Endogenous Midbrain Dopaminergic Fluctuations Selectively Modulate Late-Stage Reward Learning

Kadri Kenza[1], Horsch Belana[1], Dome Lenard[1,2] Kakaei Ehsan[1], T.U.Hauser[1,2,3,4]

[1]Department of Psychiatry and Psychotherapy, Faculty of Medicine, University Tuebingen (Germany),
[2]German Center for Mental Health (DZPG), Partner Site Tübingen (Germany),
[3]Functional Imaging Laboratory (FIL), Department of Imaging Neuroscience, University College London, London (United Kingdom),
[4]Max Planck UCL Centre for Computational Psychiatry and Ageing Research, University College London (United Kingdom)

Main findings

- **Endogenous dopaminergic fluctuations** in the Ventral Tegmental Area (VTA) and the Substantia Nigra (SN) **selectively enhance discrimination** between high- and low-reward stimuli in the **later stages** of a probabilistic learning task
- This modulation has a **persistent effect on stimulus valuation**, as revealed by stronger reward probability-based **confidence** in a post-scan preference task
- Dopaminergic fluctuations in the SN/VTA elicit **sustained BOLD responses** in the midbrain that may reflect the neural basis of these learning effects

Methods

n = 28 healthy participants (15 females) age = 28.28, SD = 5.24

fMRI probabistic reward learning task task with **5 blocks** of **24 trials**
4 objects in each condition with **low** [0.2 0.4] and **high** [0.6 0.8] reward probability

Introduction

How do endogenous midbrain fluctuations drive variability in human learning and decision-making?

Humans do not always make the same decision, even when facing identical options, a pervasive source of behavioural variability whose origins remain poorly understood.

Endogeneous fluctuations in dopaminergic midbrain activity have been shown to contribute to this variability, modulating risky decision-making (Chew et al., 2019).

Our aim was to extend these findings to reward learning, probing whether dopaminergic state in the SN/VTA shapes how well individuals acquire and maintain stimulus-reward associations.

Experimental design

Condition are triggered using the real-time BOLD average in the SN/VTA

Baseline calculated over 2min moving windows

Trough ≤ 15th percentile
Peak ≥ 85th percentile

ITI between 20-50s

Day 1

Structural scans (MPM)

Extraction of the SN/VTA

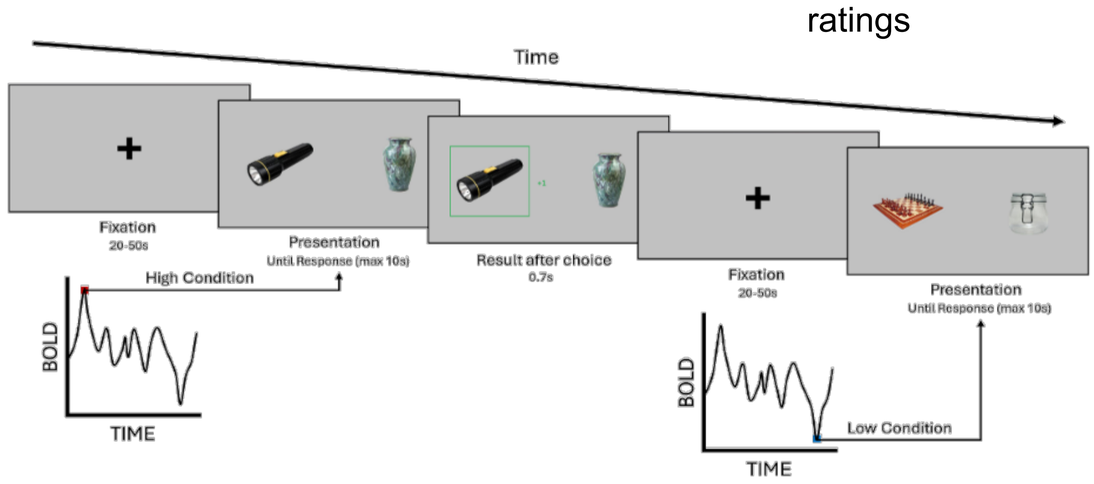
Day 2

Structural scan (T1)

Coregistration

Task-based real-time fMRI

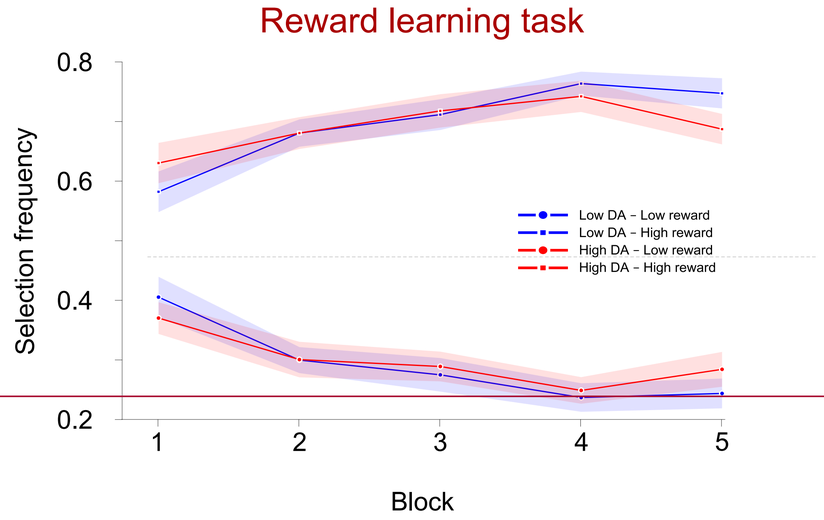
Offline preference task with confidence ratings



Behavioural results

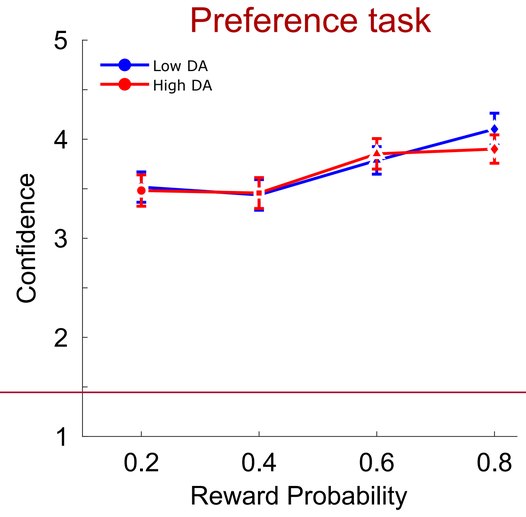
By the final blocks, low dopaminergic activity in the SN/VTA selectively enhanced discrimination between high- and low-reward objects, driven by a significant Probability × Condition × Block interaction ($F(1,552) = 5.49$, p **= .019**).

Reward learning task



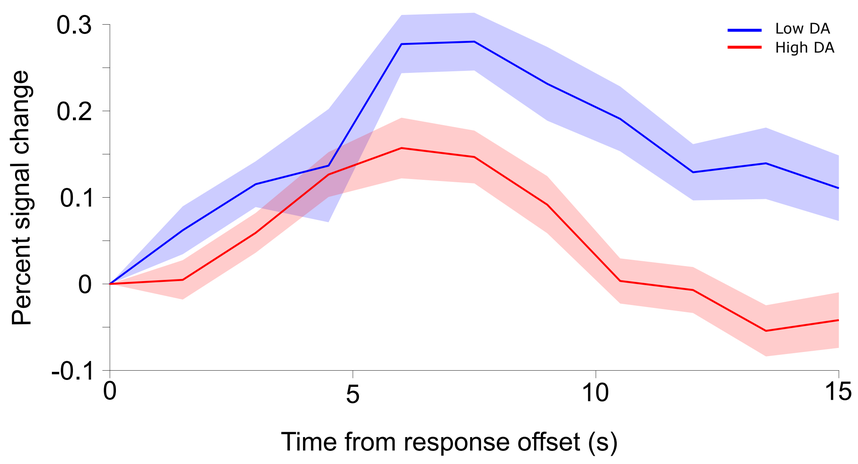
Confidence ratings increased with stimulus reward probability in both conditions, but this relationship was stronger under low midbrain dopaminergic activity, as indicated by a significant Condition × Reward Probability interaction ($F(1,1564) = 4.63$, p **= .032**).

Preference task



Post-feedback BOLD response

Following feedback, midbrain BOLD activity peaked then rapidly declined under high dopaminergic states, whereas low dopaminergic states showed a sustained elevation, consistent with a post-trough rebound in dopaminergic tone.



Outlook

- Three candidate **models** showed the best fit to behavioural data will be compared:
  - Decaying value for non-presented stimuli
  - Decaying learning rate
  - Anticorrelated updating (non-selected stimuli value tend toward the opposite feedback)
- Sustained midbrain BOLD will be correlated with behaviour to link neural dynamics to learning
- Analyses will be extended to other regions of interest, including the vmPFC

References Chew, B., Hauser, T. U., Papoutsi, M., Magerkurth, J., Dolan, R. J., & Rutledge, R. B. (2019). Endogenous fluctuations in the dopaminergic midbrain drive behavioral choice variability. Proceedings of the National Academy of Sciences of the United States of America, 116(37), 18732–18737. https://doi.org/10.1073/pnas.1900872116; Pessiglione, M., Seymour, B., Flandin, G., Dolan, R. J., & Frith, C. D. (2006). Dopamine-dependent prediction errors underpin reward-seeking behaviour in humans. Nature, 442(7106), 1042–1045. https://doi.org/10.1038/nature05051 ; Weiskopf, N.; Suckling, J.; Williams, G.; Correia, M. M.; Inkster, B.; Tait, R.; Ooi, C.; Bullmore, E. T.; Lutti, A.: Quantitative multi-parameter mapping of R1, PD(*), MT, and R2(*) at 3T: A multi-center validation. Frontiers in Neuroscience 7, 95 (2013)

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