nature neuroscience

Article

https://doi.org/10.1038/s41593-023-01378-5

Using temperature to analyze the neural basis of a time-based decision

In the format provided by the authors and unedited

Using temperature to analyze the neural basis of a time-based decision

Tiago Monteiro[1,2,*], Filipe S. Rodrigues[1,*], Margarida Pexirra[1,3,*], Bruno F. Cruz[1,4], Ana I. Gonçalves[1], Pavel E. Rueda-Orozco[5], Joseph J. Paton[1,†]

[1] Champalimaud Foundation, Neuroscience Programme, Lisbon, Portugal.
[2] Current address: Department of Biology, University of Oxford, UK.
[3] Current address: Sainsbury Wellcome Centre for Neural Circuits and Behaviour, University College London, London, UK.
[4] Current address: NeuroGEARS Ltd., London, UK.
[5] Institute of Neurobiology, UNAM Juriquilla, Mexico.
* These authors contributed equally to the work
† To whom correspondence should be addressed, joe.paton@neuro.fchampalimaud.org

Supplementary Text

NOTE 1: thalamic ventrobasal complex

Importantly, in these experiments we did not seek to recapitulate the exact circuit mechanism by which population dynamics are produced during timing behavior. However, VB does integrate somatosensory signals that originate in areas throughout the body, including whisker and orofacial regions. These regions would receive mechanical stimulation at interval onset when rats insert their snout into the initiation port, and thus, VB thalamus represents one potential source of precisely timed[1] information about the onset of interval stimuli.

NOTE 2: behavioral manipulation devised to create a similar scenario to that of striatal temperature manipulations in terms of unsignalled and surprising feedback

While the effects of temperature on timing judgments were robust in the first sessions of manipulations (**Fig. 4**), these effects diminished with experience (**Extended Data Fig. 9A**, **D**, **G**). Though we had sought to minimize opportunities for animals to learn to adapt to the temperature manipulations by applying them in blocks of trials lasting only three minutes, always interspersed with a control temperature block (**Fig. 1B**), and alternating manipulation sessions with “washout” sessions where temperature was not manipulated (**Extended Data Fig. 4D**), we wondered whether animals might have learned to adapt to the effects of temperature. To assess this possibility, we performed a set of behavioral experiments in which the boundary between intervals rewarded for short judgments, and those rewarded for long judgments was shifted in the same blockwise manner (**Extended Data Fig. 9B**) as was temperature during the previously described experiments (**Fig. 1B**). This manipulation was devised to create a similar scenario to that created by striatal temperature manipulations in terms of unsignalled and surprising feedback that could be used by the animal to adapt their decision-making strategy to maximize rewards. Indeed, animals developed the ability to shift their decision thresholds over a small number of sessions, similar to the observed diminishing effects of temperature on temporal judgments (**Extended Data Fig. 9**). Thus, while temperature manipulations might also produce physiological adaptations that render neural systems more robust to future temperature variations[2], we found that the changing impact of temperature on timing judgments was consistent with learning to compensate for decision variables whose features might be changing. These data suggest that in general the behavioral impact of manipulating neural systems should be evaluated continuously from the moment the manipulations begin, as opposed to evaluating end-point or average effects alone, as the adaptation ability of animals may be capable of overcoming what are initially significant effects on performance[3].

References

1. Foffani, G., Morales-Botello, M. L. & Aguilar, J. Spike timing, spike count, and temporal information for the discrimination of tactile stimuli in the rat ventrobasal complex. *J. Neurosci.* **29**, 5964–5973 (2009).
2. Robertson, R. M. & Money, T. G. A. Temperature and neuronal circuit function: compensation, tuning and tolerance. *Curr. Opin. Neurobiol.* **22**, 724–734 (2012).
3. Fetsch, C. R. *et al.* Focal optogenetic suppression in macaque area MT biases direction discrimination and decision confidence, but only transiently. *Elife* **7**, (2018).