Distinct Value & Choice Information Across Putative Subtypes of Primate Orbitofrontal Neurons

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Abstract

The primate orbitofrontal cortex (OFC) plays a key role in economic decision-making by encoding economic value and other decision-related variables. It has been proposed that different subtypes of OFC neurons may have different encoding properties corresponding to different functions in decision-making. However, there has been no attempt to classify OFC neurons according to their physiological subtype in primates. Here, we identified putative neuron types using an unsupervised clustering algorithm based on the extracellular waveform. We found that specific clusters of neurons had distinct encoding profiles defined by the timing and magnitude of task variable representations. We also identified a cluster of putative pyramidal neurons with choice-predictive activity far above that of other subtypes. These results represent a first step in understanding the cell subtype-specific roles of OFC neurons in choice.

Keywords: primate, ofc, cell-type, choice, value, inhibitory, excitatory, decision-making

Introduction

Cortical pyramidal and interneurons are thought to have distinct functions in neural computation, yet how this diversity contributes to decision-making is unclear. The lack of methods to identify cell types in primates makes it challenging to study cell-type-specific computations in vivo. However, previous studies show that neuronal subtypes can be estimated to an extent from extracellular waveforms (Mountcastle et al., 1969). In this study, we aimed to identify functional differences in subtypes of neurons in the primate OFC in value-based decision-making, using waveform-based cell-type classification.

Methods

We recorded from the OFC of two monkeys performing a two-alternative value-based decision-making task (Fig. 1A). We first used a semi-automated spike sorting method (Kilosort 2.0) to isolate putative single neurons (n=1179). We then classified neurons into putative neuron types using an unsupervised clustering algorithm, based on the average extracellular waveforms (Lee et al., 2023).

To assess the encoding of task variables in putative subtypes, we fit for every cell a general linear model (GLM) that explained neural activity as a function of four task variables: the values of the two choice stimuli (“first value” and “second value”), the left/right location of the first-viewed stimulus (Fig. 1A, “first location”), and the left/right location of the stimulus that was chosen (“chosen action”). Then, we computed the coefficient of partial determination (CPD), which gives the unique variance explained by each variable over and above the variance explained by the other variables.

To quantify the ability of neural activity to predict choice behavior, we used a GLM-based linear encoder/decoder model similar to that used by McGinty and Lupkin (2023).

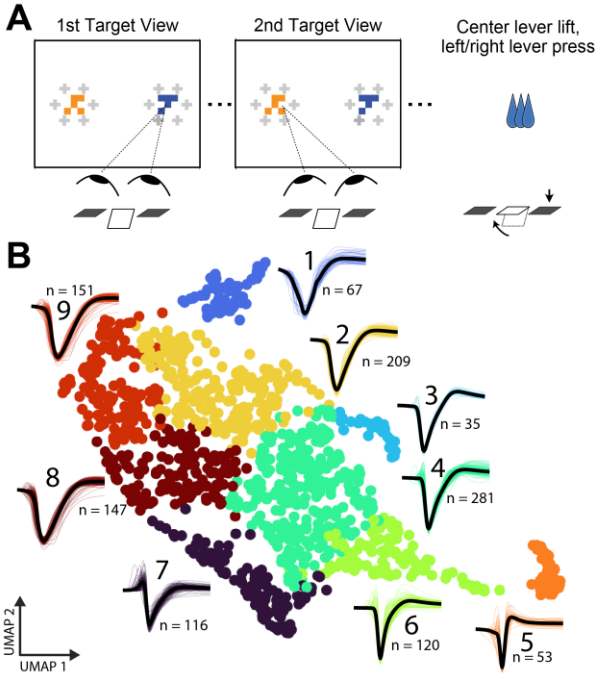

Figure 1: **A)** Value-based decision task. **B)** Waveforms of the classified cells.

Results & Discussion

In every trial, the monkeys viewed two stimuli in sequence (each associated with a volume of juice reward) and then initiated a choice by lifting their hand from a central lever and pressing the left or right lever (Fig. 1A). To assess the encoding of task variables, neural data were time-locked to the viewing of the first stimulus, or to the central lever lift. Fig. 2A shows the average encoding (CPD) across all neurons.

We identified nine clusters of OFC neurons based on the extracellular waveforms (Fig. 1B). Two clusters had narrow-spiking waveforms (# 5 & 6 in Fig. 1B), six clusters had broad-spiking waveforms (# 1, 2, 3, 4, 8 & 9), and one cluster had a broad-spiking tri-phasic waveform (# 7).

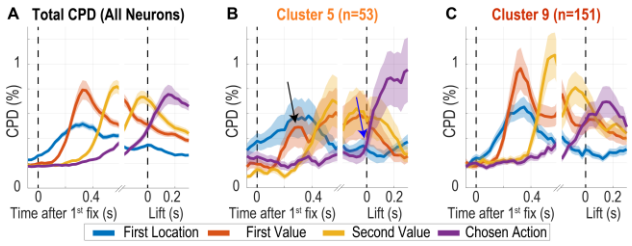

Figure 2: Mean CPD (shaded area shows SEM) time locked to first target viewing and center lever lift.

Below, we highlight results from clusters 5 and 9 (Fig. 2B, C), which have distinct encoding patterns compared to the population average. Compared to the average, cluster 5 (a putative inhibitory cluster) showed stronger first location encoding and reduced value encoding (Fig. 2B black arrow). Cluster 5 also showed a sharp increase in the chosen action signal at the time of lift (Fig. 2B blue arrow), as opposed to the gradual increase seen in the average of all neurons. In contrast, cluster 9, a putative excitatory cluster, showed slightly elevated encoding of value and first location compared to the average. Other clusters (not shown) also showed differences from the grand average.

Using a linear decoder, we quantified the ability of single neurons to predict the monkeys' choices in individual trials. Consistent with previous studies, the mean choice decoding performance was not above chance when combining all neurons (Fig. 3, gray, see McGinty & Lupkin, 2023). However, for cluster 9, the mean decoder performance was significantly above chance ~150 ms before the center lever lift (the time when animals commit to a choice, Fig. 3, red). This finding is notable, as cluster 9 shows an encoding profile very similar to the average of all neurons (Fig. 2C) but contains unique information related to choice. Other clusters did not significantly predict choice (not shown). This suggests that cluster 9 contains neurons that are important for the readout of value information in downstream circuits.

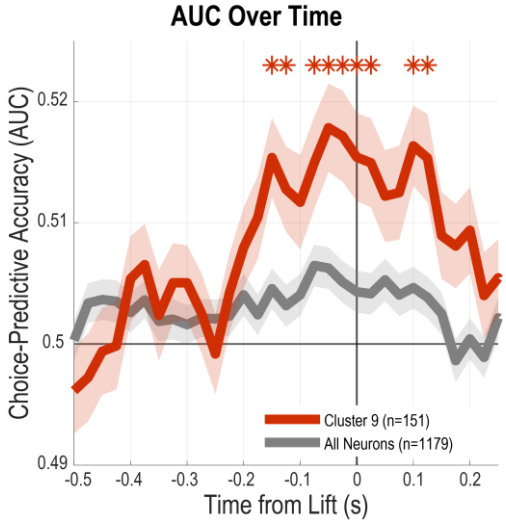

Figure 3: Single-cell choice decoding performance time locked to lever lift. Stars indicate significant difference from chance ($p<0.001$, uncorrected).

In summary, OFC neuronal subtypes defined by waveform appear to have distinct coding of value and decision-related variables, including the predictive encoding of upcoming choices. Future plans include population-level analysis, which may reveal additional functional differences.

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