

Real-Time fMRI of Midbrain Dopaminergic Activity During Effort-Based Decision-Making

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Introduction

Dopamine plays a central role in decision-making, particularly in the arbitration between effort and reward - a process that is crucial for motivation and is known to be impaired in mental disorders such as depression. While intra-individual fluctuations in effort-reward arbitration are linked to motivation (Hewitt et al., 2025), their mechanistic underpinnings remain unclear. Building on prior work (Chew et al., 2019), we hypothesise that endogenous fluctuations in the dopaminergic midbrain, specifically the substantia nigra and ventral tegmental area (SN/VTA), may drive these behavioural fluctuations. The aim of this study was to mechanistically probe the relationship between SN/VTA activity and effort-reward arbitration using a real-time functional magnetic resonance imaging (rt-fMRI) approach.

Methods

We developed a real-time fMRI framework to track intrinsic fluctuations in SN/VTA activity, measured as blood-oxygen-level dependent (BOLD) signal, and to trigger effort-based decision-making trials in high and low activity states. This allowed us to assess the impact of endogenous dopaminergic activity on behaviour. The study design included parametric manipulation of reward and effort levels to quantify the effects of SN/VTA fluctuations on effort-reward arbitration. We used a computational effort-reward model to assess individual differences in sensitivity to effort and reward and collected self-report measures of impulsivity, anhedonia, and (subclinical) depression.

Results

We present results from our real-time fMRI paradigm, including a detailed evaluation of the task and quantitative evidence demonstrating the impact of SN/VTA fluctuations on effort-reward arbitration. Our findings reveal associations between endogenous dopaminergic activity and behavioural performance, providing novel insights into the neural mechanisms underlying motivational processes. High vs low activity states in the SN/VTA modulated the subsequent BOLD response, which may account for the behavioural differences.

Conclusions

These results advance our understanding of how endogenous fluctuations in the dopaminergic midbrain influence effort-reward arbitration. By linking SN/VTA activity to motivational behaviour, this work contributes to the theoretical framework of dopamine's role in decision-making and offers potential avenues for future research in mental disorders involving motivational impairments.

References

- Chew, B., Hauser, T. U., Papoutsis, 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*, 116(37), 18732–18737. <https://doi.org/10.1073/pnas.1900872116>
- Hewitt, S. R. C., Norbury, A., Huys, Q. J. M., & Hauser, T. U. (2025). Day-to-day fluctuations in motivation drive effort-based decision-making. *Proceedings of the National Academy of Sciences*, 122(12), e2417964122. <https://doi.org/10.1073/pnas.2417964122>