Population decoding of visual motion direction in V1 marmoset monkey : effects of uncertainty.

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Introduction

Studying the **internal representation** of natural features (fig. 1) in the primary visual cortex (V1), like direction or spatial frequency, is crucial to understand how we perceive the external world. Research on 2D motion direction in **non-human primates** [1, 2] in particular when displaying **naturalistic stimuli** like MotionClouds [3] reveals substantial diversity and multiple mechanisms within the neuronal population [4] (fig. 2). The aim of this project is to examine how a large population of V1 neurons encodes stimulus direction and how this representation is modulated by the uncertainty using **decoding methods**.





Methods

Neuronal recordings (fig. 3) were made in V1 of one marmoset monkey using the Neuropixel 1.0 technology [5] during 2D motion presentation in eight directions (θ) from 0° to 375° and two precision levels (B_{θ} , high : 22° or low : 90°). The decoding method (fig. 4) optimizes the weights of a multinomial logistic regression to achieve optimal decoding accuracy on a training set. The objective is to decode the direction of the motion for each precision level. The training is conducted (1) on a broad time-window at the begining or the end of the stimulus presentation, (2) by applying temporal generalization [6] or (3) after reducing dimensionality with dPCA [7]. All the results presented here are computed on







Figure 1: Uncertainty in natural images and MotionClouds.

21 Spikes/s 39: 90 θ(°) . 180

Figure 2: Two subpopulation in cats area 17 (from [4]).

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Results	
train on [0.000s : 0.125s] train on [0.375s : 0.500s] train on [0.000s : 0.125s] train on [0.375s : 0.500s]	







40

35

30 a

25

20

Figure 5: Decoding results after training (left) on the begining of the evocked activity or (right) on the end for two precision level $(B_{\theta}).$



Figure 7: Decoding results after training (left) on the begining or (right) on the end of the time course of dPCA components for two precision level (B_{θ}) .

0

0

0

45 90 135 180 225 270 315

45 90 135 180 225 270 315

Figure 9: Temporal generalisation of the direction based on neuronal activity for two level of precision (B_{θ}) .



Figure 10: Temporal generalisation of the direction based on dPCA components Figure 8: Weights learned for three components ($n^{\circ}0, 1, 2$). Figure 6: Weights learned for three neurons ($n \circ 0, 31, 32$). for two level of precision (B_{θ}) .

Discussion

This decoding approach clarifies the representation of directional information in the marmoset primary visual cortex, its stability accross time and its modulation by the precision level (fig. 5 and 9). The existence of transient and sustained representations may support distinct functional roles for differents cortical layers [4, 8]. Demixed principal component analysis allows us to reduce the dimension, work in a **neural state space** and filter the raw activity. This transformation improve the decoding accuracy (fig. 7 and 10) and improve the decoder's ability to generalise between time steps. Overall, this analysis shows qualitatively the existence of a **stable representation** of the information wich is modulated by the precision level of the stimulus.

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