Article

Neuron

Decoding a Decision Process in the Neuronal Population of Dorsal Premotor Cortex

Highlights

- DPC persistent population coding is shared for stimulus identity and decision outcome
- Two major DPC components, transitory and persistent, are combined to reach a decision
- Timing of task events can be identified from context-dependent, non-coding signals
- Error trial analyses reveal that population signals are linked to monkeys' behavior

Authors

Román Rossi-Pool, Antonio Zainos, Manuel Alvarez, Jerónimo Zizumbo, José Vergara, Ranulfo Romo

Correspondence

romanr@ifc.unam.mx (R.R.-P.), rromo@ifc.unam.mx (R.R.)

In Brief

Rossi-Pool et al. show that the population response of dorsal premotor cortex codes information about event timing, parameters, and decision outcome of a temporal pattern discrimination task. The authors provide evidence that this population code co-varies with behavior.

Rossi-Pool et al., 2017, Neuron *96*, 1–15
December 20, 2017
https://doi.org/10.1016/j.neuron.2017.11.023

CellPress

Please cite this article in press as: Rossi-Pool et al., Decoding a Decision Process in the Neuronal Population of Dorsal Premotor Cortex, Neuron (2017), https://doi.org/10.1016/j.neuron.2017.11.023

Neuron
Article

Decoding a Decision Process in the Neuronal Population of Dorsal Premotor Cortex

Román Rossi-Pool,[1,*] Antonio Zainos,[1] Manuel Alvarez,[1] Jerónimo Zizumbo,[1] José Vergara,[1] and Ranulfo Romo[1,2,3,*]
[1]Instituto de Fisiología Celular, Neurociencias, Universidad Nacional Autónoma de México, 04510 Mexico City, Mexico
[2]El Colegio Nacional, 06020 Mexico City, Mexico
[3]Lead Contact
*Correspondence: romanr@ifc.unam.mx (R.R.-P.), rromo@ifc.unam.mx (R.R.)
https://doi.org/10.1016/j.neuron.2017.11.023

SUMMARY

When trained monkeys discriminate the temporal structure of two sequential vibrotactile stimuli, dorsal premotor cortex (DPC) showed high heterogeneity among its neuronal responses. Notably, DPC neurons coded stimulus patterns as broader categories and signaled them during working memory, comparison, and postponed decision periods. Here, we show that such population activity can be condensed into two major coding components: one that persistently represented in working memory both the first stimulus identity and the postponed informed choice and another that transiently coded the initial sensory information and the result of the comparison between the two stimuli. Additionally, we identified relevant signals that coded the timing of task events. These temporal and task-parameter readouts were shown to be strongly linked to the monkeys' behavior when contrasted to those obtained in a non-demanding cognitive control task and during error trials. These signals, hidden in the heterogeneity, were prominently represented by the DPC population response.

INTRODUCTION

Many brain processes are involved during perceptual decision tasks. Central to understanding these brain processes is how the sequence of neuronal population responses unfolds between a subject's sensory receptor activation and their actions. The flutter submodality of tactile stimulation provides a convenient channel to study perceptual decision making based on the evaluation of temporal patterns. First, the same set of cutaneous receptors is activated because the stimulator moves perpendicularly to the skin (Talbot et al., 1968). Second, this sensation is conveyed by a highly specific set of primary afferents to the spinal cord (Douglas et al., 1978) and thalamus (Vázquez et al., 2013), up to the primary somatosensory cortex (S1; Mountcastle et al., 1969; Salinas et al., 2000). Third, humans and monkeys have similar detection and discrimination capacities (Talbot et al., 1968; LaMotte and Mountcastle, 1975), in such a way that neural coding of flutter stimuli can be linked to perception in these tasks (Romo et al., 1998). Thus, the temporal stimulus pattern is represented in a homogeneous population of peripheral and central neurons directly linked to flutter perception.

However, this is not the case in areas downstream of S1: they show a high heterogeneity among their neuronal responses during flutter tasks (Romo et al., 1999, 2002, 2003; de Lafuente and Romo, 2006). In addition to heterogeneity among responses, single neurons by themselves show complex dynamics often attributable to more than one task component ("mixed selectivity"; Rigotti et al., 2013). A reasonable approach to handle this heterogeneity and mixed selectivity is the use of dimensionality reduction methods; the resulting responses depict population activity in a compact format and could convey clearer, latent signals. The relevance of this approach is well supported by recent works showing the potentiality of these methods to decode population responses that cannot be inferred from single units (Kobak et al., 2016; Murray et al., 2017).

Here, we focus on the population response recorded in dorsal premotor cortex (DPC), while trained monkeys performed a temporal pattern discrimination task (TPDT; Rossi-Pool et al., 2016). During the TPDT, monkeys reported whether the temporal patterns of two vibrotactile stimuli (of equal mean frequency) were the same or different (Figure 1A). In each trial, monkeys had to pay attention to the first stimulus pattern (P1), store a trace of it during the delay between stimuli, and then pay attention to the second stimulus pattern (P2) and compare it to the trace of P1; finally, after another delay period in which the comparison between P2 and P1 had to be remembered, the monkey pressed one of two push buttons to indicate whether P2 = P1 (match) or P2 $\neq$ P1 (non-match). As a prelude to our current work, the coding profile of each recorded neuron was exhaustively studied. We considered all possible combinations of relevant task parameters to determine the coding capacity of each neuron (Rossi-Pool et al., 2016). We found that single DPC neurons coded the stimulus patterns as broader categories and signaled them during working memory, comparison, and postponed decision periods. Furthermore, a large proportion of DPC neurons exhibited mixed selectivity. Nevertheless, how the conjoined activity of the heterogeneous neuronal population of DPC relates to the TPDT remains an open question.