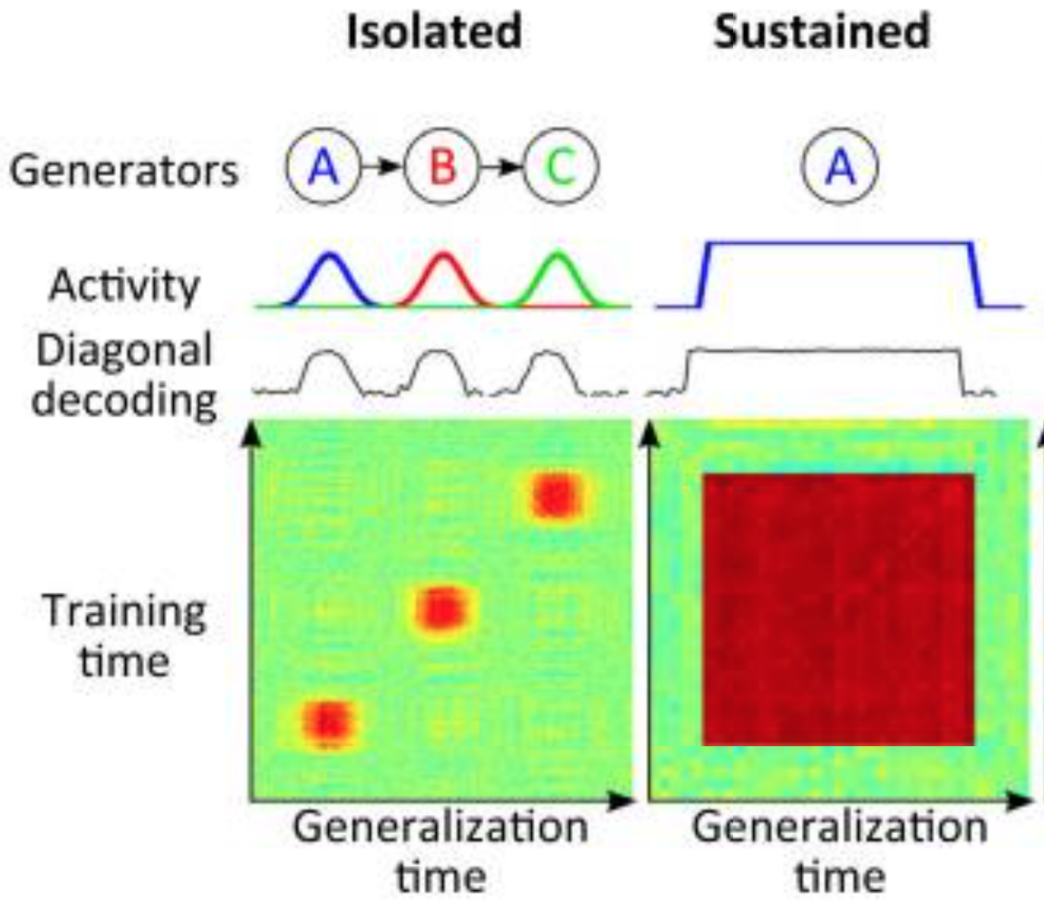
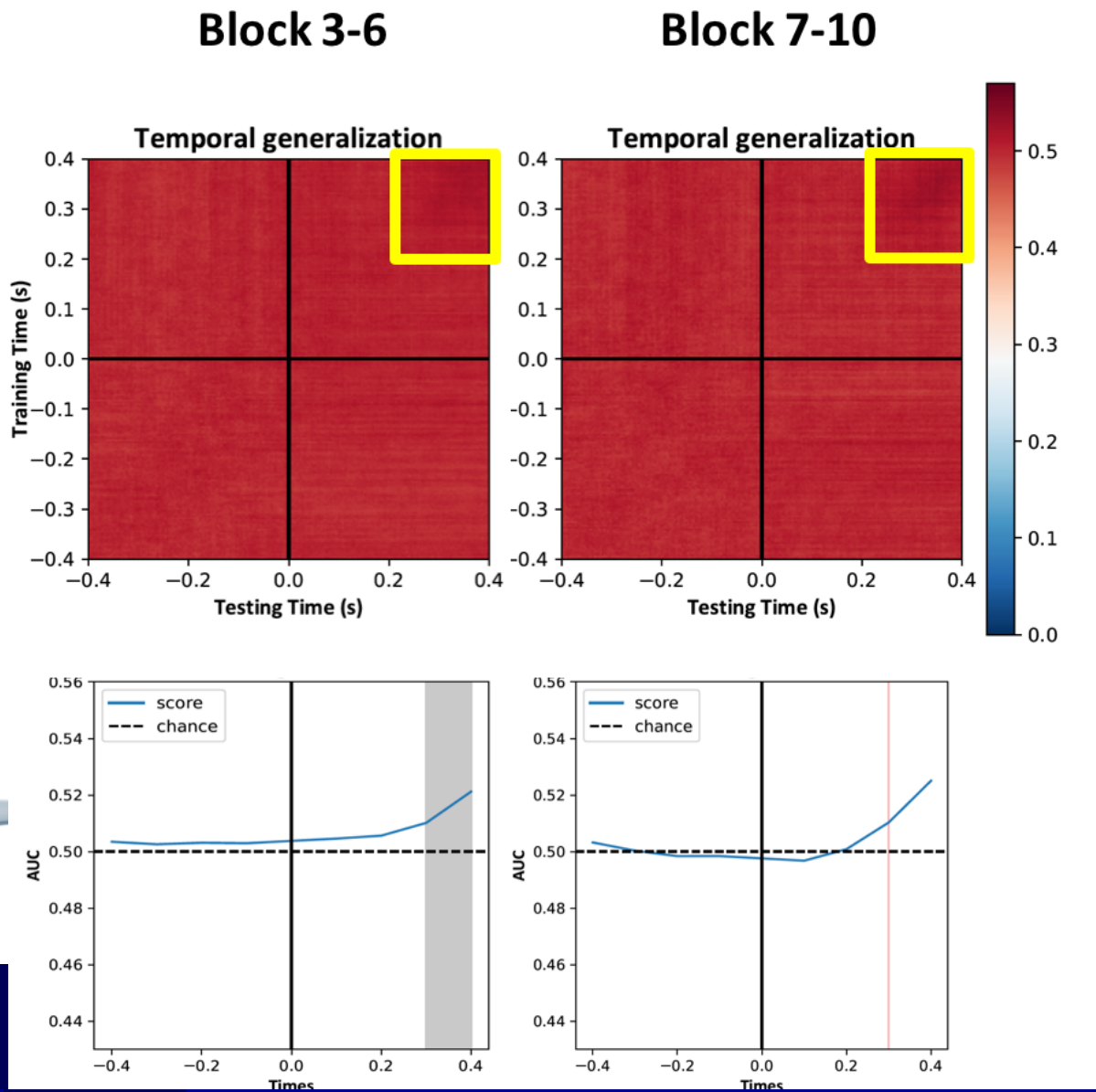
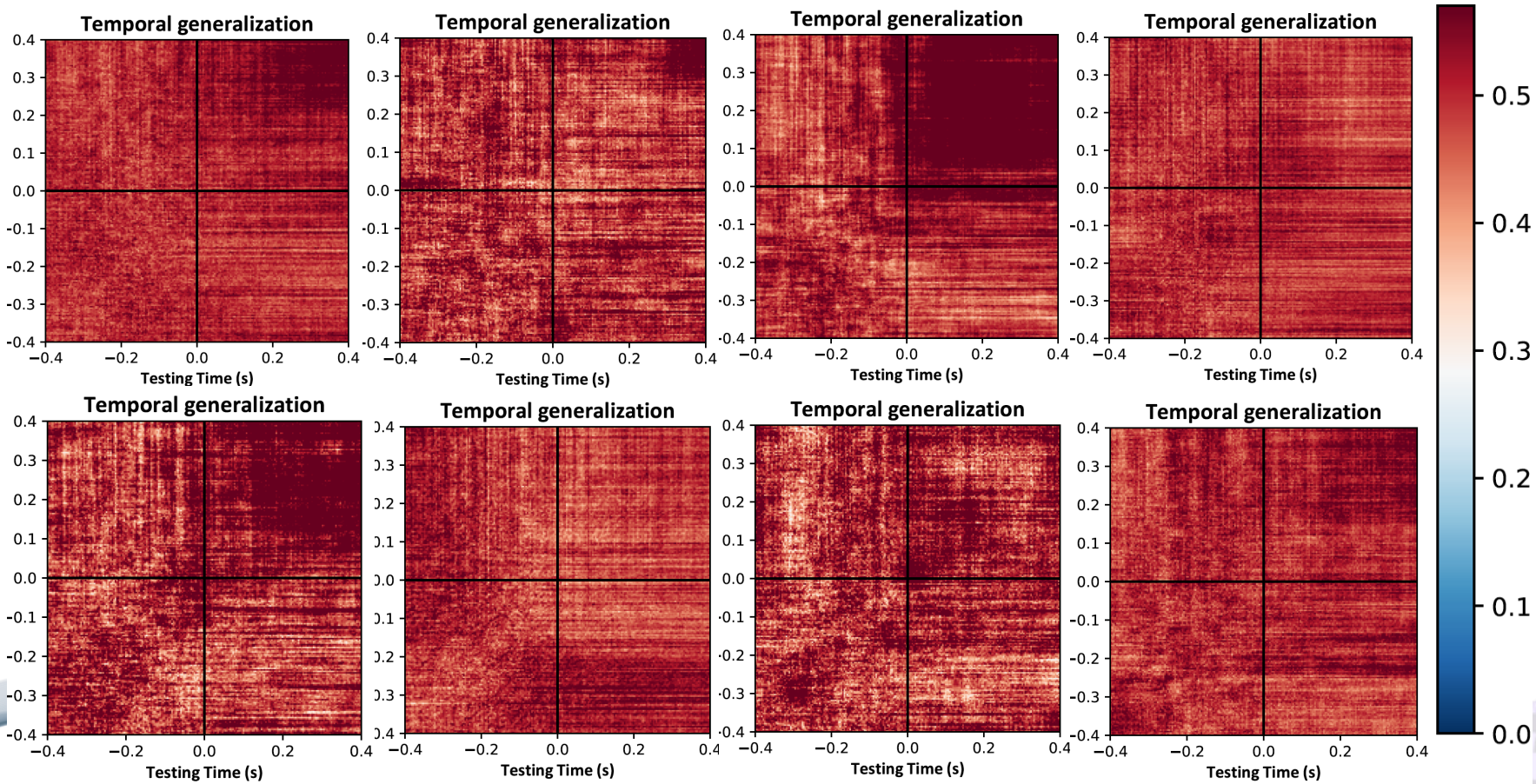


Figure: King, J.-R. Dehaene, S. C*haracterizing the dynamics of mental representations: the temporal generalization method.* Trends Cogn. Sci. 18, 203–210 (2014).

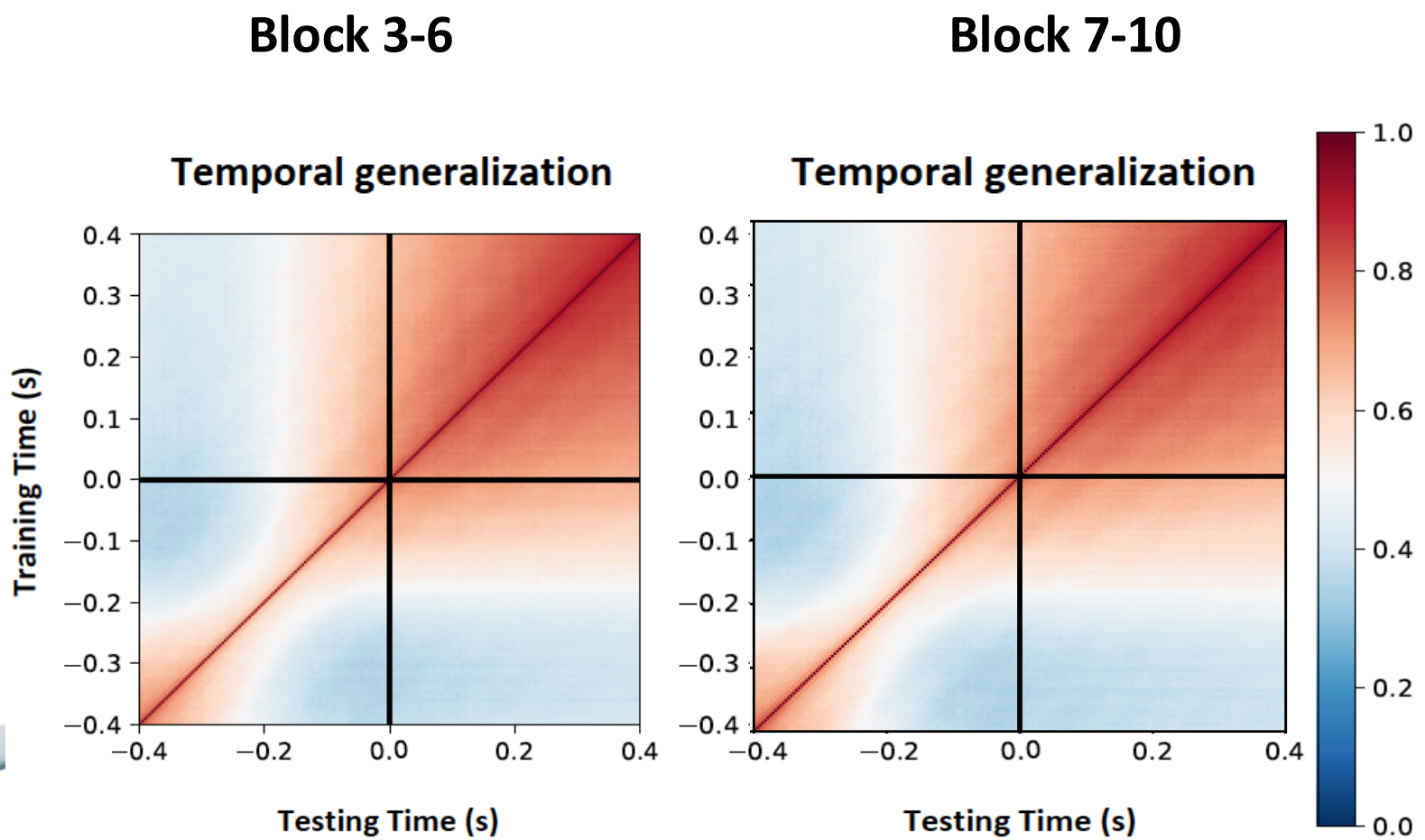
With Cross Validation



With Cross Validation



No Cross Validation



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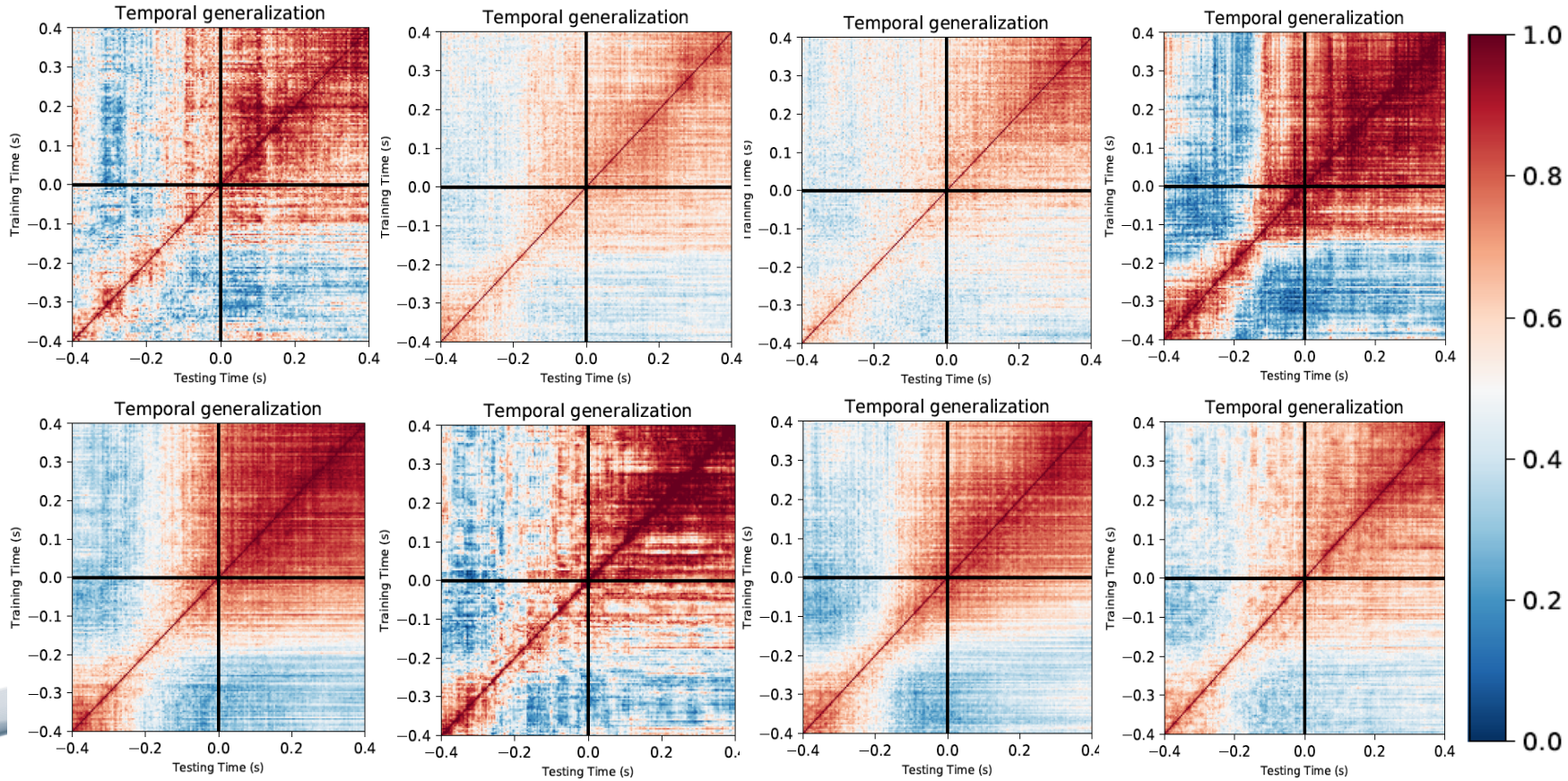


Summary

Summary

Key Findings:

- **General learning;** Faster responses over time.
- Consistent behavioral results over 3 experiments.
- Effect of ISI on pure perceptual learning
- EEG results showed a promising pattern of temporal generalization

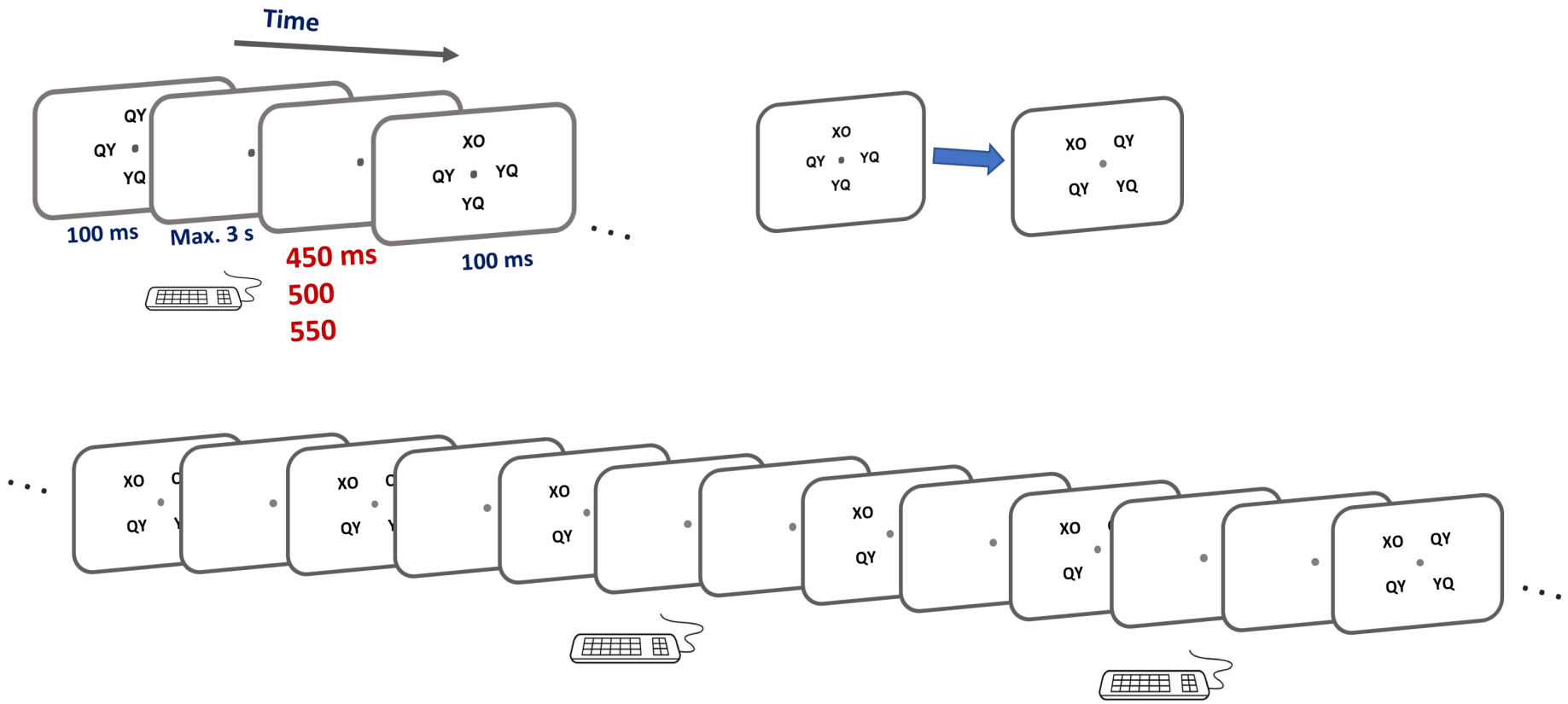
Summary

Challenges:

- Implicit learning
- Pure perceptual learning
- Longer ISI

Next Experimental Paradigm

New Experimental Paradigm



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End!