Decoding visible and memorized stimulus features from neuronal ensembles in the prefrontal and visual cortices

Panos Sapountzis[1,2], Sofia Paneri[1,2], Sotirios Papadopoulos[1], Georgia G. Gregoriou[1,2]

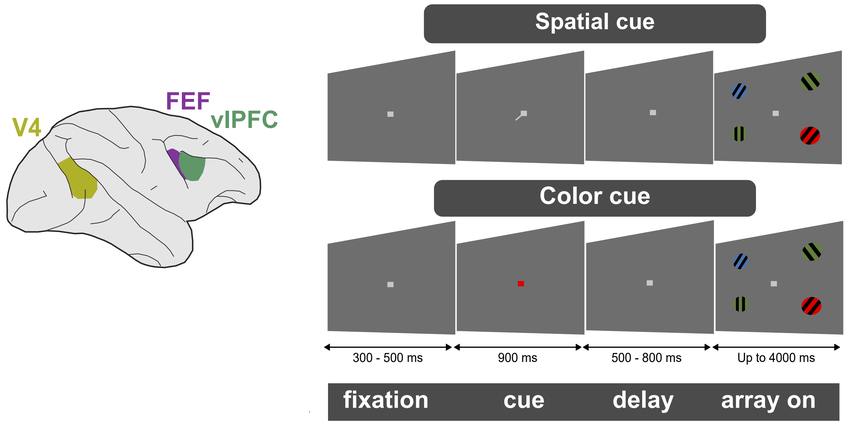
[1]University of Crete, Faculty of Medicine, Heraklion, Crete, Greece, [2]Foundation for Research and Technology-Hellas (FORTH), Heraklion, Crete, Greece

1. Objectives & Methods

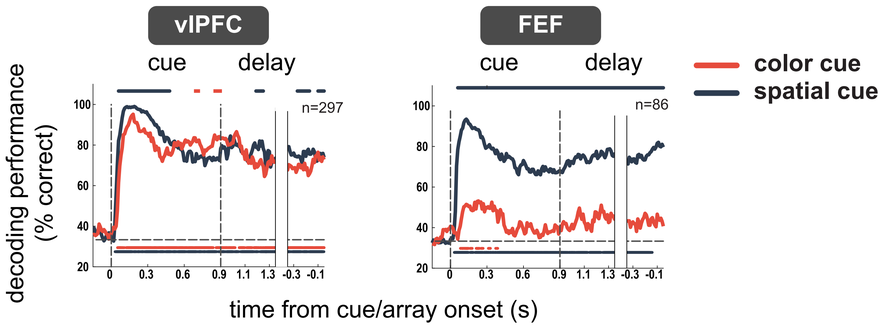
• A long-standing question in neuroscience is how sensory information is encoded and maintained in working memory (WM). Although activity in the prefrontal cortex (PFC) is critical for WM, the contribution of distinct PFC regions to the encoding of different visual features is not well understood.

• We performed simultaneous extracellular recordings from the ventrolateral PFC (vlPFC), the frontal eye field (FEF) and visual area V4 from the right hemisphere of two monkeys engaged in an attention task with spatial and color cueing conditions. Sites that evoked saccades when microstimulated with currents up to 100μA were assigned to FEF.

• To examine how color and spatial information about the future target is encoded in the cue and delay periods we employed a linear SVM classifier to decode feature information from population activity patterns on a trial by trial basis. A time-resolved representation of decoding accuracy was obtained by averaging spike counts or Hilbert transformed LFPs within 100ms windows advanced in 10ms steps. Accuracy was estimated by means of a 5-fold cross-validation. To match the number of categories between spatial and color cueing conditions we considered 3 out of 4 spatial cues (upper left, lower left and lower right), thus chance was at 33.3%.

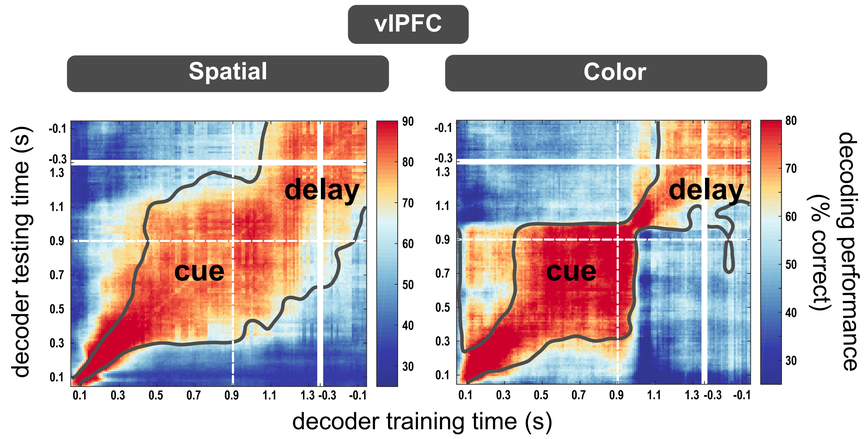


2. Information in spiking activity



vlPFC encodes and retains information about both spatial and color cues, whereas FEF carries spatial information only.

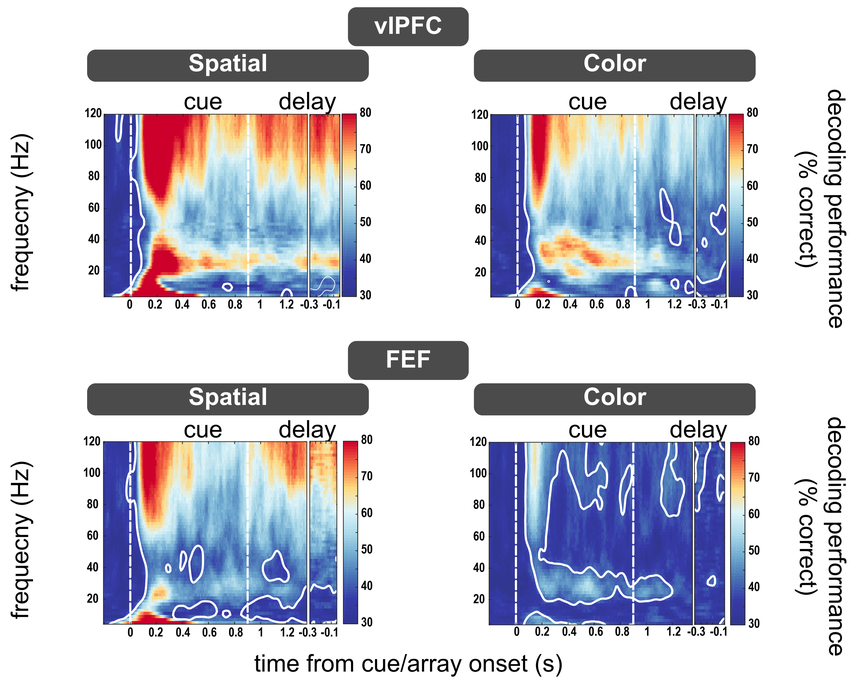
3. Population code dynamics



• To study the temporal dynamics of the neuronal code we used a cross-temporal decoding analysis in which we trained the classifier at one time period and tested with data from another time period.

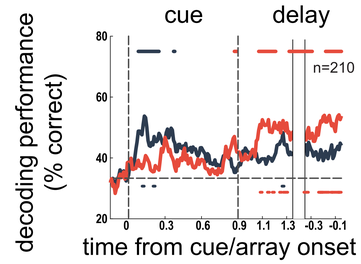
• Cross-temporal decoding analysis revealed a population code shift in vlPFC during working memory for color but not for location.

4. Information in Local Field Potentials

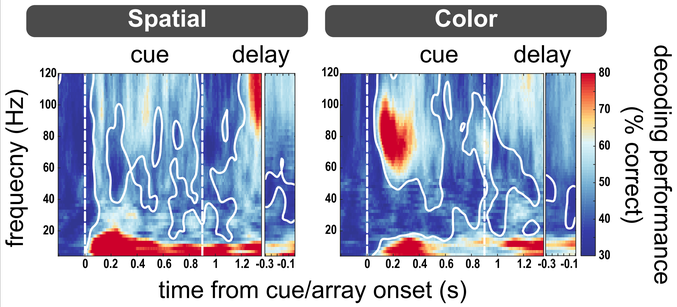


LFP analysis indicated that spatial information can be robustly decoded from both areas from high-gamma and beta LFP bands, whereas color information can be more reliably decoded from vlPFC.

5. Information coding in V4



V4 neurons with non-central RFs carried color information in their firing patterns during the delay.



Spatial information in V4 LFPs can be robustly decoded from theta and alpha bands, whereas color information from alpha and high-gamma bands.

6. Conclusions

• PFC encodes and retains sensory information in an anatomically-specific manner. Specifically, spatial information can be decoded from both FEF and vlPFC, whereas color information can be reliably decoded from vlPFC only.

• Our analysis revealed a population code shift in vlPFC during the delay period for color but not for location, suggesting a dynamic coding regime for color during working memory.

• A selective V4 neuronal subpopulation with RFs at the upcoming possible target's location retained color information in working memory.

Acknowledgements

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