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Beyond Behavioral Relevance: Primate Superior Colliculus Retains Visual Event Features in an Attention Task

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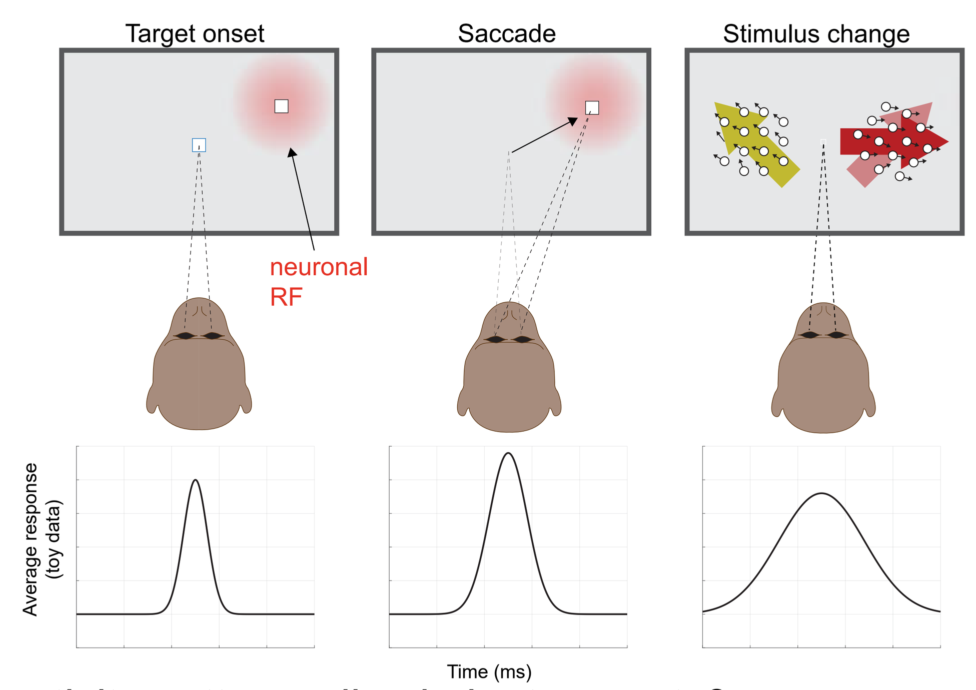
Introduction / Background

- The primate superior colliculus (SC) responds stimulus onset(s), saccade(s) and subtle stimulus changes with phasic increases in activity.
- Do SC activity patterns discriminate these events or does interpretation of SC output rely on other structures?
- Here we present a method for quantifying and comparing population encoding of task variables using partial least squares discriminant analysis (PLS-DA).

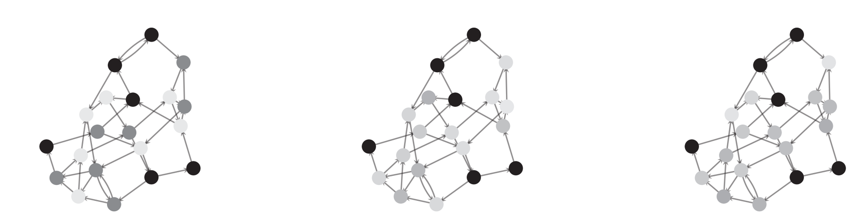
How are visual and behavioral events encoded in the SC?

- SC responds to diverse events with transient increases in average activity.

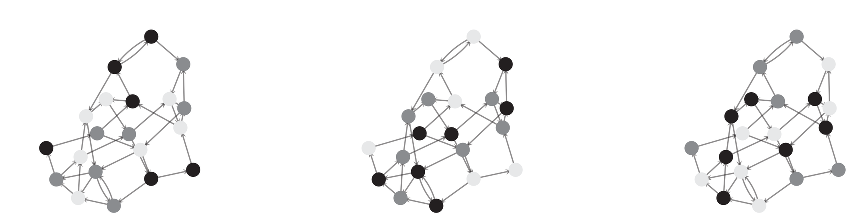


Do underlying activity patterns discriminate events?

- Similar activation patterns do not discriminate events.

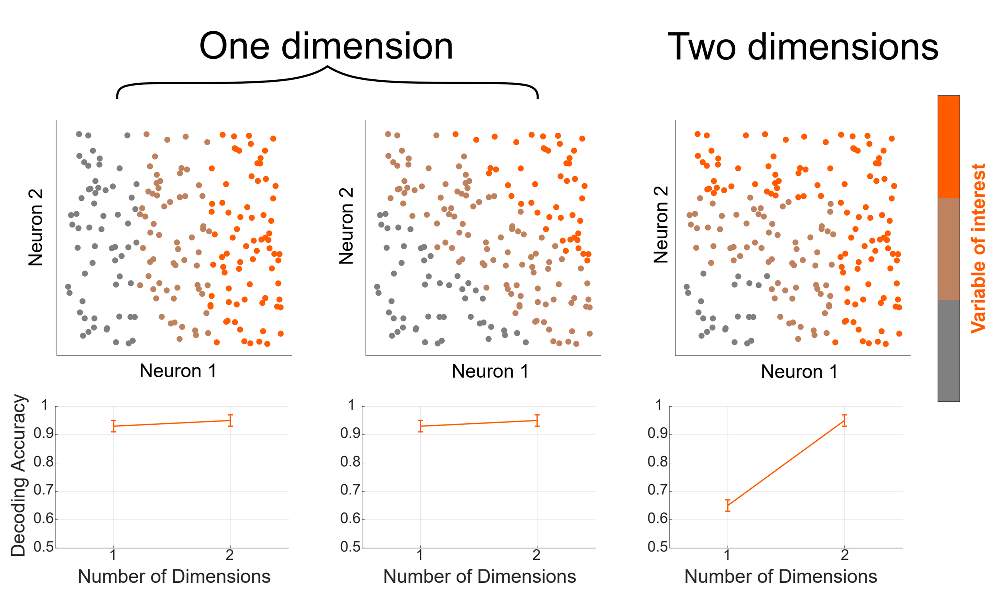


- Distinct activation patterns do discriminate events.



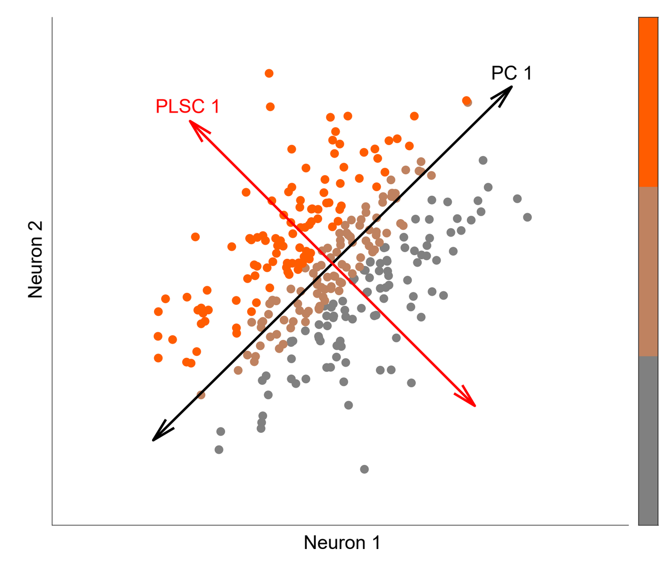
Quantifying population encoding patterns: a 2D toy example

- A **variable of interest** may be encoded in **one** or **two** dimensions of a 2D population.
- How many dimensions of activity are needed to reach the decoding accuracy available in the full population?



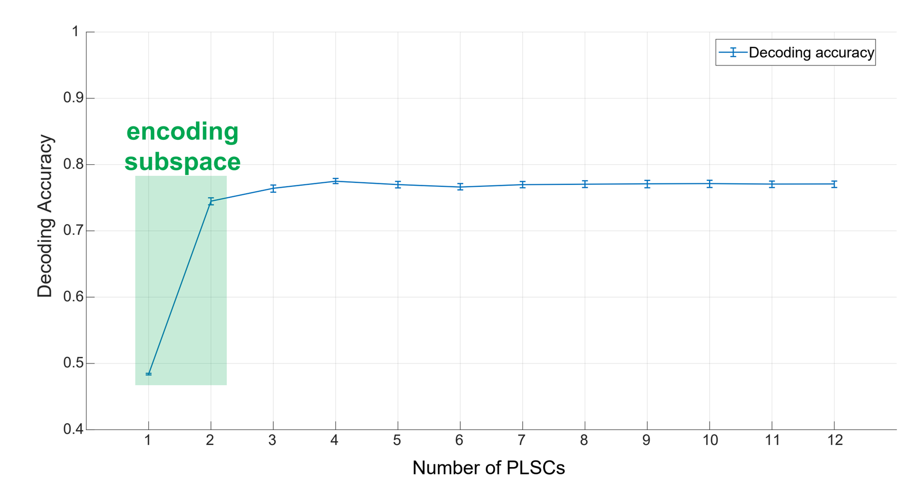
How can we intelligently select a minimal subset of encoding dimensions?

Partial least squares discriminant analysis (PLS-DA)



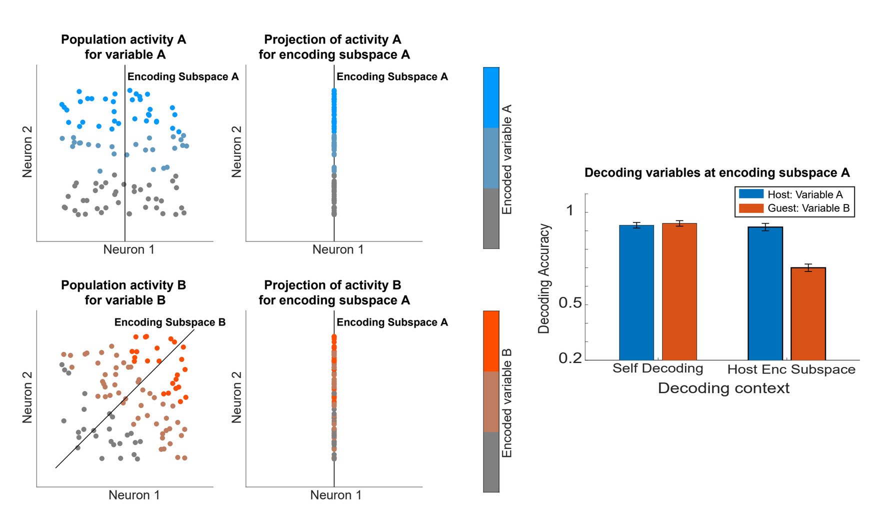
- PLS-DA is an iterative, supervised method that identifies components (dimensions) of the input that **maximize covariance between input features and class labels**.
- The identified dimensions capture the most relevant information for **prediction** while **reducing dimensionality**.
- **Difference from principal component analysis (PCA):** PCA maximizes variance in the data without considering class labels.

Identifying an encoding subspace using PLS-DA



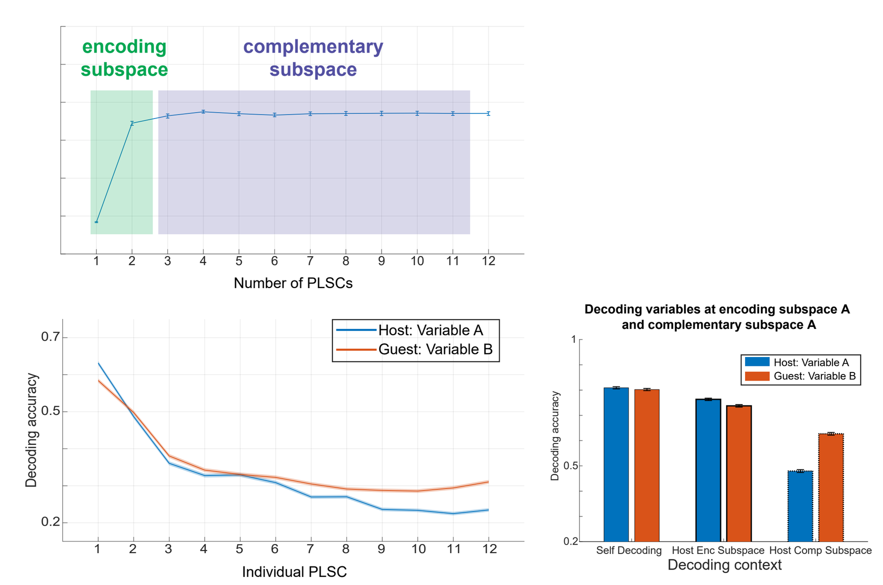
- Individual labeled trials are used.
- Decoding is performed while **incrementally increasing** the count of PLS components (PLSCs).
- The **encoding subspace** is the subset of PLS components where decoding accuracy plateaus.

Comparing encoding of two variables using an identified subspace



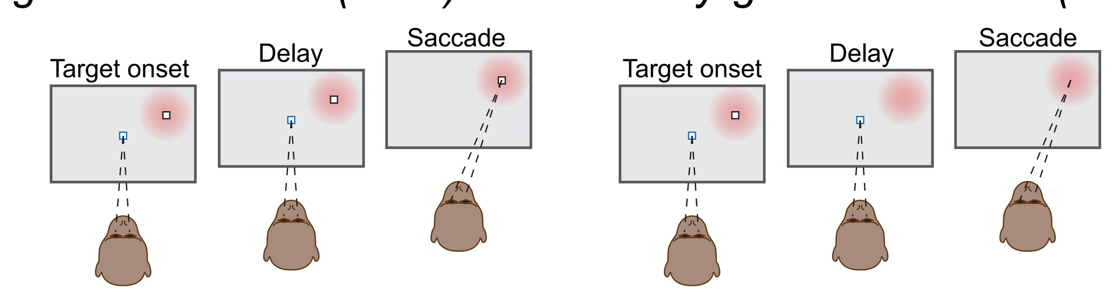
- We identify the encoding subspace of **variable A** (the **host**), called encoding subspace A.
- We define **Variable B** as the **guest**.
- Population activity for variables **A** and **B** is projected onto encoding subspace A.
- Variables **A** and **B** are decoded within encoding subspace A to estimate the similarity or difference in the neural population's encoding of each variable.

What about the other dimensions?

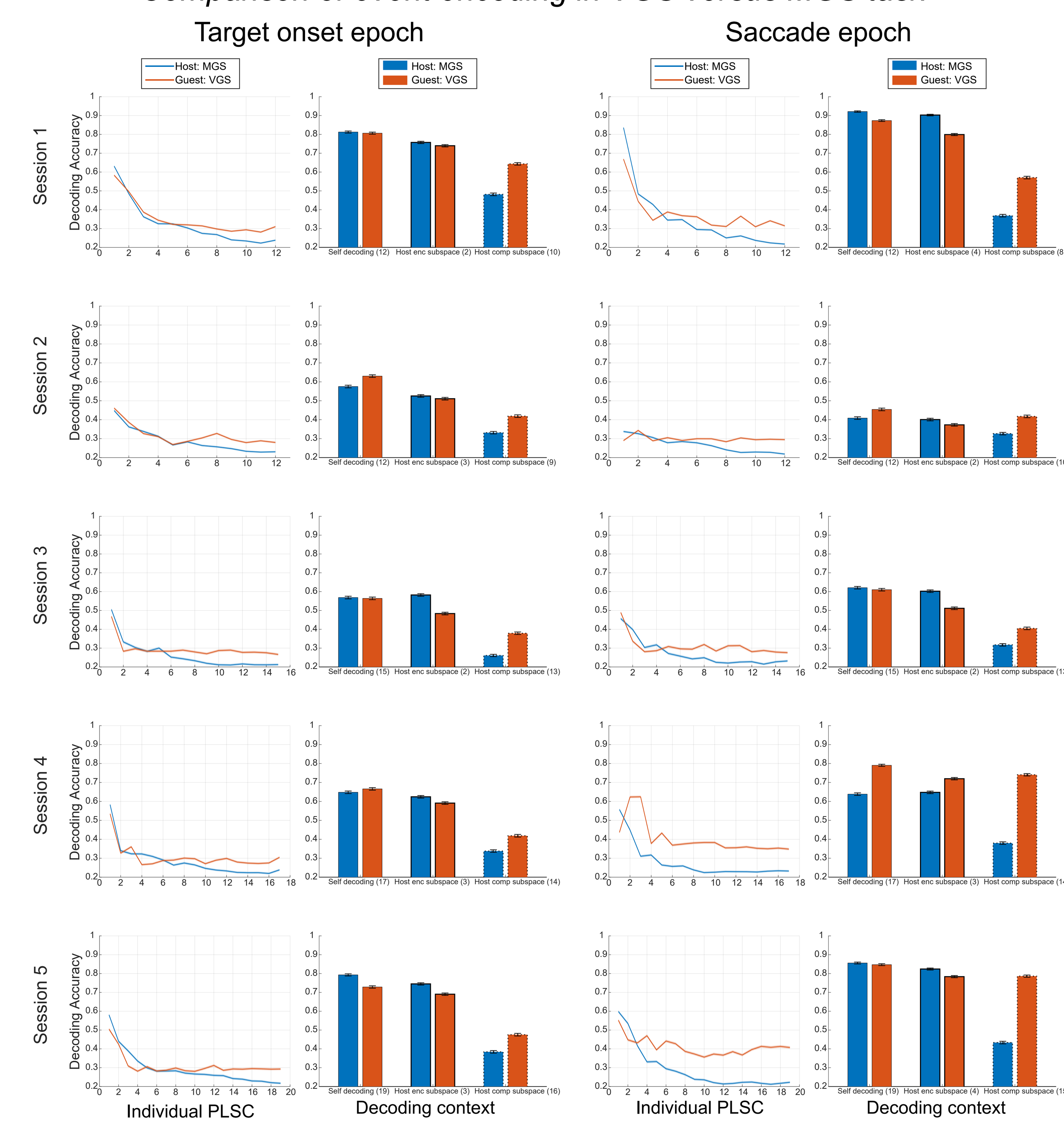


- Components not in the **encoding subspace** form a **complementary subspace**.
- Is the **complementary subspace** a "null" space? Or does it contain information?
- For a detailed view of how information is distributed across dimensions, we can **decode from individual dimensions**.

Visually guided saccade (VGS) and memory-guided saccade (MGS) tasks



Comparison of event encoding in VGS versus MGS task



- **Target location** was decoded from a target onset epoch (+50 to +200 ms) and a saccade epoch (-25 to +75 ms). Locations varied between sessions, but each session used a single set of 4 locations for both VGS and MGS tasks.
- Decoding accuracy in the **first few dimensions are most consistent**, but more **differences emerge** in the **later dimensions**.
- Encoding differences between tasks divergence more prominently in the **saccade epoch** compared to the **target onset epoch**.
- We suspect variations across sessions reflect functional differences in recorded neuronal populations.

Conclusion

- We propose using the "encoding subspace" to investigate neuronal population coding.
- PLS-DA offers a principled approach to defining the encoding subspace.
- Superior colliculus neuronal populations exhibit distinct encoding patterns for the same target locations across different task contexts.